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Hospital Efficiency in Massachusetts:

A Comparison of Short Term Acute Care Hospital Performance Pre and Post Reform

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HOSPITAL EFFICIENCY IN MASSACHUSETTS: A COMPARISON OF SHORT TERM ACUTE CARE HOSPITAL PERFORMANCE PRE AND POST REFORM

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Abstract

The goal of this Interactive Qualifying Project was to evaluate the Massachusetts health care reform of 2006 to determine its impact, if any, on the hospital level. Through background research of reforms in Canada and Taiwan, it was discovered that hospital efficiency is an aspect that may be influenced by health reform. The relative efficiency scores of 65 hospitals were calculated through the use of Data Envelopment Analysis (DEA). Significant positive change in efficiency was observed through Window Analysis, supporting the hypothesis. Through the use of multiple regression however, the hypothesis was disproved. Instead, the results suggested that the occupancy rate of hospitals was a significant factor.

1.0 Introduction

On April 1st, 2006 the state of Massachusetts underwent a monumental health care reform with the legislation formally known as Chapter 58 of the Acts of 2006. The reform overhaul was the first successful implementation of near universal healthcare in the United States, and has since been looked at and evaluated by other states and nations for guidance, most notably the United States and its national reform in 2010. The goal of the reform was to "provide access to affordable, quality, and accountable healthcare" (An Act Providing Access to Affordable, Quality, and Accountable Health Care, 2006). It achieved its goal through a variety of means, those of which include an individual mandate for health insurance, a marketplace of quality health care providers, expansions to previous state aid plans, and further legislation regarding employer-based insurance.

The expansions in health coverage raise the question of whether or not the reform had an impact at the hospital level, specifically hospital performance. In this paper our goal is to evaluate whether or not the reform in 2006 has had an effect on short term acute care hospitals in Massachusetts by determining the change in hospital efficiency from 2004 through 2008 using data envelopment analysis (DEA). DEA is a non-parametric form of analysis commonly used among researchers and management alike to determine the relative efficiency of decision making units (e.g., bank branches, hospitals, and other firms). DEA is preferred by some researchers because of its ability to create a more comprehensive efficiency rating by taking multiple factors into consideration. The factors taken into consideration are grouped as inputs and outputs. Efficiency, defined as "a ratio of output to input" (Sherman and Zhu, 2006, p.51), can be increased by minimizing input while maximizing output.

Previous studies conducted on hospital efficiency in Canada and Taiwan have provided insight on the use of DEA to evaluate hospital performance. As a precursor to our analysis, we look towards work done in these countries as examples of how a reform can affect hospital performance and how efficiency can be evaluated. While conducting research on the changes in hospital performance due to the 1995 health care reform in Taiwan, researchers found an increase in hospital efficiency preceding the reform and a decrease in efficiency post reform. Researchers also observed an overall increase in both input and output in anticipation of the reform. The researchers' goal in Canada was to analyze the technical efficiency of community hospitals in Ontario, Canada, and to determine whether or not ownership, size, or location had a significant effect on hospital efficiency. Through the use of DEA and test statistics, researchers found no significant change in performance of hospitals. We hypothesized that because the individual mandate on health insurance in Massachusetts increased the mean coverage rate by five percent (Kolstad & Kowalski, 2010) and increased patient volume in hospitals, the change in hospital usage will have a slight positive impact on hospital efficiency. Through the use of DEA and two specific methods to measure efficiency over the period of reform, our findings were somewhat inconclusive. However, the results of one particular test suggest that relative efficiency increased after the implementation of the reform. Through the use of regression on the efficiency scores from this particular test, no significant correlation was found between the reform and the change in efficiency noted. Instead, the results suggest that the occupancy rate of hospitals held a significant positive role in the change. Our original hypothesis was disproved, as there was no direct link between the reform and hospital efficiency, but the significance of occupancy rate during the reform period could have occurred due to the reform, thus being an indirect effect due to the health reform.

2.0 Massachusetts Background

2.1 Leading up to the Reform

At the turn of the 21st century, the state of Massachusetts was already accustomed to success with regards to medical health care. Prior to the reform, the average coverage rate of its residents was 89.5%, and was higher than the national average coverage rate of 82.7%; at the time, Massachusetts was the 7th leading state in health insurance coverage (Kolstad & Kowalski, 2010). The state hosted a multitude of public and private programs including MassHealth, a subsidized range of plans whose goal was to aid both the elderly and the financially needy have access to adequate healthcare. Those without access to health insurance still held the right to utilize some hospital services without compensation. In order to compensate hospitals for unpaid medical bills, the state government amassed a fund of approximately 700 million dollars known as the Uncompensated Care Pool or UCP in 1985. The fund functioned as a safety net until the 1990s, where the remaining funds formed a free care program to serve as health insurance for those who could not afford it. Coverage under the free care program would range from 200% to 400% of the federal poverty line. The federal bill known as Emergency Medical Treatment and Active Labor Act of 1986 (EMTALA) was passed soon after in 1986. The national law was a mandate for hospitals to provide a medical screening examination in order to determine whether or not a patient has a medical condition. If so, the hospital is obligated to stabilize the patient without pay before discharging or transferring the patient to another hospital. Concern was that the uninsured in the state would begin to crowd emergency services and utilize them as a source of primary care instead of seeing a physician for preventable conditions. In a study conducted in 2003 by the Massachusetts Division of Health Care Finance and Policy (DHCFP), researchers

sought to describe the population utilizing hospital emergency services, the results of which are shown below.

Table 1: Hospital Frequency Usage by Insurance Status (2006)

Payer Type	Total Residents	Non-ED Users, %	Infrequent ED Users, %	Frequent ED Users, %
Medicaid	794,668	75.3	22.7	2.1
Uninsured	439,000	53.9	44.0	2.1
Medicare	965,943	70.8	27.2	2.0
Private	4,233,811	78.8	20.7	0.4
Total	6,433,422	75.5	23.5	1.0

(Fuda & Immekus, 2006)

The state found that 44% of all infrequent visitors to the emergency department (ED) from October 1, 2002 to September 30, 2003 were uninsured patients seeking treatment. Also, the study found that of the total population in Massachusetts, 1% were frequent users of the ED, with five visits to the ED during the aforementioned timeframe qualifying a patient as a frequent user. Of this subset, 15% of frequent users were currently uninsured in the state (Fuda & Immekus, 2006). With an increasing number of both uninsured patients and Medicaid patients putting pressure on hospitals providing uncompensated or subsidized care, the concern arose that taxes would have to increase to support hospital compensation, causing the debate that led to the reform (Holahan & Blumberg, 2009).

2.2 Reform Specifications

The reform, formally known as Chapter 58 of the Acts of 2006, introduced a variety of amendments onto pre-existing programs as well as created new programs to aid in the

accessibility of health care. The most prominent feature of the legislation was a mandate that required each individual to obtain healthcare. In order to enforce this mandate, a fee is incurred by means of a tax penalty on those who opt out of having health insurance, with the exception of those who are too poor or have a religious objection. The amount incurred for penalties has been amended multiple times to increase the fee and can currently be determined with the following table.

Table 2: Penalty Chart (2010)

Individual Income Category*	150.1-200% FPL	200.1-250% FPL	250.1-300% FPL Age 18-26	Above 300% FPL Age 18-26	Above 300% FPL Age 27+
Penalty	$19/month $234/year	$38/month $462/year	$58/month $696/year	$66/month $792/year	$93/month $1,116/year

(Assessment of Penalties, Massachusetts Department of Revenue, 2010)

Massachusetts also expanded its Insurance Partnership Program, which provides subsidies and incentives for employers to provide and for employees to enroll in employer-sponsored insurance. Under the program, the state government would subsidize insurance costs for employees who would be able to attain government subsidized insurance (due to income level) but are on employer-sponsored insurance instead (Doonan & Tull 2010). The bill also included a mandate for employers to provide health insurance if the number of full-time employees exceeds eleven. Employers who do not meet this requirement are charged a fee of 295 dollars per employee. In order to avoid this penalty, employers must provide at least 33% of their employees' health insurance premiums and have 25% of their employees enrolled under an

employer-sponsored program (McDonough, Rosman, Butt, Tucker, & Howe, 2008). The bill also expanded on previous programs such as MassHealth by decreasing requirements necessary to qualify for coverage. The initial expansion included an increase from 200% to 300% of the federal poverty line for children. Previous benefits cut from the 2002-03 recession were reinstated, including dentures, eyeglasses, and dental care (McDonough et al., 2008). The remainder of the UCP fund was used to conceive a new program called CommCare, which offered partially subsidized and fully subsidized care depending on eligibility. Initially, it provided full care for residents that did not qualify for MassHealth and earned up to 150% of the poverty line. It also offered partial care for those who earned up to 300% of the poverty line. The legislation also called for the creation of a new program called the Connector; a health insurance marketplace aiming to make healthcare more accessible in Massachusetts. Individuals who do not qualify for subsidized health care can use the Connector to purchase health insurance from a multitude of private insurers and other forms of unsubsidized care. Below is a timeline illustrating the various amendments and implementation dates of the reform since its beginning in 2006.

Table 3: Health Care Reform Timeline

Date	Amendment/Implementation

April 12, 2006	Health reform signed into law
July 1, 2006	MassHealth eligibility, benefit expansions and enrollment cap increases implemented
October 30, 2006	CommCare for <100% and employer fair share contribution implemented
January 1, 2007	CommCare for 101-300% implemented, family policies support up to 25 years, and insurance rating changes, "case characteristics" eliminated (excluding tobacco) Open enrollment for non-subsidized plans through Connector with coverage effective
July 1, 2007	Open enrollment begins for Commonwealth Choice
May 1, 2007	Employers with 11 or more full-time-equivalent Massachusetts employees must make a "fair and reasonable" contribution toward an employee health plan or pay a state assessment of $295 per employee, per year
December 1, 2007	Connector publishes premium schedule of the lowest premium on the market for which an individual would be eligible for "creditable coverage" under the individual mandate
January 1, 2008	Individual mandate penalty raised to 50% of minimum premium
January 1, 2009	Health insurance benefits an adult must carry to avoid penalties now include prescription drug coverage, preventative and primary care, with no annual limit on treatment for any sickness
Sources: Health Care Reform: Timeline and Health Care Reform Implementation Timeline	

2.3 After effects

Since its implementation, the effects of the reform have been analyzed; shedding light on the impact it had on multiple levels. Most research has been devoted into looking at the impact on the individual level, changes in coverage rates, and cost analysis. For example, coverage expansion and an individual mandate led Massachusetts to define affordability standards, establish a minimum level of insurance coverage, adopt insurance market reforms, and add both institute incentives and penalties to encourage coverage (Doonan & Tull 2010). Data obtained

from 2008 shows that the uninsured rate of the non-elderly decreased to 7% from its original uninsured rate of 14% (Steinbrook, 2008). It also cut the number of uninsured working adults in half (i.e., from 14% to 7%) (Long, Cook, & Stokley 2008). As of May 2008, the amount of newly insured equaled 350,000, and approximately 409,000 were considered newly insured by 2009. In addition, 44% of the coverage expansion was due to the new Commonwealth Care while 24% was due to the new Medicaid expansions (Steinbrook, 2008).

There are issues despite the reform's overall success. There is still a portion of the population that remains uninsured today. Cost due to the reform is increasing, and the challenges of sustaining the subsidized program have been exacerbated by the recent economic downturn. In addition, the results from a series of interviews conducted in 2007 show that those with lower incomes found it more difficult to arrange appointments or find a doctor that would see them (Long, 2008). Despite its success post-reform, spending for CommCare was $132.9 million and was estimated to increase to $674.4 million in fiscal year 2008. Overall, the per-capita cost of medical care in Massachusetts is high compared to the national average (Steinbrook, 2008). As with any other health reform, there is always a reason that drives people to want change in health care. In Massachusetts it was the concept of near universal coverage and issues dealing with hospital compensation. These goals may have had an impact on hospital efficiency, but to be certain the reforms of Canada and Taiwan were evaluated to see if they were under similar conditions pre and post reform, and also to evaluate what affect their reforms had on hospital efficiency.

3.0 Taiwan Background

3.1 Economy as fuel for Reform

The health care reform law implemented in Taiwan on March 1st, 1995 is a marking point in the history of the country's development. Taiwan has been regarded as an "economic miracle" by many, as it experienced an economic boom for much of the last quarter of the 20th century and is still growing today. This is due, in part, to the industrialization of the island in conjunction with its already strong agriculture. Taiwan is one of the few areas in the East that have developed to the extent of western countries. After World War II, Taiwan had no industrial base, spiraling inflation and an increase in population. Taiwan's government was forced into action by investing money into local industrialization (Vogel, 1991). In 1952, 18% of all goods and services originating in Taiwan came from manufacturing whereas 35% came from agriculture. After industrializing, the country's GNP increased annually by 10% on average from 1961 to 1981. In 1982, 8.7% of all goods and services originating in Taiwan came from agriculture while 43.9% came from industry, all while the unemployment rate rarely passed 2% (Chai, 1986). This rapid growth in Taiwan's economy is what led the people to demand health care of the government. Prior to the reform, Taiwan's government kept a laissez-faire approach to the medical industry, except in the event of a disease outbreak or an epidemic that threatened social stability. The medical profession remained independent from the government, allowing private companies to drive and control the health industry (Chung-tung, 1998). The following table shows the basic and health indicators in Taiwan from select years between 1960 and 1994.

Table 5: Taiwan Pre-reform Health Indicators (Chiang, 1997)

Table 1
Basic and health care indicators: Taiwan, 1960–1994

	1960	1970	1980	1990	1994
Basic Indicators					
Population (million)	10.7	14.7	17.8	20.2	21.0
Per capital GNP (US$)	154	389	2344	7954	11604
Crude death rate (1/1000)	6.8	4.9	4.8	5.2	5.4
Life expectancy (years)					
Male	61.8	66.1	69.6	71.3	71.8
Female	67.1	71.2	74.5	76.8	77.7
% of population aged 65+	2.5	3.0	2.3	6.2	7.2
Health Care Resources					
Physicians per 1000 persons	0.5	0.4	0.7	1.0	1.1
Hospital beds per 1000 persons	0.7[a]	2.4[b]	3.2[c]	4.1	4.5
% of public hospital beds	71.3[a]	60.8[b]	53.3[c]	42.7	39.9
Health Care Financing					
Per capita health spending (US$)	NA	NA	78	330	599
Health spending as % of GDP	NA	NA	3.3	4.2	5.1
% of population insured	6.3	7.9	16.0	47.3	57.0

Source: Council for Economic Planning and Development, Republic of China, Taiwan Statistical Data Book, 1995; Department of Health, Executive Yuan, Republic of China, Health and Vital Statistics, Volume I. General Health Statistics, 1994; Chiang, T.L., Hospital policies in Taiwan, 1945–1994 (in preparation); Wu, K.S., Social health insurance in Taiwan: A review. In C.L. Yaung (ed.), Health Insurance (2nd edn.), Chu-Liu Book Co., Taipei, 1995. (in Chinese).
[a]1961.
[b]1971.
[c]1982.

According to the table, the number of hospital beds has been decreasing since the 1960's, but it also shows a decrease in public beds in Taiwan. In 1994, the percentage of public hospital beds was only 39.9%. There was also a lack of general practitioners and primary care physicians in Taiwan, making care even harder to find. In 1994, there were only 1.1 practitioners per every 1000 citizens. Prior to the health reform in 1995, there were a total of 13 health care plans in Taiwan, three of which are of the greatest importance. These three plans, the Government Employee Insurance (GEI), the Labor Insurance (LI), and the Farmer's Health Insurance (FHI) were established in 1948, 1959, and 1989 respectively. They were operated by the Central Trust of China and the Bureau of Labor Insurance located in Taiwan. These health systems were complex, and they also had different premium rates, premium collection policies, benefits for the insured, and payment standards. The percentages covered by the three plans GEI, LI, and FHI were 8.2%, 37%, and 8.2%, respectively. The remaining 47% of the population was composed of

mainly children, the elderly, and housewives (Chou, 2003). Since the only method of obtaining insurance was through employment and the only program that offered insurance to children and elderly was the GEI, over half of the population was uninsured (Chou, 2003).Those who were uninsured were deterred from seeking necessary medical services, and this created unequal access to healthcare between socioeconomic classes (Hung, 2008). By 1980, both the LI and the GEI only covered 16% of the population (Chiang, 1997). In addition, they failed to cover children under the age of 14 as well as adults over the age of 65 (Hung, 2008). In total, the insurance plans only covered about 60% of the total population in Taiwan. Coverage was 14%, 77%, and 57% for those aged under 20, 20-64, and 65 years and over respectively (Lee, 2010). Many of the insurance plans offered in Taiwan ran under deficit for years, and this fueled the need for reform as members of the government and the public wanted to overcome the financial deficits of the current insurance systems and disproportion of public access to adequate healthcare (Hung, 2008).

3.2 Reform Specifications

To care for the health of its people, the Taiwanese government set up a planning committee under the Council for Economic Planning and Development in 1988 to develop a new healthcare plan. The process of conceiving the National Health Insurance bill took a total of five years to develop, from 1989 to 1995 (Chang, 1998). During this time Taiwan studied the health insurance plans of developed worlds. They began to create a system similar to the Medicaid system already formed in the United States. The NHI's main goal was to create a universal health care plan that forced all to participate, where citizens would get the same uniform comprehensive benefits, and would be partially financed by payroll tax and government

subsidies. Its main concern was to provide coverage for the non-working population whom otherwise would have no access to health care (i.e. children, elderly, non-working adults). It required that all participate regardless of family status, income, or location. The comprehensive benefits included ambulatory care, primary physician care, dental care, home care, emergency care, inpatient care, prescription drugs, laboratory tests, and mental illness treatment. The NHI is financed primarily by income-related premiums (payroll), with employees, employers, and the government all paying a share of the premiums (Lee, 2010). In general, the amount of premiums covered by employees was based not on their income alone, but also the source of the income itself. The coverage rates are explained in the following table.

Table 6: Taiwan Subsidy Rates

Type of Job	Covered by Government	Covered by Employer	Covered by Insured
Public employees	10%	50% (Government)	40%
Private employees	10%	60%	30%
Farmers and veterans	70%	-	30%
Low income families and military personnel	100%	-	-
High income self-employed	-	-	100%
Other unemployed	40%	-	60%

(Wen et al., 2008)

3.3 After effects

The national health insurance implemented in Taiwan on March 1st, 1995 sought to improve the overall quality, access, and cost of health insurance to the people of Taiwan. "The Taiwanese have more equal access to health care, greater financial risk protection, and equity in health care financing" (Lu & Hsiao, 2003, para.1). A step Taiwan took towards improving the overall benefits of the national health insurance was to include an extremely comprehensive list of health services now provided to anyone insured under the national health insurance. Those covered receive a number of prescription drugs, preventative care, in home care services, Chinese medicine, annual checkups, maternal care and even dental services (Lu & Hsiao, 2003). With the benefit of these services, Taiwanese citizens were also allowed to choose their own hospitals and doctors to receive those services. These benefits did not only affect patients in a positive manner, but physicians as well. Physicians could choose to continue to charge a fee for service if they wished and also were allowed to continue to practice western or Chinese medicine in the manner of their choosing. Recipients of any care do have to pay a copayment of about five American dollars. The only people exempt from this fee are those citizens who come from a poor household.

Although the national health insurance sought to cover all of Taiwan's citizens, as expected, not everyone was covered. "With astounding speed, 92 percent of the population had enrolled in the NHI by the end of 1995, and 96 percent had enrolled by the end of 1996. By the end of 2001, 97 percent of the total eligible population had enrolled. The three percent not enrolled may be living overseas or in very remote areas, and perhaps includes the near poor with irregular income sources or independent minded wealthy self-employed people" (Lu & Hsiao,

2003, para. 11). Because of the geological terrain and percentage of poor people living in mountainous area, health care access could not be easily obtained by all. "1.64 percent of its [Taiwan's] population lives on remote islands and in mountainous areas" (Lu & Hsiao, 2003, para. 15). The majority of citizens living in remote islands is very poor and cannot afford health care and simply cannot access it. "59 percent of residents in mountainous areas reported having more than thirty minutes of travel time (one way) to their primary doctor" (Lu & Hsiao, 2003, para. 15). The previous quote illustrates the poor distribution of health care resources throughout Taiwan. Taiwan's government acknowledged this issue as a serious problem. The goal of the reform was to provide equal access to all citizens of Taiwan, rich or poor, so they sought to solve this issue. In order to provide health care to those living in poor regions the Bureau of National Health Insurance encouraged doctors to make weekly, bi-weekly, or even monthly trips out to these remote areas to provide health services to those in need, who would otherwise not be able to receive services. Doctors did so with the promise of incentives.

Although the goal of the National Health Insurance in Taiwan was to provide equal access of health care to all its citizens, this was not immediately accomplished. The government recognized that there were still some who were not able to afford or access the necessary health care. With their recognition of the problem, the Taiwanese government alleviated the situation so that the National Health Insurance may cover as many as possible.

3.4 Comparison to Massachusetts Health Care Reform

Comparing the country of Taiwan to the state of Massachusetts is difficult due to the number of differences that exist between them. On the other hand, both health reforms had similar goals and outcomes. The NHI was the Taiwanese government's attempt to play a larger

role in the health care industry by providing equal access to coverage for all citizens in the country. The health care reform in Massachusetts sought to provide affordable and quality health care. Prior to the reform, the initial coverage rates were significantly higher in Massachusetts compared to Taiwan, with a difference of 29.5%. In Taiwan, the majority of the uninsured consisted of children, elderly, and non-working adults due to healthcare being limited only to those who were employed at the time. Essentially, Taiwan was lacking the equivalent of Massachusetts Medicaid to provide health care to poor families. The NHI established a single payer system in Taiwan funded through taxes and supplemented with government subsidies, while Massachusetts operates under a free market, where individuals choose and pay for insurance. The number of uninsured decreased 36% and 7% in Taiwan and Massachusetts after two years following implementation, respectively.

4.0 Canada Background

4.1 Motivation for Reform

With the many economic changes that occurred throughout Canada just a few years prior to the implementation of the Canada Health Act, there was a real necessity for health care reform. Prior to the reform, in 1978 the wage and price controls policy were ended by the government. Wage and price controls are regulations implemented by a government to control the incomes of labor and capital in response to inflation. At times these regulations also indicate the need to distribute the wealth of the country between its citizens. In response to the removal of the wage and price controls as well as the country's inflation and recession, doctors and nurses began to negotiate with the provincial governments to compensate for their lost income. Doctors would begin to charge additional fees that were tacked onto certain care services and some where even charging an extra fee each day a patient stayed in a hospital. In addition, 32 strikes were held by the nurse's union, demanding improvement to working conditions and higher pay. During this time, Canada had previously established that health care was a right for all citizens so they were forced to find a way to alleviate this crisis. These pressures lead to the implementation of the Canada Health Act of 1984 (Making Medicare: The History of Health Care in Canada 1914-2007, 2010).

4.2 Canada Health Act of 1984

Canadian health care has been in the works since the early 1900s. For years Canada struggled with developing a strong health care system that would benefit citizens and their government alike. After many years of change and discussion the official reform came about in 1984. The reform passed in 1984 by the House of Commons is officially called the Canada Health Act, but is more commonly known as Medicare. The Canada Health Act is a

publicly funded health care system that covers all persons under the basis of legal status in Canada, permanent residents included. Policy makers in Canada desired to "protect, promote, and restore the physical and mental well-being of residents of Canada and to facilitate reasonable access to health services without financial or other barriers" (Canada Health Act: Annual Report 2007-2008, p.3). The Canada Health Act is a single payer system meaning that the care provided is comprehensive and universal. The system is funded through tax money. When deciding how to meet the financial demands of such a large health care system, the authors established the Canada Health Transfer. All participants must be within the criteria and conditions of the Canada Health Act established in order to receive full government funding. The goal of the Canada Health Act is to provide medical services to those in need on a prepaid basis without the need for any fee at the time of service.

4.3 Reform Specifications

Because a single payer system defines that recipients receive universal and comprehensive health care, writers of the Canada Health Act established certain definitions for all participants to be certain of their entitlements if covered under Medicare. There are six definitions clearly laid out. The definitions are as follows:

1. Insured Persons: "Eligible residents of a province or territory are people lawfully entitled to be or to remain in Canada who makes his home and is ordinarily present in the province, but does not include a tourist, a transient or a visitor to the province" (Canada Health Act: Annual Report 2007-2008, p.3).

2. Insured Health Services: “Medically necessary hospital, physician, and surgical-dental services provided to insured persons” (Canada Health Act: Annual Report 2007-2008, p.3).

3. Insured Hospital Services: “Medically necessary in and out patient service such as accommodation and meals, nursing service, laboratory, radiological, diagnostic procedures with necessary interpretations, drugs, use of operating room, case room, anesthetic facilities, radiotherapy facilities, and physiotherapy facilities” (Canada Health Act: Annual Report 2007-2008, p.3).

4. Insured Physician Services: “Medically required service rendered by medical practitioners” (Canada Health Act: Annual Report 2007-2008, p.3).

5. Insured Surgical-Dental Services: “Services provided by a dentist in a hospital, where a hospital setting is required to properly perform the procedure” (Canada Health Act: Annual Report 2007-2008, p.3).

6. Extended Health Care Services: “Certain aspects of long-term residential care (nursing home intermediate and adult residential care services) and the health aspects of home care and ambulatory care services” (Canada Health Act: Annual Report 2007-2008, p.4).

Further conditions of the Canada Health Act are spelled out to define “accountability and citizen engagement” (The Canada Health Act: Fact Sheet, 2000, p.1). Conditions defined are, comprehensive, universality, portability, and accessibility. The insurance must be accessible to

those in need of services free of any charge. The act is comprehensive meaning the publicly funded health care must include "all medically necessary services for the purpose of maintain health, preventing disease, or diagnosing or treating an injury, illness, or disability" (The Canada Health Act: Fact Sheet, 2000, p.1). Universality refers to the requirement that the Canada Health Act service all legal residents of Canada and those residents do not have to pay any health care premiums in order to receive care. Portability refers to the necessity to cover all permanent residents and citizens "by a provincial insurance plan during short absences from that province" (The Canada Health Act: Fact Sheet, 2000, p.1). Since the Canada Health Act was implemented in 1984, one hundred percent of all its citizens are covered by Medicare.

4.4 After effects

Prior to the Canada Health Act of 1984, the coverage rate across all provinces in Canada was 100%. Because the Canada Health Act of 1984 outlined all citizens' entitlements to health care more clearly, rather than include restrictions that would lower the coverage rate, 100% of the country remained covered.

4.5 Comparison to Massachusetts' Health Care Reform

Despite differences between the Canada Health Act of 1984 and the Massachusetts health reform of 2006, they share certain characteristics. At the heart of both reforms is the idea of universality. Both Canada and Massachusetts' reforms set out the goal to have everyone continue to be covered as well as begin to be covered under some sort of health insurance plan. While this is true, Canada's goal was to create a system under which all citizens would be covered and receive a comprehensive list of free medical service funded through tax payers while Massachusetts' goal was slightly different. As it is now in Massachusetts, all permanent

residents are required to have some form of health insurance, but Massachusetts does not dictate where or from whom a person is buying insurance. This point brings up another significant difference. Canada's reform gave free health care to all its citizens while Massachusetts mandates that all residents buy some form of insurance or are covered by Medicare or Medicaid. Canada's reform in comparison to Massachusetts' reform portrays health care as more of a right while Massachusetts' reform portrays it as a requirement.

5.0 Literature Review

5.1 Introduction

A review of relevant literature is necessary in preparation for our own evaluation of the relationship between hospital efficiency and health care reform. This review serves as both one that establishes what subjects have already been researched with the methods used in prior literature as well as a starting point for our research. To model our own analysis we look towards research conducted in Canada and Taiwan due to the fact that their present reforms have been in existence for more than fifteen years, making it is easier to gain a clear understanding of how the reforms affect both hospitals and the countries' population. Papers published from Taiwan and Canada have shown the impact of reform at the hospital level and its effect on hospital efficiency. These papers provide motivation for similar research in Massachusetts due to its recent reform in 2006, as an evaluation of the reform's impact on the hospital level could reveal a change in hospital efficiency.

5.2 Determinants of Hospital Performance

When evaluating hospitals by means of an analysis, it is important to enumerate a list of possible factors or determinants that may have an influence on the aspect being studied, whether evaluating changes in hospital efficiency, utilization, or cost. From this list, a limited amount of determinants are drawn and then tested using a method with the knowledge that these factors are considered to be the most important. Across the three reforms, we have enumerated a list of determinants used in papers that may have an impact on what we choose to use in our analysis.

Quantitative analyses of hospital utilization under universal systems include evaluations of its different aspects, including papers illustrating changes in utilization due to health reform

and others establishing determinants of utilization. The authors Pran, Broyles, and Angus (1987) researched the determinants of hospital utilization in Canada. They looked at the individual level to derive data useful to the hospital level analysis. The authors compared socio-demographic factors, economic factors, and importance of medical need to determine the use of hospitals in Canada (Manga, Broyles, & Angus, 1987). In Kolstad and Kowalski (2010), the authors' goal was to evaluate changes in hospital utilization and coverage rates due to the Massachusetts reform in 2006 by utilizing multiple regressions. To determine the change in coverage rates they compared coverage rates in Massachusetts before, during, and after reform to each other as well as to a nationwide average. In order to evaluate changes in types of coverage they chose to compare the number of uninsured to those with coverage (private, Medicare, Medicaid, CommCare, and other programs).

The most prominent method used to evaluate hospital efficiency is data envelopment analysis, also known as DEA. This method uses a list of inputs and outputs assumed to affect the efficiency in a number of firms in order to calculate an efficiency score for each unit. A review of literature on the use of DEA including Cooper et al. (2004) has shown that the majority of hospital efficiency papers use similar determinants, regardless which aspect of efficiency is focused on. This is done purposely in order to facilitate the comparison of publications; DEA would lose credibility if researchers all chose different inputs and outputs (Cooper, Seiford, & Zhu, 2004). These determinants primarily include basic hospital characteristics such as number of beds and staff, while including outputs such as profit and number of cases. In a paper evaluating the emergency units of hospitals in Montreal (Ouellette & Vierstrate, 2002), the authors chose to include quasi-fixed inputs and outputs, i.e. factors that are not dependent on

number of hours worked but change with employment. The inputs used in the analysis included number of physicians, labor hours excluding those of physicians, furniture and equipment expenditures, and number of stretchers while the outputs consisted only of number of cases. In another paper, Gruca and Nath (2000) evaluated the effect hospital ownership, size, and location had on efficiency. The authors chose determinants that would reflect these aspects. The inputs used included staffing information in the form of number of nurses, ancillary services, administration, cost of services and supplies, and total beds. The outputs considered included both inpatient and outpatient cases, and long term days of care. In both papers from Canada the authors chose to include similar determinants, despite the difference in topic of interest. This shows that there is somewhat of a trend in determinants when evaluating hospital efficiency.

In Taiwan, DEA papers were also written evaluating hospital efficiency, but as with the efficiency papers in Canada, these studies were conducted with different interests in mind. Chang (1998) evaluated differences in hospital efficiency between government and private hospitals pre-implementation of the NHI in 1995. Its inputs were composed solely from staff information including physicians, nurses, administration while its outputs contained number of clinic visits, and also contained general, acute, and chronic patient days. The author chose not to include capital inputs because Taiwan's central government supplies all health providers similarly. He also claims that the costs are beyond the control of the hospitals in Taiwan. Chang et al. (2004) examined the reform's effect on hospital efficiency by running analyses from multiple years. The authors avoided capital measures as well but included more hospital characteristics. The inputs included patient beds, doctors, nurses, medical support, and ancillary personnel. Its outputs included patient days, clinic visits, and number of patients receiving

surgeries. There have been no papers illustrating the change in hospital efficiency in Massachusetts post-reform thus far. In hospital efficiency papers, researchers advise avoiding the use of physicians as an input in teaching hospitals, since they do not always focus on the care of their patients and can be working on other projects (Cooper, et al., 2004).

By reviewing the literature, a list of inputs and outputs was enumerated. A table describing where the inputs and outputs were found is shown below. As seen from the table, all physical inputs and outputs were used previously in literature.

Table 8: Inputs and Outputs in Literature

Inputs	Chang et al., 2004	Chang, 1998	Gruca & Nath, 2001	Cooper et al., 2004
Number of Beds	x	X	x	
Number of Physicians	x	X		
Number of Licensed Nurses	x	X	x	
Number of Nurse Practitioners	x	X	x	x
Auxiliary Employees	x	X	x	x
Other Employees			x	x
Supply Expenditures			x	
Outputs	**Chang et al., 2004**	**Chang, 1998**	**Gruca & Nath, 2001**	**Cooper et al., 2004**
Inpatient Cases			x	
Outpatient Cases			x	
Total Patient Days	x	X		x
Inpatient Surgeries	x	X		x
Outpatient Surgeries	x	X		

5.3 Data Envelopment Analysis and Regression

A key paper illustrating the methodology similar to that which will be conducted in this paper is Chang et al., (2004). This paper used DEA to evaluate the efficiency of hospitals in Taiwan from 1994 to 1997, excluding the year of implementation of the NHI program in 1995. The paper also aims to assess the changes in hospital performance following the implementation of the National Health Insurance program. The data used was in the form of surveys distributed to accredited district hospitals; the largest group of health care service providers in Taiwan. The authors chose to use DEA analysis in order to measure relative efficiency in terms of physical inputs and outputs, instead of using capital. "Input cost and output price are often times susceptible to wide variations and managerial manipulations across comparable units" (Chang, Chang, Das, & Li, 2004, p. 484). The inputs the paper employed included number of patient beds and the amount of staff available (i.e. number of doctors, nurses, and medical support personnel including ancillary services). The three outputs considered were length of stay, number of patient visits, and number of patients receiving surgery. In order to compare hospital efficiency across time, the researchers utilized window analysis. The results from the DEA analysis were tested statistically with student t-tests to prove the difference in efficiency from before and after the reform. The efficiency scores were then used as dependent variables for a regression model aiming to determine which hospital factors had a greater impact on the change in efficiency obtained from DEA. The hospital factors used included hospital ownership, local market competition, illness severity, number of departments, teaching status, a dummy variable for NHI status, degree of specialization, and ratio of nursing hours to patient days. The results of the regression found that degree of specialization, defined as the number of departments, was linked

to the increase operating efficiency. The NHI coefficient was negative and statistically significant at the 1% level, meaning that the researchers were 99% confident of the NHI having a significant impact on hospital efficiency. The remaining variables were found to be statistically insignificant. Using this method, the data suggests that the average operating efficiency decreased after the implementation of the NHI program in 1995.

In Chang (1998), a different population consisting of only government hospitals was used, and its goal was to evaluate the relative efficiency of government hospitals in Taiwan from 1990 to 1994 (i.e. prior to the reform). The paper employed the same combination of DEA and regression also found in Chang et al. (2004) in two separate stages to determine the overall efficiency and its variations within the aforementioned timeframe. The inputs used only staffing information in the form of number of full time equivalent physicians, licensed nurses, and medical support personnel. The outputs used included acute and chronic patient days, and the total number of clinic visits. The DEA analysis gave efficiency scores for each hospital which were used as dependent variables in a regression analysis. The independent variables used for the regression analysis included scope (number of departments), occupancy rate, a dummy variable (year) for the year, and proportion of retired veteran patients. The analysis showed that hospitals with higher occupational rates performed better than those with a lower amount of occupation rates and a wider variety of offered services. The paper explains that the scope of services offered and the proportion of retired veterans seeking medical services negatively impacted hospital efficiency while general occupancy of a hospital positively affected efficiency. Also, the study reveals a steady increase in relative efficiency of public hospitals leading up to the reform. This could be due, in part, to the anticipation of the NHI program or by accumulated

operating experience; an unintentional increase in efficiency due to improvement in hospital management.

Gruca and Nath (2000) is an important paper that utilizes DEA to determine the relative efficiency of hospitals in Canada. This paper focused on hospital size, ownership, and location to determine if these factors have an effect on hospital efficiency. The authors focused on community hospitals in Ontario, Canada. In the analysis, the authors sampled 168 community hospitals and separated them by ownership. Twenty two of the community hospitals are religious; fourteen are government run, while the remaining 132 hospitals are secular, non-profit. A Kruskal-Wallis test was then performed to determine whether or not hospital efficiency was statistically significant with regards to ownership. To measure efficiency based on hospital size the authors separated their sample by number of beds each hospital contained. They separated the hospitals into three groups. The first group was hospitals which had less than one hundred beds, second was one hundred to three hundred and fifty beds, and the last group contained hospitals with more than three hundred and fifty beds. When testing efficiency for hospital location, the authors based their analysis of the size of the population receiving service. After their analysis the authors found that there is no significant difference in efficiency based off of ownership, location or hospital size.

6.0 Methodology

6.1 Intro

Our main objective is to evaluate the relative efficiency of short-term acute facilities in Massachusetts in order to determine if any changes have occurred since the implementation of the reform. In order to do so we will conduct efficiency tests using data envelopment analysis. The resulting efficiency scores will then be used to calculate the malmquist indices of the hospitals in order to observe the overall change in productivity throughout the given time period. Also, change in efficiency will also be observed through window analysis. Regression will then be used to evaluate whether or not the reform was a significant factor in the change of hospital efficiency. The results of the analysis will be compared and any noticeable trends between the two will be noted. We expect that after comparison of our two quantitative analyses, the two will reinforce each other.

6.2 Data Envelopment Analysis

To complete the quantitative aspect of our analysis, we will use data envelopment analysis (DEA) to measure relative hospital efficiency before and after the reform. DEA is a non-parametric form of analysis that uses a set list of factors sorted into inputs and outputs to compare a list of decision making units (DMUs). DMUs are the units compared to each other in order to determine relative efficiency; common DMUs are bank branches, hospitals, and various businesses. In our analysis, the decision making units will be short-term acute hospitals in Massachusetts. The analysis uses inputs and outputs to determine the most efficient DMUs, called the best practices. With these best practices, a frontier is created that will be used to determine the efficiencies of the remaining DMUs not already on the frontier. Each inefficient DMU is compared to the frontier and given a relative efficiency score correlating to the distance

between the DMU under evaluation and the frontier; a process known as benchmarking. The efficiency scores range from zero (least efficient) to one (best practices) (Sherman & Zhu, 2006). The model used is an input-oriented envelopment model, meaning the program compares input between DMUs while keeping output static in order to determine the results. This was chosen due to the nature of hospitals; hospital can do little to affect the amount of patients it receives per year. The study will also utilize both variable return to scale (VRS) and constant return to scale (CRS).VRS is an assumption in which the program simply assumes a non-constant return to scale, either increasing or decreasing, while CRS assumes a linear scale between inputs and outputs. The model used in this study is a variation of one found in Sherman and Zhu (2006). The model illustrated from Sherman and Zhu as well as our edited model are shown below.

Table 9: DEA Input and Output

Sherman & Zhu, 2006	Our Variation
Input	
Weighted Acute Beds	Total Beds (Beds)
Long Term Beds	
FTE Registered Nurses	Full Time Registered Nurses (RN)
FTE Licensed Nurses	Full Time Licensed Nurses (LN)
FTE Other Clinical Labor	-
FTE Non Clinical Labor	Full Time Other Labor (Other)
FTE Long Term Labor	-
Output	
Case Mix Adjusted Discharges	-
Acute Care Patient Days	Total Patient Days (PD)
Long Term Care Days	
Outpatient Visits	Total Outpatient Visits (OV)
Ambulatory Surgeries	Total Surgeries (Surg)
Inpatient Surgeries	

Substitutions for the illustrated model were made due primarily to issues with data acquisition. The alteration of the model could potentially result in significant changes to the

resulting efficiency scores, due to the envelopment model taking different factors into consideration. In the variation, total beds will be used instead of acute and long term beds, total surgeries is used instead of ambulatory and inpatient surgeries, and patient days is used instead of acute care patient and long term days. The envelopment model will be run once for every year between 2004 and 2008 for calculation of the malmquist scores and once for every time period in the window analysis, discussed later.

6.2.1 Malmquist

With the efficiency scores for each year determined through the envelopment model, the Malmquist productivity scores will be calculated. Färe, Grosskopf, & Lovell (1994) derived a specialized DEA based productivity index for calculating change in productivity over time for each unit, or DMU. The equation shown below is one for input-based scores.

$$M_o = \frac{\theta_o^t(x_o^t, y_o^t)}{\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \cdot \left[\frac{\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{\theta_o^t(x_o^{t+1}, y_o^{t+1})} \frac{\theta_o^{t+1}(x_o^t, y_o^t)}{\theta_o^t(x_o^t, y_o^t)} \right]^{\frac{1}{2}}$$

Cook & Zhu (2008)

In this equation, $\theta^t{}_0$ ($x^t{}_o$, yt0) and $t\theta^{t+1}{}_0(x^{t+1}{}_o, yt^{+1}{}_0)$ are single period efficiency measurements at time t and t+1, respectively. Both $\theta^t{}_0$ ($x^{t+1}{}_o$, $yt^{+1}{}_0$) and $t\ \theta^{t+1}{}_0(x^t{}_o$, yt0) are mixed period measurements of efficiency; measurements that account for the change in time. The first mixed measure compares DMUs at time period t+1 to benchmarks at t while the second compares DMUs from time t to benchmarks at time t+1. The first portion of the equation calculates the change in technical efficiency between time periods t and t+1 while the second

portion evaluates the shift in the frontier. The use of this equation requires the calculation of two single periods and two mixed periods. The single periods are the results of the input-oriented envelopment model described earlier. The mixed periods are the result of the comparison of the efficiency scores of one year with the benchmarks of another year. If the resulting M_o is below or above one, productivity increased or decreased between the two time periods, respectively. If the number is exactly one, productivity remained the same. The same observations may be recorded for the individual portions of the equation (change in technical efficiency and frontier shift).

6.2.2 Window Analysis

Window analysis, utilized in Chang (1998) and Chang (2004), takes a different approach to comparing DMUs across time. Window Analysis is a method that allows the consolidation of separate time periods by treating the same units in different time periods as separate entities. The use of window analysis requires the assumption of no significant progress in technology. Data for DMUs will be divided into two time groups, a pre-reform period (2004-2005) and a post-reform period (2007-2008). Data envelopment models will be run for both groups and the two periods will be compared using Wilcoxon's two sample test; a non-parametric variation of typical t-tests.

6.3 Regression

DEA cannot be used to determine the reason why the efficiency of a DMU changes over time, therefore additional analysis to supplement the results is required. Regression will be used in the second portion of the analysis to evaluate the reason influencing change in hospital efficiency, if any. The efficiency scores obtained from the DEA analysis will be used as the

dependent variable, and a number of determinants known to influence hospital efficiency will be used as independent variables in the analysis. Scope, defined as the total number of hospital departments, was found to be negative and statistically significant in Chang (1998). Redefined as degree of service specialization in Chang (2004), it was found to be positive and statistically significant. Occupancy rate, defined as total patient days/ (beds*365), was found to be positive and statistically significant in Chang (1998). To determine whether the reform had an impact on hospital efficiency, the dummy variable reform will be included in the analysis as in Chang (2004); pre-reform will be considered as zero while post-reform will be considered as one. The three factors will form the equation shown below, where beta signifies coefficients relating to their perspective variables.

$$\text{Efficiency} = \beta_o + \beta_1\text{Scope} + \beta_2\text{Reform} + \beta_3\text{Occupancy}$$

6.4 Challenges & Limitations of DEA

DEA has the capability of determining efficiency while taking multiple factors into consideration, but its use requires knowledge of its limitations. It is important to note that DEA is only capable of determining relative efficiency of DMUs, meaning the efficiency scores for all DMUs depends on the amount of DMUs in the analysis and how efficient they are. This attribute makes DEA suitable for determining efficiency when an efficiency standard isn't already established. When an efficiency standard is available, DEA is an unnecessary method. Capital input and output are subject to a wide variety of factors including inflation, geological variations, and different vendor rates, and are therefore not best suited for DEA analysis (Sherman & Zhu, 2006). One must also take precaution when choosing sample size and models, as an insufficient amount could weaken the results of the analysis. It is best to have a high proportion of DMUs to

the number of inputs and outputs in the model. It is also recommended in Sherman and Zhu (2006) that researchers use similar models compared to those used previously in order to facilitate the comparison of results between papers.

There are challenges associated with the use of DEA to evaluate efficiency over time. DEA, as stated previously, is a method that allows the comparison of multiple inputs and outputs to determine relative efficiency of firms. Although it is a useful tool for spotting inefficiencies, one must take into account that DEA alone is incapable of comparing efficiencies over periods of time. Therefore, research was done to find different methods used previously in literature with the same issue. Chang (1998) and Chang (2004) illustrated ways in which to overcome this issue while also using regression. Literature was found using malmquist scores to effectively measure change in productivity, but none used regression in addition with malmquist to determine factors that were significant in the change in efficiency.

6.5 Qualitative Data

In order to conduct a formal interview, the first step to insure a productive session is to make sure that an appropriate amount of research on the topic in question has been conducted prior to the interview. When there is certain confidence in the amount of research, the next step is to prepare questions for the interviewee, organize all thoughts and determine good candidates to interview. Once those candidates have been identified, they will be contacted to see if they would be willing to participate in an interview and if so, set up an appropriate date and time. When conducted, the interview will be recorded and later reviewed to pick up on fine details overlooked during interview and to write an appropriate summary. A thank you note will then be sent to those interviewed as well as a summary of the interview to insure accuracy. Some issues

that may arise when conducting an interview are privacy concerns. There are many who prefer not to be visually or verbally recorded. In addition to this, some may choose not to disclose certain information about their hospitals or their opinions on a matter.

7.0 Data

7.1 Data Collection

A list of 65 short term acute care hospitals was obtained from the Massachusetts Division of Finance Health Care and Policy (DHCFP). This list is representative of the majority of short term acute care hospital in Massachusetts. The list contained some hospitals at the system level while others were at the individual level. Although the entire sample set is comprised of short term acute care facilities, there are variations in ownership, as shown by the chart below

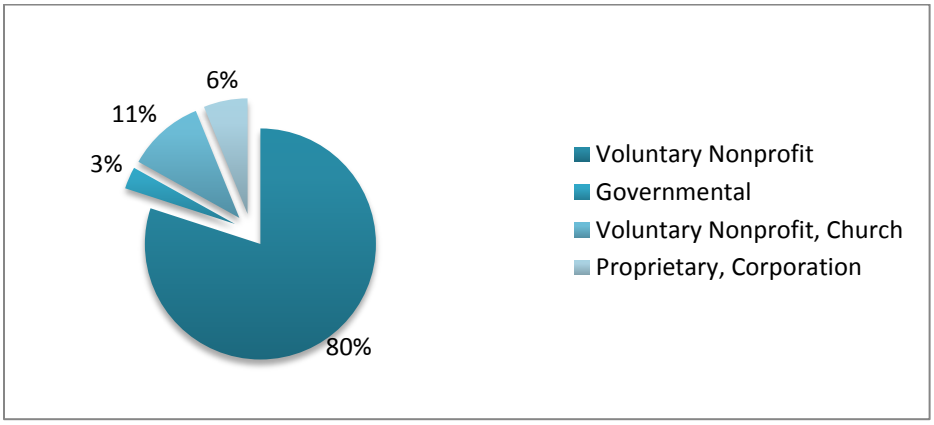

Figure 1: Type of Control

This table illustrates the percentage of hospitals pertaining to a specific type of ownership. As seen in the graph, the majority of the hospitals (80%) in the data set are voluntary nonprofit facilities. The remaining 20% belong to multiple other hospital controls of varying types. The majority of hospitals excluded from the study included specialized care facilities, nursing homes, and psychiatric hospitals. The hospital data used in the study was acquired through the American Hospital Association (AHA). Data for some hospitals was either missing or not recorded, and the amount of sources from which data was collected was kept to a

minimum. This was done in order to reduce discrepancies and also to prevent mistakes when filling in information. Data for DMU # 31 was nonexistent in the AHA data for the year 2008, despite verification that it was still active. Also, data for total surgical procedures was missing for DMU # 20 and 21for 2004-2007 and 2008, respectively.

7.2 Challenges and Limitations

There are multiple challenges associated with data collection. It is difficult to find a free source that offers all of the information necessary for the analysis. Therefore, at the beginning of the study we resorted to using multiple data sources for information. This was a potential issue, as some data sources are more reliable than others and sometimes display different information. In addition, some data sources displayed information in an inefficient manner, requiring the user to record data datum by datum. This method of data collection was time consuming and facilitated mistakes that could have been costly later in the analysis. In addition, overcoming data format issues between sources of information is both a limitation and a challenge. Different data sources refer to hospitals using different names, and thus it becomes confusing as to what is the correct name of the hospital the data is referring to. In some data sources, hospital information is given on the system level and not on the individual level, which introduces another limitation to the study. Aside from lowering the amount of DMUs, hospitals on the system level are considered one unit, which might influence the DMUs efficiency score in the envelopment model. By the end of the study, a more user friendly spreadsheet was provided through the AHA. Though it did not provide all of the recommended data for the analysis, it provided data that would otherwise be unobtainable through previous means. Overall, issues with data collection

can be solved by thoroughly documenting and handling data with the upmost care to detail in order to prevent discrepancies in the data used for the analysis.

Conducting interviews posed more challenges along with data collection during the study. Finding interviewees for the study was difficult due to the nature of our analysis, which made employees in management positions preferred interviewees. Also, DEA is relatively new compared to most statistical analyses available today, and therefore it proved difficult to explain the concept to those unfamiliar with it.

8.0 Results

8.1 Descriptive Statistics

Prior to using DEA, the summary statistics for all DMUs were calculated in order to record any noticeable trends in the data. The results of the descriptive statistics are shown below with more information, including trends in averages, shown in the Appendix.

Table 10: Summary Statistics

Variables	2004	2005	2006	2007	2008
Inputs					
Beds					
Average	223.7	224.7	224.4	226.8	228.7
Standard Deviation	196.72	198.48	199.11	201.91	202.93
Minimum	898	902	902	907	907
Maximum	13	13	13	12	12
RN					
Average	261.3	257.6	257.9	297.0	311.3
Standard Deviation	348.22	347.40	361.77	402.50	404.91
Minimum	14	12	13	15	15
Maximum	1832	1824	1979	2186	2216
LP					
Average	14.6	11.8	11.1	12.3	12.1
Standard Deviation	22.63	16.53	15.93	16.34	16.78
Minimum	0	0	0	0	0
Maximum	106	77	74	64	69
Other					
Average	963.7	909.0	852.2	919.6	966.6
Standard Deviation	1374.60	1133.98	1081.72	1188.53	1241.88
Minimum	66	57	57	55	58
Maximum	9085	6077	5969	6328	6169
Outputs					
OV					
Average	283505.5	280442.9	286712.6	287442.0	312122.3
Standard Deviation	224887.17	233331.64	248130.95	246693.25	255419.65
Minimum	12729	13296	13127	14880	17080
Maximum	912976	925966	1168203	985356	982221
Days					

Average	60366.3	59935.3	60625.2	60533.8	61389.3
Standard Deviation	58883.31	58182.03	58704.46	59392.97	60487.45
Minimum	2236	1651	1597	1672	1690
Maximum	295694	266743	270035	272014	275119
Surg.					
Average	11505.2	11132.4	10372.2	10063.5	10341.3
Standard Deviation	10334.53	10156.44	8761.43	8668.08	8194.44
Minimum	0	0	0	0	0
Maximum	47170	45318	40053	37448	36701

As shown by the table, there exists a high amount of variability in the data, which was expected from the research team. Hospitals in Massachusetts range from small care facilities to multi-building teaching facilities that serve hundreds of patients each day. Also, it is important to note that all inputs and outputs increased over time, with the exception of licensed nurses and total surgical operations. Many of the averages increased significantly from 2006-2007, most notably the input for other employees. This occurrence was also noted in Chang (2004), where inputs and outputs increased between pre and post reform periods. Graphs illustrating the change in average for each input and output are in the Appendix.

8.2 Malmquist

Change in productivity over time was measured using the Malmquist formula derived specifically for DEA. Change was measured between groups of two years in succession (from 04-05, 05-06, 06-07, and 07-08). Malmquist values were first calculated under the assumption of VRS; the raw results can be found in the Appendix. The values for change in technical efficiency and frontier shift were calculated separately to add another means of comparison. The results of the analysis are summarized in the table below.

Table 11: Malmquist VRS Results

Year	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index	# of infeasible measures
04-05	0.93325	0.94401	1.08352	1.16382	0.99376	1.03543	1.03558	12
05-06	0.94401	0.95630	1.58923	0.55333	0.99143	2.34877	2.33104	34
06-07	0.95630	0.94002	0.41840	3.08956	1.02495	0.59963	2.95675	90
07-08	0.94002	0.94698	1.03085	0.39133	1.00382	2.12944	2.23164	20

The results shown in the table represent the average for all measurements of every time period evaluated. Period A represents the first year in the group and period B represents the succeeding year. Model A Frontier B and Model B Frontier A are both mixed period measure explained in the methodology. The first represents efficiency in period A with respect to the frontier in period B, and Model B Frontier A represents the opposite. As seen in the tale, there is a significant amount of variability in the data; this stems from the results of the variable benchmark models (columns 4 and 5), which are used to calculate the frontier shift and malmquist index. Many scores from the variable benchmark model were excluded from the analysis due to infeasibility, the total number of which is demonstrated in the final column. Infeasibility occurs in VRS variable benchmark models when the DMUs under evaluation are too far from the frontier for an accurate comparison. A figure illustrating the range of infeasibility is shown below.

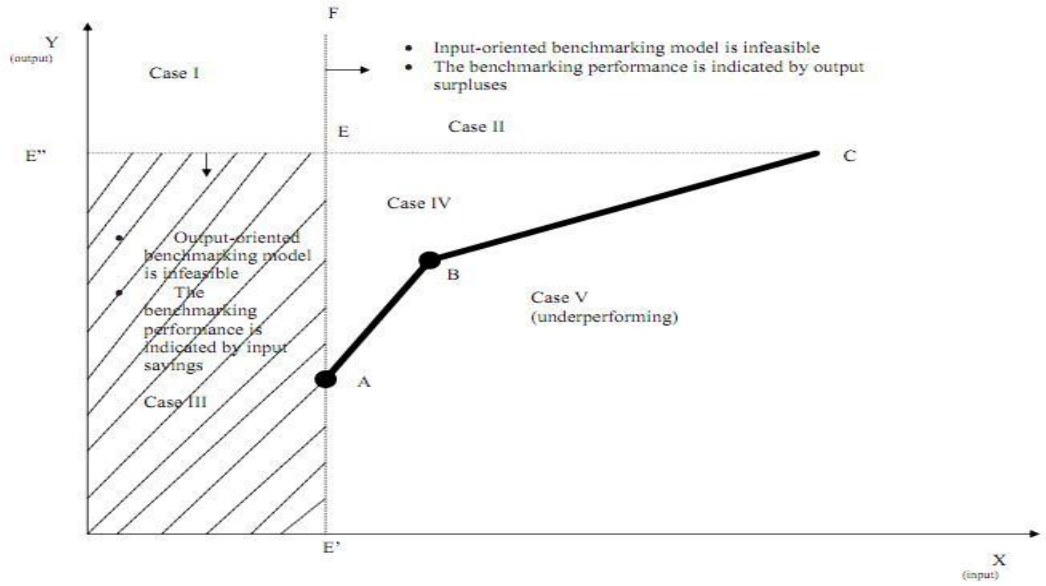

Fig. 2: Infeasibility (Cook & Zhu, 2008)

For input oriented variable benchmark models, a unit will be infeasible if it is above the line E" to C. This region is separated into two cases; case one and case two. Case one occurs when the DMU under evaluation has the least amount of input and a higher amount of output compared to the frontier, while in case two the DMU only has a higher amount on output when compared to the frontier. In both cases, one could make the argument that all DMUs that are infeasible are more efficient than the frontier evaluating it. This allowed the team to draw some conclusions from the VRS malmquist results. In the variable benchmark model comparing efficiency of 2007 to the frontier in 2006, approximately 94% of all units were infeasible. This signifies a jump in output from 2006 to 2007. When compared to the summary statistics, the two observations coincide; there was a significant jump in output in both areas of analysis. In addition, there was an observed increase in input as well from 2006 to 2007 in the summary statistics, leading to the belief that that majority of infeasible units are most likely to be in the case two region of the figure shown above, since both input and output increased over time.

According to the table, specifically the malmquist index, the increase in measurement signifies a decrease in overall productivity from 2004 to 2008. This may not be the case however, due to the omission of infeasible units in the data. Therefore the results from the malmquist VRS are inconclusive.

The prevalence of infeasible units in the VRS malmquist data influenced the team to attempt the same type of analysis while assuming CRS. With this assumption, there are increased limitations; assuming CRS in the hospital environment assumes a stricter relationship between input and output. The assumption of CRS in this particular model of inputs and outputs signifies that, for example, employees across all hospitals are capable of handling the same number of cases per year. The advantage to CRS is that values are always feasible, so any apparent trends not observed in the VRS malmquist will be noted and more importantly, conclusions may be drawn from the analysis. The same procedure was followed as in the VRS malmquist, with change in productivity being calculated in groups of two years in succession. A summary table was created with the results and is shown below.

Table 12: Malmquist CRS Results

Year	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
04-05	0.88035	0.88654	0.96645	0.96105	0.99924	1.02209	1.01831
05-06	0.88654	0.91572	0.98840	1.01584	0.98004	1.01430	0.99441
06-07	0.91572	0.89567	1.02659	0.91359	1.03031	1.05245	0.95155
07-08	0.89567	0.89941	0.93404	0.93794	1.01664	1.00037	1.01553

Compared to the VRS results, the CRS results are much more uniform and either remain static or follow a trend. As seen from this table, there are no significant changes in average technical efficiency, although the data suggests that overall technical efficiency decreased over time. The value representing frontier shift remains static, and malmquist index values suggest

that efficiency increased from 2004 to 2006, and then decreased following those years. There is a slight decrease in all aspects excluding malmquist index starting at or around the reform period (06-07). Although misleading, this observation includes both mixed period measures (Model A Frontier B and Model B Frontier A). Regardless of this observation, there is no significant change in productivity captured with this analysis.

8.3 Window Analysis

Window analysis was performed twice with DEA, once assuming VRS and the other CRS. Raw data for both tests are shown in the appendix. Mean values for VRS pre and post reform were 0.91583 ± .107 and 0.92280 ± .106, respectively. The percent of efficient DMUs was 45.4% pre reform and 41.1% post reform, respectively. The resulting efficiency scores were higher than expected, but consistent with literature. A Wilcoxon's two sample test was performed to test whether or not efficiency increased after the reform. The resulting p-value was insignificant, suggesting that there were no significant differences in efficiency from 2004-2008. The same method was performed using CRS envelopment scores, and resulted in different values. Mean values for CRS pre and post reform were 0.84291 ± .126 and 0.86523 ± .123, respectively. The percentage of efficient DMUs was 21.5% pre-reform and 24% post-reform. Compared to the efficiency scores assuming VRS, the CRS scores are significantly lower with fewer efficient DMUs. Also, overall efficiencies seem to increase in both cases. A one-tailed Wilcoxon's two sample test was performed on CRS values, with an alternative hypothesis that efficiency increased from 2004-2008. The resulting p-value was significant ($p < .05$), suggesting that efficiency increased from 2004-2008. Regression was performed using the efficiency scores from CRS window analysis as the dependent variable in order to determine what factors played a

role in the change in efficiency. The independent variables used in this study included scope, reform, and occupancy rate (explained in methodology). The regression model followed a linear fitting. Its R^2, a statistical measure of how well the equation models the data, was 0.17. The linear fitting regression resulted in the following description of coefficients shown below.

Table 13: Regression Coefficients

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.63511	0.036835	17.24222	<0.00001
Scope	-0.00194	0.001662	-1.16559	0.24487
Reform	0.019729	0.014913	1.322941	0.18704
Occupancy Rate	0.331418	0.04703	7.047022	<0.00001

The table shows the significance and coefficients of factors relating to the change in efficiency observed in CRS window analysis. The regression equation, using the coefficients above, would create the following equation.

Efficiency = 0.63511 - 0.00194Scope + 0.019729Reform + 0.331418Occupancy

The coefficient for scope was negative just as in Chang (1998), but it was found to be insignificant. The key variable of the study, reform, was positive and insignificant, suggesting that the reform had no significance in regards to the change in efficiency observed in window analysis. Occupancy rate was positive and significant at the 1% level, suggesting that patient volume in hospitals was a significant factor in the change in efficiency.

9.0 Conclusion and Future Work

The results of the malmquist VRS and CRS and those of the window analysis VRS and CRS were compared to determine any noticeable trends in the data, excluding the regression results. While the number of infeasible units was abnormally high in 2006 to 2007, the same was not found in the CRS malmquist results. In fact, a Wilcoxon's two sample test was performed on the mixed period measures in 06-07 to determine whether there was a significant decrease in efficiency between 2006 and 2007. The resulting p-value was significant at the 1% level, confirming that the two analyses yielded entirely different results. This could be due to either the choice in return to scale or a mistake in the linear programming used to calculate the mixed period measures. A more detailed study should be performed in the future to evaluate the change in efficiency between 2006 and 2007 in more detail. The results of both window analyses were more reasonable with respect to similarity. The mean efficiency scores of both analyses seem to increase over time, with mean efficiency scores for window CRS being lower than those of the VRS. The differences in all four analyses are most likely to be attributed to the returns to scale that were chosen for the analysis. The choosing of multiple returns to scale was a result of the research team being unsure of how to characterize hospital behavior, warranting more of an investigation of the similarities of hospitals with respect to employee performance standards. For the purposes of the study, the assumption of VRS seems more realistic since not all employees across all hospitals are likely to handle the same load everyday throughout every year.

The results of the regression for the window CRS results suggest that there is no direct link between the significant change in efficiency scores noted and the implementation of the reform in 2006. On the other hand, occupancy rate was determined as a significant factor in the

analysis. This could be argued as an indirect effect of the reform. The increase in coverage rates of public programs such as MassHealth and a mandate on the population could have had an impact on hospital utilization, more specifically an increase in hospital usage. This coincides with the increase in both input and output observed prior to the analysis in the descriptive statistics. An increase in output (visits, days, and surgeries), after a certain point, would require an increase in resources. A similar phenomenon was observed in Taiwan, where there was an increase in both input and output noted in the reform's timeframe. In the future, a study evaluating the increase in hospital utilization and whether or not it was influenced by the reform could be analyzed and serve to supplement the results in this study.

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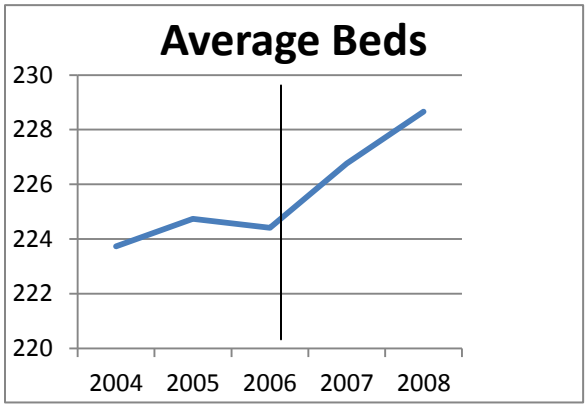
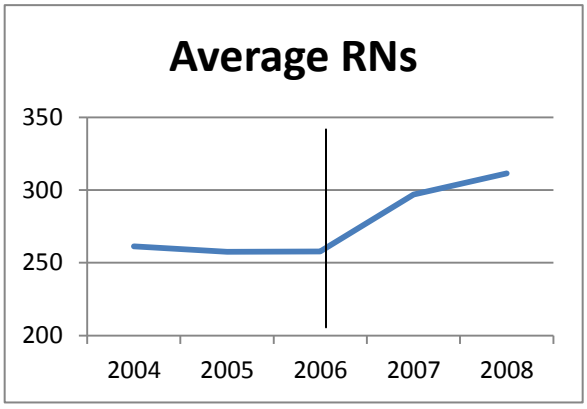
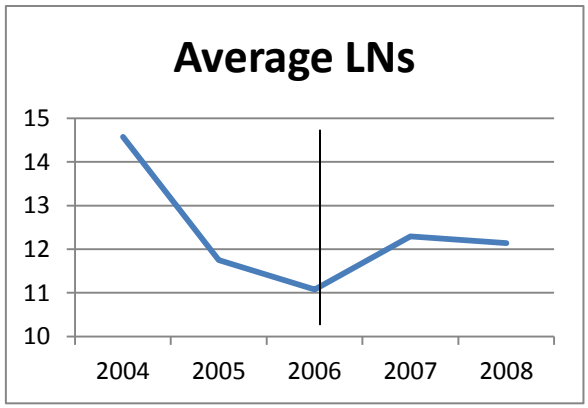
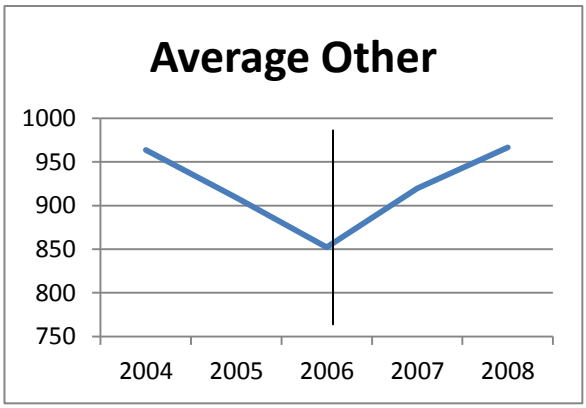
11.0 Appendix

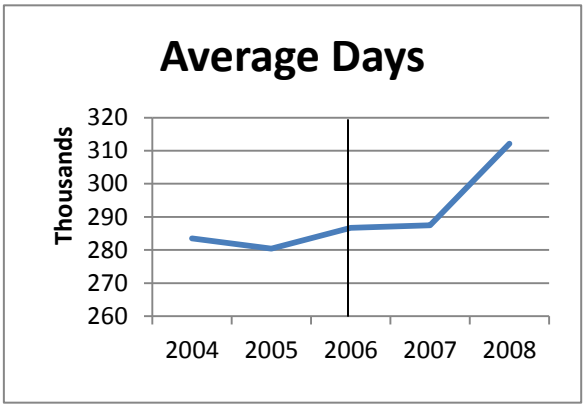
11.1 Average Statistics

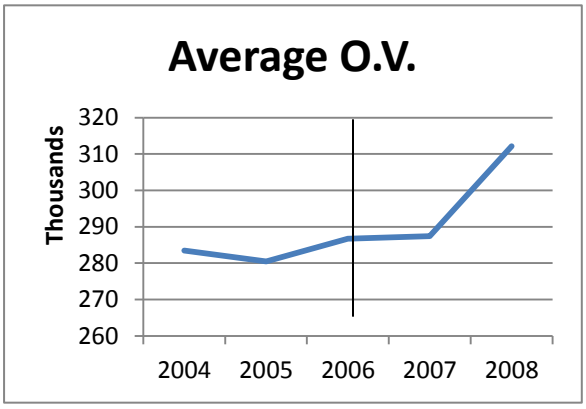


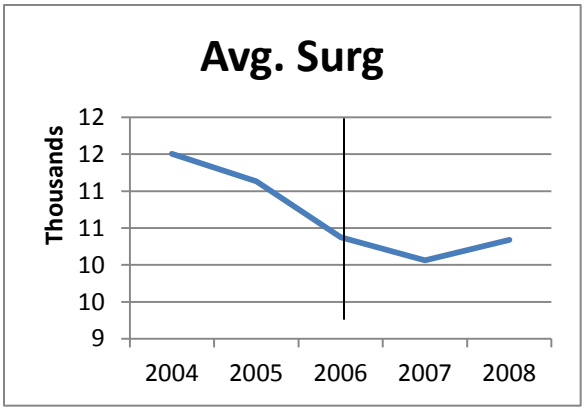












11.2 Window Analysis Results

CRS			VRS		
DMU #	2004-2005	2007-2008	DMU #	2004-2005	2007-2008
1	0.92953	0.95445	1	0.93134	0.96255
2	1.00000	1.00000	2	1.00000	1.00000
3	0.73003	0.79554	3	0.93837	0.97795
4	0.73684	0.74336	4	0.76657	0.75032
5	0.77570	0.86797	5	1.00000	1.00000
6	0.82928	0.88432	6	0.86509	0.90250
7	0.72309	0.78421	7	1.00000	1.00000
8	0.76351	0.88765	8	1.00000	1.00000
9	0.87847	1.00000	9	0.99608	1.00000
10	0.85719	0.85543	10	1.00000	0.95775
11	1.00000	0.85891	11	1.00000	0.85891
12	0.92698	0.87054	12	0.93347	0.90014
13	0.92019	1.00000	13	0.92633	1.00000
14	0.79747	0.67589	14	0.79836	0.68398
15	0.96091	0.86486	15	1.00000	0.86613
16	1.00000	0.65198	16	1.00000	0.67316
17	0.70501	0.78243	17	0.79195	1.00000
18	0.72820	0.71009	18	0.81709	0.85168
19	0.73721	0.77967	19	0.73825	0.78003
20	0.84883	1.00000	20	0.88508	1.00000
21	1.00000	1.00000	21	1.00000	1.00000
22	0.55327	0.55461	22	0.98108	1.00000

23	0.80799	0.87151	23	0.81253	0.91888
24	0.93900	0.93155	24	0.94161	0.93587
25	1.00000	1.00000	25	1.00000	1.00000
26	0.82982	0.91616	26	1.00000	0.97386
27	0.66286	0.98847	27	0.69482	0.99267
28	1.00000	1.00000	28	1.00000	1.00000
29	0.76634	0.81377	29	0.78383	0.83969
30	1.00000	1.00000	30	1.00000	1.00000
31	0.96267	0.78868	31	0.98318	1.00000
32	0.85151	1.00000	32	0.93132	1.00000
33	0.85553	0.87190	33	1.00000	0.97158
34	1.00000	0.92971	34	1.00000	0.93824
35	0.83679	0.80163	35	0.83797	0.80236
36	0.51014	0.74372	36	0.60761	1.00000
37	0.71782	0.67435	37	0.84214	0.70450
38	1.00000	1.00000	38	1.00000	1.00000
39	0.80636	0.81771	39	1.00000	0.98336
40	1.00000	1.00000	40	1.00000	1.00000
41	1.00000	0.81736	41	1.00000	0.87449
42	0.60875	0.59715	42	0.67072	0.60942
43	0.76996	0.93486	43	0.96534	0.96105
44	0.90422	1.00000	44	0.94676	1.00000
45	0.86546	0.97297	45	0.87074	0.98325
46	0.79417	0.84230	46	0.81627	0.85491
47	1.00000	0.60876	47	1.00000	1.00000
48	0.74010	0.58129	48	0.79530	0.63821
49	1.00000	1.00000	49	1.00000	1.00000
50	0.78321	1.00000	50	1.00000	1.00000
51	0.75299	0.76707	51	0.80273	0.82606
52	0.80381	1.00000	52	0.82091	1.00000
53	0.69737	0.74619	53	0.84286	0.86087
54	1.00000	0.88779	54	1.00000	0.90753
55	1.00000	0.96872	55	1.00000	0.98131
56	0.70310	0.69957	56	0.76788	0.70906
57	0.92054	0.79509	57	1.00000	0.79799
58	0.78484	0.84185	58	1.00000	0.91245
59	0.88044	0.89286	59	1.00000	1.00000
60	0.83558	0.80388	60	0.84258	0.82144
61	0.71326	0.90555	61	0.80961	0.96404
62	0.96489	0.85677	62	1.00000	0.95259

63	0.76573	0.82165	63	1.00000	1.00000
64	0.80412	0.96618	64	0.92255	1.00000
65	1.00000	1.00000	65	1.00000	1.00000
66	0.92506	1.00000	66	0.97031	1.00000
67	0.83942	1.00000	67	1.00000	1.00000
68	0.70145	1.00000	68	0.88599	1.00000
69	0.72047	0.75694	69	0.74541	0.79551
70	0.86095	0.79853	70	1.00000	0.99064
71	0.87310	0.77777	71	0.93085	0.78263
72	0.66072	0.84091	72	1.00000	1.00000
73	0.78117	0.89968	73	1.00000	0.93060
74	1.00000	0.78999	74	1.00000	1.00000
75	0.91009	0.87400	75	1.00000	1.00000
76	1.00000	0.77660	76	1.00000	0.87099
77	0.86740	1.00000	77	0.87882	1.00000
78	1.00000	1.00000	78	1.00000	1.00000
79	0.85360	0.84105	79	1.00000	0.88565
80	0.85536	0.89210	80	0.85610	0.89656
81	0.97775	0.57500	81	0.99073	0.58212
82	0.72124	0.93266	82	0.81201	0.95674
83	0.74524	0.71329	83	0.83270	1.00000
84	0.73153	0.71140	84	0.73507	0.85745
85	0.88997	0.75410	85	0.91548	0.75645
86	0.84436	1.00000	86	0.96619	1.00000
87	0.55898	1.00000	87	0.80096	1.00000
88	0.87000	0.67720	88	0.87876	0.97453
89	1.00000	0.90731	89	1.00000	0.97959
90	0.96451	1.00000	90	0.96763	1.00000
91	0.81696	0.97760	91	1.00000	1.00000
92	0.68641	0.96006	92	0.70778	0.96074
93	0.86029	0.95476	93	0.86883	0.95535
94	0.73996	0.85687	94	0.75102	0.88044
95	0.95983	0.88494	95	0.96137	0.90042
96	1.00000	-	96	1.00000	-
97	0.85841	0.95998	97	0.92202	0.96005
98	0.88475	0.90005	98	1.00000	1.00000
99	0.82414	0.99410	99	0.82423	1.00000
100	0.76418	0.79108	100	0.76657	0.79113
101	0.59579	0.74430	101	1.00000	1.00000
102	0.65480	1.00000	102	0.74721	1.00000

103	1.00000	0.82704	103	1.00000	1.00000
104	0.72418	0.98077	104	1.00000	0.99087
105	0.95649	0.70692	105	1.00000	0.76126
106	0.87012	0.54207	106	0.90453	0.54673
107	0.50208	0.94079	107	0.54240	0.97919
108	0.82509	0.87556	108	1.00000	0.90468
109	0.93678	1.00000	109	0.97342	1.00000
110	1.00000	0.81512	110	1.00000	0.82054
111	0.74372	0.53575	111	0.79310	0.82623
112	1.00000	0.68081	112	1.00000	0.71846
113	0.70383	1.00000	113	0.75572	1.00000
114	1.00000	1.00000	114	1.00000	1.00000
115	0.85098	0.76318	115	0.95768	0.81228
116	0.75764	0.96210	116	0.80382	0.96595
117	0.70371	0.84411	117	0.70734	0.94195
118	0.74936	1.00000	118	0.89565	1.00000
119	0.94611	0.96305	119	0.97481	0.97165
120	1.00000	0.63475	120	1.00000	0.64021
121	0.53162	0.95983	121	0.56746	0.96723
122	0.86132	1.00000	122	1.00000	1.00000
123	0.73977	0.80721	123	0.82835	0.96327
124	0.86645	0.88860	124	1.00000	1.00000
125	1.00000	0.83933	125	1.00000	0.85215
126	0.99354	1.00000	126	1.00000	1.00000
127	0.84464	0.79733	127	0.95882	0.88903
128	0.82877	0.88889	128	1.00000	1.00000
129	0.80279	0.90814	129	1.00000	0.96760
130	1.00000	0.93204	130	1.00000	0.93303
Summary	2004-2005	2006-2007		2004-2005	2006-2007
Mean	0.84291	0.86523	Mean	0.91517	0.92272
Std. Dev.	0.12553	0.12299	Std. Dev.	0.10779	0.10646
# of Efficient DMUs	28	31	# of Efficient DMUs	59	53
Proportion	21.5%	24.0%	Proportion	45.4%	41.1%
Wilcoxon's sample test (2-tailed)			Wilcoxon's sample test (2-tailed)		
P Value	0.045		P Value	0.4615	
Wilcoxon's sample test (1-tailed)			Wilcoxon's sample test (1-tailed)		
P Value	0.0225		P Value	0.23075	

11.3 Malmquist VRS 04-05 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	0.94069	1.00000	1.02785	0.97031	0.94069	1.06117	0.99824
2	1.00000	1.00000	2.17334	1.16862	1.00000	1.36373	1.36373
3	0.98445	0.89687	0.95629	0.93307	1.09765	0.96629	1.06064
4	0.76882	0.77238	0.79759	0.75015	0.99539	1.03352	1.02875
5	1.00000	1.00000	1.18386	1.14262	1.00000	1.01789	1.01789
6	0.87257	0.97973	0.92664	0.93127	0.89063	1.05698	0.94138
7	1.00000	1.00000	1.09402	Infeasible	1.00000	-	-
8	1.00000	1.00000	1.00107	1.03340	1.00000	0.98423	0.98423
9	1.00000	1.00000	0.99959	1.57542	1.00000	0.79655	0.79655
10	1.00000	1.00000	Infeasible	7.40838	1.00000	-	-
11	1.00000	1.00000	1.17770	1.34663	1.00000	0.93518	0.93518
12	1.00000	0.89240	0.95828	0.96769	1.12058	0.94006	1.05341
13	0.92780	1.00000	1.09292	Infeasible	0.92780	-	-
14	0.81248	1.00000	0.85236	Infeasible	0.81248	-	-
15	1.00000	0.95945	1.07215	0.89875	1.04226	1.06984	1.11505
16	1.00000	1.00000	1.11921	0.99466	1.00000	1.06076	1.06076
17	0.82258	0.81201	0.79195	0.84372	1.01302	0.96259	0.97512
18	0.82378	0.86758	0.84957	0.83782	0.94952	1.03341	0.98124
19	0.74820	0.81069	0.85748	0.75478	0.92291	1.10948	1.02396
20	1.00000	0.92588	0.89987	1.15878	1.08005	0.84794	0.91582
21	1.00000	1.00000	1.28021	0.96883	1.00000	1.14952	1.14952
22	1.00000	0.85973	1.05383	0.84614	1.16315	1.03477	1.20359
23	0.84402	0.99382	0.86329	0.89320	0.84927	1.06679	0.90599
24	0.96540	1.00000	0.98896	1.23230	0.96540	0.91175	0.88021
25	1.00000	1.00000	1.59265	0.99349	1.00000	1.26613	1.26613
26	1.00000	1.00000	1.81463	1.19505	1.00000	1.23226	1.23226
27	0.79117	0.84564	0.84297	0.86786	0.93559	1.01891	0.95329
28	1.00000	0.88447	1.17876	0.91454	1.13062	1.06771	1.20717
29	0.79294	0.83077	0.89660	0.76557	0.95446	1.10771	1.05727
30	1.00000	1.00000	1.16581	0.96426	1.00000	1.09955	1.09955
31	1.00000	1.00000	1.01158	1.91300	1.00000	0.72718	0.72718
32	1.00000	0.92882	0.96637	1.00738	1.07664	0.94393	1.01627
33	1.00000	1.00000	1.11804	1.04086	1.00000	1.03641	1.03641
34	1.00000	0.86684	1.19550	0.86380	1.15361	1.09532	1.26357
35	0.86757	0.81091	0.88088	0.77746	1.06988	1.02908	1.10100
36	0.61934	1.00000	0.64486	1.37497	0.61934	0.87020	0.53895
37	0.90679	0.96595	1.01474	0.78725	0.93876	1.17178	1.10001

38	1.00000	1.00000	1.46354	1.23786	1.00000	1.08734	1.08734
39	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
40	1.00000	1.00000	1.26064	1.02396	1.00000	1.10957	1.10957
41	1.00000	1.00000	2.97958	0.91628	1.00000	1.80328	1.80328
42	0.67404	0.56518	0.69516	0.54629	1.19261	1.03296	1.23192
43	1.00000	1.00000	0.96727	1.16283	1.00000	0.91204	0.91204
44	0.94728	1.00000	1.00135	0.97342	0.94728	1.04209	0.98715
45	0.90839	1.00000	0.92217	1.37487	0.90839	0.85929	0.78056
46	0.83374	0.84331	0.84383	0.80339	0.98865	1.03073	1.01902
47	1.00000	1.00000	1.71606	1.24123	1.00000	1.17582	1.17582
48	0.82826	1.00000	0.98221	0.81154	0.82826	1.20882	1.00123
49	1.00000	1.00000	1.20954	Infeasible	1.00000	-	-
50	1.00000	0.96752	1.01209	1.08842	1.03357	0.94851	0.98035
51	0.80540	0.85970	0.83974	0.80478	0.93685	1.05536	0.98871
52	0.86779	0.86741	0.82860	0.73200	1.00044	1.06371	1.06417
53	0.84484	0.93616	0.88234	0.89602	0.90245	1.04460	0.94270
54	1.00000	1.00000	1.08550	1.06923	1.00000	1.00758	1.00758
55	1.00000	1.00000	1.21315	1.10205	1.00000	1.04919	1.04919
56	0.76802	0.58871	0.80236	0.57634	1.30458	1.03303	1.34767
57	1.00000	1.00000	1.19509	1.15210	1.00000	1.01849	1.01849
58	1.00000	0.82890	1.04980	0.89617	1.20642	0.98539	1.18879
59	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
60	0.85260	1.00000	0.92318	1.17865	0.85260	0.95847	0.81719
61	0.84232	1.00000	0.80961	Infeasible	0.84232	-	-
62	1.00000	1.00000	1.14022	0.95882	1.00000	1.09050	1.09050
63	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
64	1.00000	1.00000	0.92255	1.26227	1.00000	0.85491	0.85491
65	1.00000	1.00000	1.00755	3.40705	1.00000	0.54381	0.54381
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	38	39					
%	58.5%	60.0%					
Mean	0.93325	0.94401	1.08352	1.16382	0.99376	1.03543	1.03558
Std. Dev.	0.09582	0.09406	0.36006	0.92948	0.09887	0.16598	0.19241

11.4 Malmquist VRS 05-06 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	1.34477	Infeasible	1.00000	-	-
2	1.00000	1.00000	4.99493	1.32262	1.00000	1.94334	1.94334
3	0.89687	0.94825	0.88141	0.06078	0.94581	3.91556	3.70339
4	0.77238	0.78604	0.81130	0.13515	0.98262	2.47171	2.42875
5	1.00000	1.00000	1.18621	0.06644	1.00000	4.22546	4.22546
6	0.97973	1.00000	0.96115	Infeasible	0.97973	-	-
7	1.00000	1.00000	1.01572	0.06090	1.00000	4.08380	4.08380
8	1.00000	1.00000	0.99425	0.05124	1.00000	4.40513	4.40513
9	1.00000	1.00000	2.99620	0.92763	1.00000	1.79720	1.79720
10	1.00000	0.98611	Infeasible	0.10916	1.01408	-	-
11	1.00000	1.00000	1.24469	Infeasible	1.00000	-	-
12	0.89240	1.00000	2.99620	Infeasible	0.89240	-	-
13	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
14	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
15	0.95945	0.80320	1.04957	0.37357	1.19454	1.53363	1.83198
16	1.00000	1.00000	1.49810	Infeasible	1.00000	-	-
17	0.81201	0.89985	0.87994	0.04004	0.90239	4.93481	4.45311
18	0.86758	0.78501	1.85112	0.84102	1.10519	1.41122	1.55967
19	0.81069	0.87186	0.95231	0.27904	0.92983	1.91583	1.78140
20	0.92588	1.00000	2.40497	Infeasible	0.92588	-	-
21	1.00000	1.00000	1.16465	0.88255	1.00000	1.14876	1.14876
22	0.85973	0.84378	2.83277	1.02014	1.01890	1.65086	1.68206
23	0.99382	0.90821	1.27159	0.91063	1.09426	1.12965	1.23612
24	1.00000	1.00000	2.99620	0.49337	1.00000	2.46433	2.46433
25	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
26	1.00000	1.00000	0.85928	0.15440	1.00000	2.35907	2.35907
27	0.84564	1.00000	1.31162	0.42115	0.84564	1.91907	1.62284
28	0.88447	1.00000	1.06887	0.33596	0.88447	1.89662	1.67751
29	0.83077	0.91986	1.04382	Infeasible	0.90315	-	-
30	1.00000	1.00000	1.61178	Infeasible	1.00000	-	-
31	1.00000	1.00000	2.95155	Infeasible	1.00000	-	-
32	0.92882	1.00000	0.97119	Infeasible	0.92882	-	-
33	1.00000	1.00000	1.17490	0.05055	1.00000	4.82089	4.82089
34	0.86684	0.89602	1.13580	0.72063	0.96744	1.27639	1.23483
35	0.81091	0.85654	1.02953	0.29466	0.94673	1.92107	1.81874
36	1.00000	1.00000	4.41672	4.08030	1.00000	1.04041	1.04041

37	0.96595	0.88136	2.27750	0.75056	1.09597	1.66393	1.82362
38	1.00000	1.00000	2.43049	Infeasible	1.00000	-	-
39	1.00000	1.00000	0.97124	0.03465	1.00000	5.29470	5.29470
40	1.00000	1.00000	1.15662	Infeasible	1.00000	-	-
41	1.00000	0.90541	1.59236	0.99522	1.10447	1.20361	1.32935
42	0.56518	1.00000	0.57352	0.46045	0.56518	1.48453	0.83902
43	1.00000	1.00000	1.02985	0.26859	1.00000	1.95814	1.95814
44	1.00000	1.00000	1.38287	Infeasible	1.00000	-	-
45	1.00000	1.00000	1.67871	Infeasible	1.00000	-	-
46	0.84331	0.82162	0.92603	0.19547	1.02641	2.14840	2.20513
47	1.00000	1.00000	Infeasible	0.91326	1.00000	-	-
48	1.00000	0.62829	1.73877	0.39613	1.59161	1.66068	2.64315
49	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
50	0.96752	1.00000	1.14647	0.27975	0.96752	2.05810	1.99125
51	0.85970	0.93398	1.23355	1.79179	0.92046	0.86483	0.79604
52	0.86741	1.00000	1.38164	Infeasible	0.86741	-	-
53	0.93616	0.83072	1.18491	0.08324	1.12693	3.55407	4.00519
54	1.00000	1.00000	2.99620	Infeasible	1.00000	-	-
55	1.00000	1.00000	1.29249	Infeasible	1.00000	-	-
56	0.58871	0.69376	0.59881	0.12862	0.84858	2.34235	1.98766
57	1.00000	0.98762	1.30247	0.38428	1.01253	1.82959	1.85252
58	0.82890	0.98004	0.84035	0.17008	0.84578	2.41702	2.04426
59	1.00000	1.00000	1.08432	Infeasible	1.00000	-	-
60	1.00000	1.00000	1.49810	Infeasible	1.00000	-	-
61	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
62	1.00000	0.99193	1.86484	Infeasible	1.00813	-	-
63	1.00000	1.00000	0.99628	Infeasible	1.00000	-	-
64	1.00000	1.00000	0.93084	0.24552	1.00000	1.94713	1.94713
65	1.00000	1.00000	4.16276	0.85042	1.00000	2.21245	2.21245
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	39	43					
%	60.0%	66.2%					
Mean	0.94401	0.95630	1.58923	0.55333	0.99143	2.34877	2.33104
Std. Dev.	0.09406	0.08168	0.95062	0.71164	0.11126	1.19205	1.18582

11.5 Malmquist VRS 06-07 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
2	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
3	0.94825	0.98890	0.05552	Infeasible	0.95889	-	-
4	0.78604	0.83168	0.12112	Infeasible	0.94512	-	-
5	1.00000	1.00000	0.09653	Infeasible	1.00000	-	-
6	1.00000	0.94176	Infeasible	Infeasible	1.06184	-	-
7	1.00000	1.00000	0.06052	Infeasible	1.00000	-	-
8	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
9	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
10	0.98611	0.98214	0.11407	Infeasible	1.00404	-	-
11	1.00000	0.87404	Infeasible	Infeasible	1.14411	-	-
12	1.00000	0.93112	Infeasible	Infeasible	1.07398	-	-
13	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
14	1.00000	0.69125	Infeasible	Infeasible	1.44665	-	-
15	0.80320	0.87377	0.35437	Infeasible	0.91923	-	-
16	1.00000	0.70557	Infeasible	Infeasible	1.41730	-	-
17	0.89985	1.00000	0.05314	Infeasible	0.89985	-	-
18	0.78501	0.89693	0.61622	Infeasible	0.87521	-	-
19	0.87186	0.80919	0.25320	Infeasible	1.07746	-	-
20	1.00000	1.00000	1.00000	Infeasible	1.00000	-	-
21	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
22	0.84378	1.00000	1.01366	2.99620	0.84378	0.63321	3.03712
23	0.90821	0.92195	0.56748	Infeasible	0.98510	-	-
24	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
25	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
26	1.00000	1.00000	0.15168	Infeasible	1.00000	-	-
27	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
28	1.00000	1.00000	0.51190	Infeasible	1.00000	-	-
29	0.91986	0.83988	0.54459	Infeasible	1.09523	-	-
30	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
31	1.00000	1.00000	Infeasible	2.82355	1.00000	-	-
32	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
33	1.00000	1.00000	0.06595	Infeasible	1.00000	-	-
34	0.89602	0.97989	0.77074	Infeasible	0.91441	-	-
35	0.85654	0.81649	0.27508	Infeasible	1.04904	-	-
36	1.00000	1.00000	Infeasible	3.54227	1.00000	-	-
37	0.88136	0.70473	0.78196	Infeasible	1.25064	-	-

38	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
39	1.00000	1.00000	0.03043	Infeasible	1.00000	-	-
40	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
41	0.90541	0.91927	0.89952	Infeasible	0.98492	-	-
42	1.00000	0.66530	Infeasible	Infeasible	1.50308	-	-
43	1.00000	0.99354	0.37409	Infeasible	1.00650	-	-
44	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
45	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
46	0.82162	0.90306	0.21364	Infeasible	0.90981	-	-
47	1.00000	1.00000	0.96001	2.99620	1.00000	0.56605	2.87638
48	0.62829	0.63821	0.38279	Infeasible	0.98446	-	-
49	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
50	1.00000	1.00000	0.36301	Infeasible	1.00000	-	-
51	0.93398	0.82606	0.98810	Infeasible	1.13065	-	-
52	1.00000	1.00000	0.94258	Infeasible	1.00000	-	-
53	0.83072	0.92709	0.08132	Infeasible	0.89605	-	-
54	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
55	1.00000	0.99334	Infeasible	Infeasible	1.00670	-	-
56	0.69376	0.78711	0.07403	Infeasible	0.88139	-	-
57	0.98762	0.81377	0.27040	Infeasible	1.21364	-	-
58	0.98004	1.00000	0.17315	Infeasible	0.98004	-	-
59	1.00000	1.00000	0.11061	Infeasible	1.00000	-	-
60	1.00000	0.88699	0.60316	Infeasible	1.12740	-	-
61	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
62	0.99193	0.95849	0.93909	Infeasible	1.03489	-	-
63	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
64	1.00000	1.00000	0.24891	Infeasible	1.00000	-	-
65	1.00000	1.00000	Infeasible	Infeasible	1.00000	-	-
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	43	37					
%	66.2%	56.9%					
Mean	0.95630	0.94002	0.41840	3.08956	1.02495	0.59963	2.95675
Std. Dev.	0.08168	0.09730	0.33915	0.31259	0.11723	0.04749	0.11366

11.6 Malmquist VRS 07-08 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	1.02612	Infeasible	1.00000	-	-
2	1.00000	1.00000	1.02122	Infeasible	1.00000	-	-
3	0.98890	1.00000	1.03355	Infeasible	0.98890	-	-
4	0.83168	0.85054	0.76506	0.58723	0.97782	1.15429	1.12868
5	1.00000	1.00000	1.05600	0.05754	1.00000	4.28406	4.28406
6	0.94176	0.81745	0.92593	0.10923	1.15208	2.71256	3.12508
7	1.00000	1.00000	Infeasible	0.09282	1.00000	-	-
8	1.00000	0.93844	1.03352	0.17752	1.06560	2.33744	2.49078
9	1.00000	1.00000	1.07602	0.06099	1.00000	4.20036	4.20036
10	0.98214	1.00000	0.96042	0.06458	0.98214	3.89137	3.82187
11	0.87404	0.87099	0.90266	0.05879	1.00351	3.91151	3.92523
12	0.93112	1.00000	0.95424	Infeasible	0.93112	-	-
13	1.00000	1.00000	1.13617	Infeasible	1.00000	-	-
14	0.69125	1.00000	0.80740	0.62828	0.69125	1.36349	0.94251
15	0.87377	1.00000	0.95878	0.28082	0.87377	1.97674	1.72721
16	0.70557	0.58286	0.67554	0.07394	1.21053	2.74726	3.32565
17	1.00000	1.00000	1.08761	1.05528	1.00000	1.01520	1.01520
18	0.89693	1.00000	0.87138	0.19055	0.89693	2.25797	2.02525
19	0.80919	0.87518	0.82308	0.63665	0.92459	1.18248	1.09331
20	1.00000	0.79191	1.32006	0.20034	1.26277	2.28427	2.88451
21	1.00000	1.00000	2.51347	Infeasible	1.00000	-	-
22	1.00000	1.00000	1.17081	Infeasible	1.00000	-	-
23	0.92195	1.00000	0.94281	0.97179	0.92195	1.02582	0.94576
24	1.00000	1.00000	0.94179	0.92707	1.00000	1.00790	1.00790
25	1.00000	1.00000	1.15385	Infeasible	1.00000	-	-
26	1.00000	1.00000	0.99126	0.34634	1.00000	1.69177	1.69177
27	1.00000	1.00000	1.02368	Infeasible	1.00000	-	-
28	1.00000	1.00000	1.13531	0.50847	1.00000	1.49426	1.49426
29	0.83988	1.00000	0.95935	0.54563	0.83988	1.44688	1.21520
30	1.00000	0.90489	1.11826	0.49772	1.10510	1.42586	1.57572
31	1.00000	-	1.29166	-	-	-	-
32	1.00000	0.98521	1.04557	0.47729	1.01501	1.46909	1.49114
33	1.00000	1.00000	0.97158	0.09958	1.00000	3.12360	3.12360
34	0.97989	1.00000	0.98322	Infeasible	0.97989	-	-
35	0.81649	0.81453	0.84441	0.22731	1.00241	1.92506	1.92969
36	1.00000	1.00000	1.09731	1.09865	1.00000	0.99939	0.99939

37	0.70473	1.00000	0.74235	Infeasible	0.70473	-	-
38	1.00000	1.00000	1.15360	0.03430	1.00000	5.79899	5.79899
39	1.00000	1.00000	0.98456	0.76170	1.00000	1.13692	1.13692
40	1.00000	0.79437	1.22418	0.27558	1.25885	1.87849	2.36474
41	0.91927	0.57366	0.92365	0.06567	1.60248	2.96262	4.74755
42	0.66530	0.99482	0.65576	0.55690	0.66876	1.32693	0.88740
43	0.99354	1.00000	0.97788	0.57666	0.99354	1.30644	1.29800
44	1.00000	1.00000	1.13563	Infeasible	1.00000	-	-
45	1.00000	0.84187	0.98673	0.21452	1.18783	1.96782	2.33744
46	0.90306	0.87027	0.87608	0.82623	1.03768	1.01086	1.04895
47	1.00000	0.84704	1.27473	0.43840	1.18058	1.56938	1.85278
48	0.63821	1.00000	0.76743	Infeasible	0.63821	-	-
49	1.00000	1.00000	1.26793	Infeasible	1.00000	-	-
50	1.00000	0.85478	1.13527	0.33101	1.16989	1.71221	2.00310
51	0.82606	1.00000	0.89737	0.77391	0.82606	1.18477	0.97869
52	1.00000	0.95345	1.04709	0.15834	1.04883	2.51097	2.63357
53	0.92709	1.00000	0.89353	Infeasible	0.92709	-	-
54	1.00000	0.98689	0.91139	Infeasible	1.01329	-	-
55	0.99334	0.65803	1.02741	0.07079	1.50957	3.10072	4.68076
56	0.78711	1.00000	0.74303	0.24633	0.78711	1.95761	1.54086
57	0.81377	1.00000	0.82394	Infeasible	0.81377	-	-
58	1.00000	0.98082	0.96632	0.26661	1.01955	1.88546	1.92233
59	1.00000	1.00000	Infeasible	0.12861	1.00000	-	-
60	0.88699	0.85796	0.82614	0.50844	1.03384	1.25366	1.29609
61	1.00000	1.00000	0.96460	Infeasible	1.00000	-	-
62	0.95849	0.96732	1.05244	0.55491	0.99088	1.38350	1.37088
63	1.00000	1.00000	1.37888	0.04044	1.00000	5.83949	5.83949
64	1.00000	0.99339	1.06025	0.49625	1.00665	1.45685	1.46654
65	1.00000	1.00000	1.62653	0.70118	1.00000	1.52306	1.52306
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	37	40					
%	56.9%	62.5%					
Mean	0.94002	0.94698	1.03085	0.39133	1.00382	2.12944	2.23164
Std. Dev.	0.09730	0.09953	0.25643	0.30125	0.15695	1.20815	1.35464

11.7 Malmquist CRS 04-05 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	0.93292	1.00000	1.02168	0.92517	0.93292	1.08799	1.01500
2	1.00000	1.00000	2.01673	0.87179	1.00000	1.52096	1.52096
3	0.77662	0.70145	0.73003	0.73644	1.10717	0.94623	1.04763
4	0.75651	0.76411	0.78513	0.73725	0.99006	1.03713	1.02682
5	0.88500	0.86095	0.77570	0.97460	1.02794	0.87994	0.90452
6	0.86483	0.90180	0.87365	0.90630	0.95901	1.00258	0.96149
7	0.77532	0.66267	0.72956	0.71162	1.17000	0.93609	1.09522
8	0.84988	0.78117	0.76351	0.86953	1.08796	0.89838	0.97740
9	1.00000	1.00000	0.87938	1.20720	1.00000	0.85349	0.85349
10	0.93138	1.00000	0.99684	0.93294	0.93138	1.07108	0.99758
11	1.00000	1.00000	1.14543	1.03844	1.00000	1.05025	1.05025
12	1.00000	0.89234	0.95804	0.95889	1.12065	0.94422	1.05814
13	0.92717	1.00000	1.08863	1.63519	0.92717	0.84737	0.78566
14	0.81108	0.88929	0.84987	1.23001	0.91206	0.87038	0.79384
15	1.00000	0.92418	0.96119	0.89875	1.08205	0.99418	1.07574
16	1.00000	1.00000	1.02431	0.99324	1.00000	1.01552	1.01552
17	0.78475	0.72124	0.70501	0.80282	1.08805	0.89839	0.97749
18	0.75900	0.78786	0.77229	0.77387	0.96337	1.01780	0.98051
19	0.74783	0.79957	0.82776	0.74571	0.93529	1.08942	1.01892
20	1.00000	0.88997	0.84883	1.15271	1.12364	0.80954	0.90963
21	1.00000	1.00000	1.24262	0.88372	1.00000	1.18580	1.18580
22	0.57455	0.64329	0.64575	0.58199	0.89313	1.11460	0.99548
23	0.83918	0.96564	0.84687	0.88240	0.86904	1.05089	0.91326
24	0.96464	1.00000	0.96832	1.17684	0.96464	0.92357	0.89091
25	1.00000	1.00000	1.16831	0.99006	1.00000	1.08630	1.08630
26	0.90282	0.85818	0.87270	0.84735	1.05202	0.98944	1.04091
27	0.76943	0.83323	0.82931	0.83583	0.92343	1.03656	0.95719
28	1.00000	0.88048	1.11867	0.90291	1.13575	1.04445	1.18623
29	0.77774	0.79562	0.85901	0.75646	0.97753	1.07781	1.05359
30	1.00000	1.00000	1.14165	0.96100	1.00000	1.08995	1.08995
31	1.00000	1.00000	1.00193	1.91043	1.00000	0.72419	0.72419
32	0.88332	0.86706	0.88434	0.90340	1.01875	0.98025	0.99863
33	0.96597	0.88475	0.85553	0.99977	1.09179	0.88532	0.96659
34	1.00000	0.86246	1.17555	0.85078	1.15948	1.09164	1.26574
35	0.86553	0.80809	0.88030	0.77649	1.07108	1.02881	1.10194
36	0.56629	0.79438	0.56892	0.62016	0.71288	1.13440	0.80869
37	0.76708	0.83931	0.87799	0.68845	0.91394	1.18127	1.07961

38	1.00000	1.00000	1.04577	1.21593	1.00000	0.92739	0.92739
39	0.89757	0.72418	0.80636	0.80610	1.23942	0.89838	1.11347
40	1.00000	1.00000	1.24781	0.96869	1.00000	1.13497	1.13497
41	1.00000	0.94031	2.82054	0.88959	1.06348	1.72666	1.83627
42	0.64927	0.53631	0.62102	0.53629	1.21062	0.97802	1.18401
43	0.81525	0.84104	0.78314	0.87102	0.96934	0.96309	0.93357
44	0.90681	0.98536	0.96908	0.94794	0.92028	1.05397	0.96995
45	0.90261	1.00000	0.90433	1.36778	0.90261	0.85587	0.77251
46	0.82695	0.81975	0.81286	0.77134	1.00878	1.02209	1.03106
47	1.00000	1.00000	1.46722	1.11055	1.00000	1.14942	1.14942
48	0.76088	0.98378	0.97336	0.71959	0.77343	1.32247	1.02284
49	1.00000	1.00000	1.20754	1.18073	1.00000	1.01129	1.01129
50	0.82362	0.87008	0.82059	0.88683	0.94660	0.98869	0.93590
51	0.75450	0.81266	0.81154	0.76063	0.92844	1.07200	0.99528
52	0.85380	0.83332	0.80381	0.73199	1.02458	1.03526	1.06071
53	0.74284	0.82838	0.79803	0.80017	0.89674	1.05459	0.94570
54	1.00000	1.00000	1.07486	1.06358	1.00000	1.00529	1.00529
55	1.00000	1.00000	1.17956	1.10038	1.00000	1.03536	1.03536
56	0.75057	0.56322	0.72239	0.56739	1.33264	0.97744	1.30258
57	0.93591	1.00000	1.19331	0.87507	0.93591	1.20708	1.12972
58	0.79606	0.74185	0.80384	0.78232	1.07307	0.97854	1.05004
59	0.88743	0.93097	0.96327	0.87768	0.95324	1.07301	1.02284
60	0.84282	1.00000	0.91085	1.06790	0.84282	1.00599	0.84786
61	0.79392	1.00000	0.71326	0.99354	0.79392	0.95092	0.75495
62	1.00000	0.94632	1.01055	0.85258	1.05673	1.05908	1.11916
63	0.78008	0.85270	0.84235	0.88249	0.91483	1.02146	0.93446
64	0.82290	0.80577	0.81599	0.82605	1.02127	0.98349	1.00441
65	1.00000	1.00000	1.00462	3.34367	1.00000	0.54814	0.54814
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	22	23					
%	33.8%	35.4%					
Mean	0.88035	0.88654	0.96645	0.96105	0.99924	1.02209	1.01831
Std. Dev.	0.11291	0.11706	0.32003	0.37583	0.10478	0.15929	0.17659

11.8 Malmquist CRS 05-06 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	0.99860	1.16042	1.00000	0.92766	0.92766
2	1.00000	1.00000	1.08086	0.97495	1.00000	1.05292	1.05292
3	0.70145	0.80672	0.75179	0.75485	0.86951	1.07024	0.93058
4	0.76411	0.75182	0.74172	0.78378	1.01634	0.96495	0.98072
5	0.86095	0.83259	0.94992	0.75555	1.03405	1.10266	1.14021
6	0.90180	1.00000	0.88278	1.13536	0.90180	0.92855	0.83736
7	0.66267	0.86184	0.75370	0.73987	0.76890	1.15103	0.88502
8	0.78117	0.88443	0.86190	0.80159	0.88324	1.10335	0.97452
9	1.00000	1.00000	1.01925	0.99341	1.00000	1.01292	1.01292
10	1.00000	0.90478	1.02600	0.82067	1.10524	1.06356	1.17549
11	1.00000	1.00000	1.16722	1.10275	1.00000	1.02882	1.02882
12	0.89234	1.00000	0.94645	1.48043	0.89234	0.84643	0.75530
13	1.00000	1.00000	1.44038	1.37313	1.00000	1.02419	1.02419
14	0.88929	1.00000	0.95869	1.13113	0.88929	0.97625	0.86817
15	0.92418	0.77627	0.82670	0.88095	1.19054	0.88783	1.05699
16	1.00000	1.00000	1.01652	1.05595	1.00000	0.98115	0.98115
17	0.72124	0.75353	0.79578	0.68857	0.95716	1.09883	1.05175
18	0.78786	0.75268	0.77476	0.76249	1.04674	0.98525	1.03130
19	0.79957	0.86883	0.83045	0.84938	0.92029	1.03072	0.94856
20	0.88997	1.00000	1.40682	2.80858	0.88997	0.75022	0.66767
21	1.00000	1.00000	1.00882	0.99842	1.00000	1.00519	1.00519
22	0.64329	0.56759	0.58913	0.60776	1.13337	0.92481	1.04815
23	0.96564	0.90341	0.92482	0.96752	1.06889	0.94565	1.01080
24	1.00000	1.00000	1.18480	0.97615	1.00000	1.10171	1.10171
25	1.00000	1.00000	1.08441	1.41744	1.00000	0.87467	0.87467
26	0.85818	0.94517	0.84164	0.86246	0.90796	1.03672	0.94130
27	0.83323	1.00000	0.92761	0.86754	0.83323	1.13281	0.94389
28	0.88048	1.00000	0.95616	0.94327	0.88048	1.07297	0.94472
29	0.79562	0.91332	0.77890	1.07716	0.87112	0.91109	0.79367
30	1.00000	1.00000	1.16938	1.02981	1.00000	1.06561	1.06561
31	1.00000	1.00000	2.28455	1.42343	1.00000	1.26687	1.26687
32	0.86706	1.00000	0.92453	1.13711	0.86706	0.96835	0.83962
33	0.88475	0.89193	1.04791	0.75100	0.99196	1.18603	1.17649
34	0.86246	0.89084	0.84952	0.94907	0.96813	0.96155	0.93090
35	0.80809	0.85586	0.85364	0.79805	0.94419	1.06437	1.00497
36	0.79438	0.97602	0.71391	0.97335	0.81389	0.94930	0.77263
37	0.83931	0.81218	0.83561	0.79974	1.03340	1.00553	1.03911

38	1.00000	1.00000	1.46071	1.02769	1.00000	1.19220	1.19220
39	0.72418	0.80888	0.79902	0.73312	0.89529	1.10335	0.98781
40	1.00000	1.00000	1.03678	1.07393	1.00000	0.98255	0.98255
41	0.94031	0.86151	0.86210	0.93893	1.09147	0.91719	1.00108
42	0.53631	1.00000	0.52057	0.99792	0.53631	0.98624	0.52893
43	0.84104	1.00000	0.99697	0.85055	0.84104	1.18055	0.99289
44	0.98536	1.00000	0.92156	1.61455	0.98536	0.76110	0.74995
45	1.00000	1.00000	0.98990	1.89295	1.00000	0.72315	0.72315
46	0.81975	0.81008	0.84457	0.78871	1.01194	1.02869	1.04097
47	1.00000	0.55251	0.98904	0.42925	1.80992	1.12830	2.04213
48	0.98378	0.58432	0.95883	0.60107	1.68361	0.97339	1.63881
49	1.00000	1.00000	1.14213	1.05511	1.00000	1.04042	1.04042
50	0.87008	0.99916	0.98451	0.91541	0.87082	1.11132	0.96776
51	0.81266	0.88816	0.80966	0.96934	0.91499	0.95544	0.87422
52	0.83332	1.00000	0.81126	1.05453	0.83332	0.96083	0.80068
53	0.82838	0.78644	0.78992	0.75300	1.05333	0.99796	1.05118
54	1.00000	1.00000	0.98175	1.07963	1.00000	0.95359	0.95359
55	1.00000	1.00000	1.08122	1.01260	1.00000	1.03333	1.03333
56	0.56322	0.69277	0.53763	0.80181	0.81299	0.90816	0.73833
57	1.00000	0.97544	1.09346	0.95155	1.02518	1.05873	1.08539
58	0.74185	0.89782	0.78965	0.81161	0.82628	1.08512	0.89662
59	0.93097	0.90607	0.89715	1.00527	1.02749	0.93197	0.95759
60	1.00000	1.00000	1.15906	1.03539	1.00000	1.05804	1.05804
61	1.00000	0.95509	0.94121	1.01014	1.04702	0.94335	0.98771
62	0.94632	0.87541	0.88434	1.08826	1.08099	0.86703	0.93725
63	0.85270	1.00000	0.87334	2.06603	0.85270	0.70408	0.60038
64	0.80577	0.97862	0.92186	0.86507	0.82337	1.13766	0.93671
65	1.00000	1.00000	2.96241	0.97276	1.00000	1.74509	1.74509
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	23	31					
%	35.4%	47.7%					
Mean	0.88654	0.91572	0.98840	1.01584	0.98004	1.01430	0.99441
Std. Dev.	0.11706	0.11444	0.34853	0.35462	0.17122	0.14373	0.22863

11.9 Malmquist CRS 06-07 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	1.02416	1.03646	1.00000	0.99405	1.06151
2	1.00000	1.00000	1.09346	1.12648	1.00000	0.98523	1.23176
3	0.80672	0.88295	0.87408	0.81460	0.91366	1.08370	0.71202
4	0.75182	0.82145	0.80825	0.75810	0.91523	1.07930	0.61274
5	0.83259	0.99751	0.96564	0.85481	0.83467	1.16337	0.82544
6	1.00000	0.90849	1.21745	0.95480	1.10073	1.07629	1.16243
7	0.86184	0.84469	0.87189	0.82636	1.02030	1.01691	0.72050
8	0.88443	0.98956	1.00878	0.87963	0.89376	1.13276	0.88735
9	1.00000	1.00000	1.22773	0.95675	1.00000	1.13280	1.17463
10	0.90478	0.87529	0.87255	0.89291	1.03369	0.97229	0.77911
11	1.00000	0.87394	1.18361	0.82110	1.14425	1.12240	0.97186
12	1.00000	0.90376	1.21299	0.84556	1.10649	1.13863	1.02566
13	1.00000	1.00000	1.42604	0.94899	1.00000	1.22585	1.35329
14	1.00000	0.68083	1.44507	0.63497	1.46879	1.24476	0.91758
15	0.77627	0.87225	0.85488	0.84681	0.88996	1.06506	0.72393
16	1.00000	0.69627	1.14806	0.65960	1.43623	1.10086	0.75725
17	0.75353	0.91608	0.85001	0.79475	0.82256	1.14029	0.67555
18	0.75268	0.79773	0.80329	0.73979	0.94352	1.07277	0.59427
19	0.86883	0.80665	0.87643	0.80107	1.07708	1.00786	0.70208
20	1.00000	1.00000	0.96910	1.38793	1.00000	0.83560	1.34505
21	1.00000	1.00000	1.12154	1.89498	1.00000	0.76932	2.12530
22	0.56759	0.60443	0.58560	0.55533	0.93906	1.05969	0.32520
23	0.90341	0.87881	0.89175	0.95365	1.02799	0.95375	0.85042
24	1.00000	1.00000	1.10767	0.92603	1.00000	1.09368	1.02574
25	1.00000	1.00000	1.23735	0.97240	1.00000	1.12804	1.20319
26	0.94517	0.91616	0.90715	0.95449	1.03166	0.95981	0.86587
27	1.00000	1.00000	1.22356	0.93655	1.00000	1.14300	1.14592
28	1.00000	1.00000	0.95549	1.11700	1.00000	0.92489	1.06728
29	0.91332	0.81938	0.83779	0.88952	1.11465	0.91922	0.74523
30	1.00000	1.00000	1.08307	1.08339	1.00000	0.99985	1.17339
31	1.00000	0.78949	1.64317	0.78868	1.26664	1.28252	1.29595
32	1.00000	1.00000	1.06706	1.07364	1.00000	0.99693	1.14564
33	0.89193	0.93027	0.91763	0.89762	0.95878	1.03259	0.82368
34	0.89084	0.97756	0.94757	0.90397	0.91129	1.07251	0.85658
35	0.85586	0.81612	0.86717	0.83363	1.04870	0.99595	0.72290
36	0.97602	0.78748	1.02947	0.76370	1.23942	1.04289	0.78621
37	0.81218	0.67909	0.80058	0.64284	1.19599	1.02044	0.51464

38	1.00000	1.00000	1.26774	1.42853	1.00000	0.94204	1.81101
39	0.80888	0.91566	0.91264	0.81032	0.88339	1.12913	0.73953
40	1.00000	1.00000	1.00083	1.15393	1.00000	0.93130	1.15489
41	0.86151	0.87421	0.91322	0.81712	0.98547	1.06493	0.74621
42	1.00000	0.64319	1.12999	0.59636	1.55474	1.10396	0.67388
43	1.00000	0.98627	0.96981	1.01042	1.01392	0.97295	0.97991
44	1.00000	1.00000	1.23517	0.94854	1.00000	1.14113	1.17161
45	1.00000	1.00000	1.96198	0.96091	1.00000	1.42891	1.88529
46	0.81008	0.90059	0.87047	0.79924	0.89950	1.10037	0.69571
47	0.55251	0.60936	0.51678	0.60697	0.90670	0.96903	0.31367
48	0.58432	0.58172	0.59243	0.57875	1.00448	1.00950	0.34287
49	1.00000	1.00000	1.26176	1.09434	1.00000	1.07377	1.38080
50	0.99916	1.00000	0.98514	1.11905	0.99916	0.93866	1.10241
51	0.88816	0.76926	0.81203	0.75458	1.15458	0.96543	0.61275
52	1.00000	1.00000	0.99876	1.03582	1.00000	0.98195	1.03453
53	0.78644	0.86341	0.85388	0.78560	0.91085	1.09238	0.67081
54	1.00000	1.00000	1.60497	0.94572	1.00000	1.30273	1.51784
55	1.00000	0.97895	1.09016	0.98370	1.02150	1.04159	1.07239
56	0.69277	0.76650	0.74994	0.70742	0.90381	1.08302	0.53052
57	0.97544	0.80319	0.98551	0.79735	1.21446	1.00882	0.78579
58	0.89782	0.89344	0.87956	0.94135	1.00490	0.96427	0.82797
59	0.90607	0.91899	0.93466	0.90589	0.98593	1.02297	0.84669
60	1.00000	0.88631	0.94320	0.93567	1.12827	0.94522	0.88253
61	0.95509	1.00000	1.14249	0.90351	0.95509	1.15064	1.03224
62	0.87541	0.88118	0.87825	0.82854	0.99345	1.03295	0.72767
63	1.00000	0.87987	1.25357	0.82008	1.13653	1.15973	1.02803
64	0.97862	1.00000	0.91186	1.17109	0.97862	0.89199	1.06787
65	1.00000	1.00000	1.11430	1.17391	1.00000	0.97428	1.30809
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	31	23					
%	47.7%	35.4%					
Mean	0.91572	0.89567	1.02659	0.91359	1.03031	1.05245	0.95155
Std. Dev.	0.11444	0.11609	0.24304	0.21241	0.13483	0.10922	0.34188

11.10 Malmquist CRS 07-08 Results

DMU #	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
1	1.00000	1.00000	1.01796	1.22029	1.00000	0.91334	0.91334
2	1.00000	1.00000	1.01374	1.03026	1.00000	0.99195	0.99195
3	0.88295	1.00000	0.79797	1.15555	0.88295	0.88436	0.78085
4	0.82145	0.82062	0.75905	0.76148	1.00102	0.99790	0.99891
5	0.99751	0.80592	0.87018	0.88215	1.23772	0.89274	1.10496
6	0.90849	0.79689	0.91057	0.82121	1.14005	0.98621	1.12432
7	0.84469	0.84190	0.78875	0.96903	1.00332	0.90070	0.90369
8	0.98956	0.91983	0.88765	0.91678	1.07581	0.94868	1.02060
9	1.00000	0.79638	1.04592	0.84747	1.25569	0.99139	1.24488
10	0.87529	0.87400	0.91467	0.97393	1.00148	0.96839	0.96982
11	0.87394	0.78805	0.89302	0.80027	1.10899	1.00311	1.11244
12	0.90376	1.00000	0.92281	1.10328	0.90376	0.96203	0.86944
13	1.00000	1.00000	1.05342	1.19828	1.00000	0.93761	0.93761
14	0.68083	0.99914	0.80251	0.84105	0.68142	1.18333	0.80635
15	0.87225	1.00000	0.95242	0.89751	0.87225	1.10300	0.96209
16	0.69627	0.57553	0.66134	0.65425	1.20978	0.91408	1.10584
17	0.91608	0.98173	0.78243	0.97932	0.93312	0.92531	0.86343
18	0.79773	0.71329	0.71709	0.83381	1.11839	0.87691	0.98073
19	0.80665	0.71577	0.82277	0.81521	1.12697	0.94634	1.06650
20	1.00000	0.79001	1.21989	0.77648	1.26581	1.11406	1.41019
21	1.00000	1.00000	1.83211	1.19357	1.00000	1.23894	1.23894
22	0.60443	1.00000	0.56181	1.05825	0.60443	0.93719	0.56646
23	0.87881	0.77067	0.88375	0.67969	1.14032	1.06781	1.21765
24	1.00000	0.98615	0.93675	0.91331	1.01404	1.00571	1.01983
25	1.00000	1.00000	1.13921	1.31603	1.00000	0.93040	0.93040
26	0.91616	1.00000	0.95966	0.97997	0.91616	1.03387	0.94719
27	1.00000	1.00000	1.01375	1.04148	1.00000	0.98660	0.98660
28	1.00000	1.00000	1.13527	0.96237	1.00000	1.08613	1.08613
29	0.81938	1.00000	0.94966	0.86112	0.81938	1.16013	0.95059
30	1.00000	0.89854	1.11240	0.91481	1.11291	1.04529	1.16331
31	0.78949	-	-	-	-	-	-
32	1.00000	0.98113	1.04039	0.96134	1.01923	1.03044	1.05025
33	0.93027	0.90005	0.87190	0.96080	1.03358	0.93702	0.96848
34	0.97756	1.00000	0.96908	1.03256	0.97756	0.97983	0.95784
35	0.81612	0.81449	0.84288	0.81886	1.00200	1.01355	1.01557
36	0.78748	0.75359	0.77096	0.76337	1.04497	0.98309	1.02731
37	0.67909	1.00000	0.72809	1.09583	0.67909	0.98914	0.67171

38	1.00000	0.82704	1.15089	0.92730	1.20912	1.01315	1.22502
39	0.91566	1.00000	0.81771	0.98989	0.91566	0.94982	0.86971
40	1.00000	0.72510	1.16246	0.76515	1.37912	1.04958	1.44749
41	0.87421	0.56709	0.86273	0.59354	1.54158	0.97103	1.49691
42	0.64319	0.97480	0.63357	0.99582	0.65982	0.98195	0.64792
43	0.98627	1.00000	0.95056	0.87634	0.98627	1.04871	1.03431
44	1.00000	1.00000	1.11869	1.14601	1.00000	0.98801	0.98801
45	1.00000	0.84127	0.98102	0.86093	1.18868	0.97909	1.16382
46	0.90059	0.63791	0.87585	0.54016	1.41178	1.07170	1.51300
47	0.60936	0.79073	0.76741	0.68256	0.77064	1.20786	0.93082
48	0.58172	1.00000	0.67365	1.12248	0.58172	1.01571	0.59086
49	1.00000	1.00000	1.05977	1.36834	1.00000	0.88005	0.88005
50	1.00000	0.79257	1.06393	0.76748	1.26172	1.04819	1.32252
51	0.76926	1.00000	0.83178	0.96504	0.76926	1.05851	0.81427
52	1.00000	0.86256	1.04116	0.89468	1.15934	1.00189	1.16153
53	0.86341	1.00000	0.74619	1.17532	0.86341	0.85750	0.74038
54	1.00000	0.97598	0.88889	1.04426	1.02461	0.91146	0.93389
55	0.97895	0.65335	1.02029	0.70764	1.49835	0.98095	1.46981
56	0.76650	1.00000	0.72832	0.96331	0.76650	0.99317	0.76126
57	0.80319	1.00000	0.81893	1.04026	0.80319	0.99002	0.79517
58	0.89344	0.81348	0.85558	0.90803	1.09829	0.92624	1.01728
59	0.91899	0.94355	0.96261	0.90876	0.97397	1.04287	1.01572
60	0.88631	0.84793	0.81156	0.92165	1.04527	0.91783	0.95938
61	1.00000	1.00000	0.90555	1.15732	1.00000	0.88456	0.88456
62	0.88118	0.86834	0.94924	0.83689	1.01478	1.05722	1.07285
63	0.87987	0.92332	0.84050	0.92487	0.95295	0.97655	0.93060
64	1.00000	0.99329	1.05993	0.98039	1.00676	1.03628	1.04328
65	1.00000	1.00000	1.61790	0.93283	1.00000	1.31697	1.31697
Summary	A	B	Model A Frontier B	Model B Frontier A	Δ Technical efficiency	Frontier shift	Malmquist Index
# Efficient	23	26					
%	35.4%	40.6%					
Mean	0.89567	0.89941	0.93404	0.93794	1.01664	1.00037	1.01553
Std. Dev.	0.11609	0.12045	0.20128	0.16519	0.19217	0.08839	0.20566

11.11 Interview

Conference Call

Date: 2/1/11

Time: 12:00pm-1:00pm

Present at Conference Call: Cristina Fouraux, Juan Rodriguez, and Interviewee

A. Introduction

1. We introduced ourselves
2. The interviewee was very fascinated with our research because they have not seen any research similar to ours previously conducted
3. They asked about our research in Canada and Taiwan, wondering how long the studies took place after their respective reforms and the period of study they used

B. Questions

1. ***We know that you were not present for the implementation of the National Health Insurance (NHI) in Taiwan in 1995, but do you recall what health care was like before you left? Do you remember what it was like going to the doctor's? Was it any different than in the U.S?***
    i. They left Taiwan in either 1987 or 1988
    ii. There was not a lot of insurance product in Taiwan at the time
    iii. Many people did have health insurance at the time and did not care for it
    iv. Pay as you go policy
    v. They can remember going to the doctors and their parents would pay out of pocket
    vi. There was not much of a wait time to see physicians or primary care physicians
    vii. There was a bit more of a wait to see a specialist
    viii. People of modest income level had a hard time affording health care
    ix. From what they know, people seem to really like the new health care product
    x. All of their family in Taiwan is very pleased with the NHI
    xi. For people in general there are not to many cases of specialized treatment

2. ***The goals of Massachusetts health care reform, implemented in 2006, were to provide quality, accountable, and affordable healthcare to people in Massachusetts. Do you think it succeeded in what it set out to achieve? Do you think it had other goals that weren't mentioned explicitly in the act?***
    i. They think all the goals of the reform have yet to be achieved
    ii. In some ways we have worked backwards
    iii. The primary goal of covering everyone still continues
    iv. They thinks that so far the government has done a good job and will continue to do a good job
    v. They are very impressed with administration
    vi. They believe something else will have to suffer in order for us to continue
    vii. They believe that the reform accomplished it goal of covering more people, but not with quality, accountability and affordability
    viii. Quality is a very complex issue that means something different to everyone
    ix. The coverage is not yet completely affordable for everyone
    x. Payments to providers have suffered
    xi. Providers are being forced to look at what they can do to bring down costs
    xii. Providers are becoming more competitive
    xiii. They believe that within the next two or three years we can succeed with our goal
    xiv. They believe Massachusetts goals are becoming the overall goal of the nation in regards to health care

3. ***In our preliminary analysis and descriptive statistics (shown below), we have noticed a general increase in both resources (beds, registered nurses, and other employees not on the clinical level) and output (inpatient days, outpatient visits). What factor(s) do you think could have played a role in this change?***

i. Seems like increase in capacity. Increase in capacity will also increase utilization and output.
ii. Reform put pressure on hospitals
iii. Increase in output could be due to increase in health payers
iv. To compete with other health systems you have to begin to build capacity
v. You have to know where your patients are coming from
vi. Capacity expansion was on the outpatient side
vii. Expansion is not necessarily a positive for most hospitals because of increase in Medicaid product
viii. It would be foolish to say healthcare reform had not had an impact on utilization
ix. They mentioned for us to look into the mass connector enrollment data which published the percentage of coverage by insurance plans in Massachusetts

4. ***What does efficiency mean to you? Can you describe it or give a definition?***
   i. Providing same quality of care at a lower cost
   ii. At minimum providing care at a lower cost

5. ***Do you think the Massachusetts health care reform has had an impact on hospital efficiency in Massachusetts?***
   i. Foolish to say health care reform did not have an impact on utilization
   ii. The question is just how much did utilization change due to reform?
   iii. Expansion in coverage not necessarily positive for hospitals
      a. Increase in Medicaid product negative for hospitals
      b. Paid product is good for hospitals
   iv. Also need to take pressure from economy into perspective

6. ***Have you noticed any changes in your profession post-reform?***

i. For a couple of year things were looking good, but now it's back to the old days
ii. There is a lot of pressure from the state of our economy
iii. Citizens can't pay for premium increase year after year and this is where most of the pressure comes from for reform
iv. The medical profession is fairly resistant to change and it is very individualistic (They value individual judgment)