ELECTRONIC HEALTH RECORDS AND HEALTH INFORMATION EXCHANGE AND THEIR IMPACT ON INTERNATIONAL HEALTHCARE SYSTEM EFFICIENCY

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Abstract

DAVID PFAEHLER: Electronic Health Records and Health Information Exchange and Their Impact on International Healthcare System Efficiency
(Under the direction of Dr. Katherine Centellas)

The 19th century epidemiological transition in healthcare caused a major shift in physician focus from curing one-time, deadly illness to managing chronic disease. Now, even the most advanced international healthcare systems must find a way to increase their efficiency in order to compensate for heightened strains on medical systems and swelling costs of healthcare delivery. Fortunately, recent technological innovation and, chiefly, the growth of Electronic Health Records (EHRs) provide a potential solution to this looming threat. EHRs are digital charts with the potential to store and share patient health data among providers to offer the most informed, streamlined care available.Yet, their effectiveness in increasing health system efficiency remains uncertain. Relying on the concept of technical efficiency in the healthcare sector, I explore the efficacy of long-term international EHR implementation. Using OECD data, I performed a Stochastic Frontier Analysis (SFA) and measured the change in hospital subsector efficiency over time for each of the 15 chosen countries within my analysis. Followed by this data is a comprehensive EHR index as well as 5 individual country case studies to better explain the histories, successes, and failures of EHR implementation throughout the world. These measures yielded somewhat inconclusive results pertaining to EHR's effect on international healthcare efficiency. Nevertheless, the findings of this study strongly support the need for continued international healthcare efficiency analysis. Rather than submit to the difficulties of such nuanced and complex analytical processes, researchers must remain vigilant and steadfast in their pursuit of efficiency in order to provide effective, affordable healthcare to everyone in need.

Table of Contents

Chapter One: Introduction

Imagine a world void of waste and procrastination--a world where every resource was wisely used and seldom wasted. Sure, this idea of maximum efficiency might seem like a utopian concept, but what if it were realistically achievable? To be efficient is generally described as the ability to "be capable of producing desired results with little or no waste (as of time or materials)," (Merriam-Webster, 2020). Efficiency in any walk of life allows one to do more with less, thus increasing effectiveness, productivity, and profit. Nations around the globe have been consumed by the idea of increased efficiency in their governmental systems for quite some time. Over the last several decades, transportation systems have evolved to move more people over longer distances in shorter amounts of time and food systems grow produce and livestock bigger and faster than ever before. Thanks to these developments, invaluable resources--most notably time and money--have been conserved and society is considerably more productive than it was just decades ago. These accomplishments in the food and transportation system are undeniable, but how have more nuanced entities like healthcare systems been modified and made more efficient over this same period of time?

Many nations have made remarkable improvements to their healthcare systems of old, attaining higher standards of quality care and spending less money along the way. These improvements are absolutely necessary as the world's population continues to grow older, more overweight and obese, and significantly more likely to be diagnosed with chronic conditions and diseases that require frequent visits to healthcare facilities. One might ask how these countries have managed to accomplish this challenging task of reforming their outdated healthcare systems, but the answer that continues to reappear in each of these situations is not quite as complex as one might think: technological innovation.

There have been numerous recent technological innovations that have improved the efficiency of healthcare systems. These innovations use groundbreaking software to make the most of the resources they have available--whether human or financial. Suddenly, a medical discovery that once required millions of dollars in funding now only requires a fraction of the cost. Better yet, a physician that could only care for several hundred patients a week can now effectively treat thousands. Artificial intelligence, virtual reality simulations, and three-dimensional printers are just a handful of a seemingly endless number of cutting-edge innovations that have helped healthcare professionals improve their quality of care--but have electronic health records (EHRs) and health information exchange (HIE) had a similar impact on healthcare professionals and the systems in which they work?

Electronic health records are defined as “a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports,” (Menachemi, 2011, p. 48). Some of the basic benefits associated with the use of EHRs include easy access of computerized records and the elimination of poor penmanship. Additionally, three functionalities of EHRs that hold great promise in improving quality of care and reducing cost are clinical decision support (CDS) tools, computerized physician order entry (CPOE) systems, and health information exchange (HIE) capabilities (Menachemi, 2011). These dynamic functions certainly paint digital patient charts in an attractive light, but EHRs have also faced their fair share of criticism from those skeptical about their practicality in modern healthcare settings. While health information technology can operate in useful ways and promote more efficient systems, it can also be expensive, difficult to implement effectively, and even lead to burnout among healthcare workers (Brown, 2019). As the need for more intelligent and flexible healthcare systems continues to grow, it is imperative to determine whether EHR and HIE truly help enhance efficiency within medical care settings.

This task of defining efficiency can be a difficult undertaking for any sector of the economy. Even more so, defining efficiency in the health sector and within the context of EHR and HIE conjures an entirely new layer of nuance and subjectivity. Each and every health system--regardless of the country--varies greatly and is uniquely challenging to measure. The majority of efficiency studies of healthcare systems rarely conform to production-line overviews in which a set of clearly identifiable inputs is used to produce a standard type of output. Instead, health care is designed to meet the specific needs of an individual patient, with various circumstances, preferences, and needs--ultimately leading to considerable variation in how inputs are consumed and outputs are produced. The unfortunate reality is that health systems are extremely complex and there is often no consensus on which countries perform most efficiently, which method is the most appropriate, or which health outcomes should be directly attributed to certain healthcare inputs. Therefore, it is easy to understand that measuring efficiency within healthcare systems comes with serious obstacles in comprehending how systems function, evolve, and ultimately rank.

Yet, in an era characterized by cloud computing breakthroughs and pressures to digitize patient data for increased coordination, it makes sense now more than ever that electronic versions of a patient's paper chart could be a tool that many healthcare systems should be able and willing to implement in order to improve their system efficiency--especially as global health trends shift unfavorably towards populations that are increasingly old, obese, and chronically ill. This reality alone illustrates an immense need for effective, interoperable, streamlined care that can increase efficiency by limiting the amount of inputs a system must consume in order to arrive at a certain output level. In fact, many countries have already taken the leap on this front and, although the implementation of a health information exchange network is relatively new, this technology has emerged as a promising agent for improving the quality and reducing the cost of healthcare systems for many inquisitive nations aspiring for increased efficiency.

In the following chapters, the idea of utilizing EHR and HIE systems to increase health system efficiency is explored in more detail. We first begin by illustrating the modern need for more efficient healthcare delivery and the efficacy of EHR implementation. Next, we shift to the importance, methodology, and challenges of analyses involving international healthcare system efficiency. Afterwards, a comprehensive data analysis is utilized to provide an efficiency score for each of the fifteen countries within question. These scores are then compared over various time periods depending on each nation's EHR implementation date. Finally, case studies for five separate countries are provided to shed further light onto the real-life successes, failures, and intricacies of EHR and HIE implementation. All of this is done with the hope of gaining a more precise understanding of not only whether EHRs have affected international health system efficiency, but also at what point, to what degree, and in what aspects.

Chapter Two: History and Background

Epidemiological Shift: Illnesses Turn Chronic

Before exploring the efficacy of new technological tools in healthcare such as the electronic health record and health information exchange, it is first important to explain the sequence of events that have brought about the need for such innovations. Similar to any other branch of science, medicine has changed considerably over the last several centuries--and almost exclusively for the better. However, with these advances also came an equal share of unforeseen challenges.

Premodern medicine began in the western world of ancient Greece as a once fundamentally intuitive branch of knowledge. Good physicians were thought to enter the world as natural-born caretakers--literally being predestined to enter the healing arts in a way of thinking that more closely resembled religion than science. However, in the early 1500s premodern medical practice gradually dissolved and physicians began to modernize their caretaking process into a practice more consistent with what we see today. Human beings increasingly saw themselves as distinct and exceptional within the natural order of things and began their pursuit of conquering nature and the challenges it posed.

This growth of science and technology fueled the idea that human ingenuity could and should harness and control the risks of the natural environment. Enlightenment metaphysicians like René Descartes expanded upon these ideas by developing new theories based on mechanistic physiological philosophies--the idea that animal (and thus, human) bodies are machines, constituted by material mechanisms, and governed by the laws of matter alone (Stanford, 2014). Robert Boyle, largely regarded as the first modern chemist, furthered this neoteric belief through his work by treating patients with various drugs which targeted particular illnesses and conditions. Boyle even attested that he was more knowledgeable and effective in treating patients than were the era's physicians (Shapin, 2000). This newly established idea of nature as a studiable and controllable entity gave rise to medical thinking in the West that became increasingly dominated by a human responsibility to cure, manage risk and predictability, and focus on material objects and empirical processes.

Healthcare, like premodern physician practice, experienced a similar evolution from a process of caring at homes; avoiding physiological examination; and thinking deeply and intuitively about realigning divining imbalances to a modern process of caring for patients in hospitals or office buildings; analytically calculating cases; and quarantining patients in order to maximize efficiency in a factory-like production. Just as the world economy began to flourish and crystallize--stressing the need for standardized processes to ensure consistency among the workforce--so, too, did global healthcare practices require an increasingly reliable and adaptable systemization of healthcare delivery.

As this modernization took shape and physicians found creative ways to cure one-time, life-threatening illnesses, patients instead found themselves increasingly inflected with more nuanced, difficult-to-manage diseases. In the 19th century, the major causes of mortality were typically infectious diseases like pneumonia, tuberculosis, and gastrointestinal infections (Tippett, 2014). Thankfully, these conditions are largely eradicated today thanks to the development of antibiotics, vaccinations, sewage management systems, and improved education regarding sanitation and food handling. Among the most important of these discoveries are the Germ Theory of Disease proposed by Louis Pasteur in the late 1800s and the Broad Street Pump

Experiment conducted by John Snow in 1854. These revelations proved that pathogens and outbreaks could be studied, treated, and cured. And--while exceptionally beneficial for society as a whole--the adverse effect of these breakthroughs is that a large part of modern clinical practice concerns the long-term management of disease, with no focus on cure. This evolution from one-time illnesses to chronic diseases is known today by public health experts as the epidemiological shift.

Trends tend to show that as life expectancy reaches an unprecedented high of 70+ years, heart disease, cancer, and stroke replace infection as prime killers (Hinote, 2017). Even more worrisome is the fact that this burden of chronic disease is increasing worldwide. In high-income countries, chronic diseases have long been the leading causes of death and disability; and more than 70% of deaths globally are due to chronic diseases. In the United States, that statistic increases to more than 87% (Barrett, 2016)--although it should be stated that the global pandemic induced by the recent outbreak of the novel coronavirus COVID-19 may cause 2020 to deviate from this long-standing trend. Nevertheless, chronic diseases consistently and directly affect overall health care budgets, employee productivity, and economies. These diseases account for two-thirds of the overall disease burden in middle-income countries and are expected to rise to three-quarters by 2030--often in parallel with economic development, ironically (Barrett, 2016). Even deaths from smoking are expected to increase dramatically in low-income countries over this same period. In the 20th century, tobacco-use killed around 100 million people worldwide. In the 21st century, an estimated one billion will die prematurely--a tenfold increase. By 2030, more than 80% of deaths attributable to tobacco will be in low-income countries (CDC, 2012).

Our world's healthcare systems have neglected the threat of chronic disease for far too long. We are now entering an era that will pose countless strains on healthcare budgets and public health. As more and more patients find themselves diagnosed with chronic diseases like cancer, diabetes, and heart disease, it becomes clear that the epidemiological transition from one-time illnesses to chronic diseases has produced a world population that is less healthy and more at risk today than it was just decades ago. This infamous transition has been exceptionally costly--not only from the perspective of dollars, but, more importantly, lives--and our health systems must continue to adapt and evolve if we wish to continue to treat patients effectively in the future. EHR and HIE, an innovative healthcare tool that has shown promising signs of increasing the efficiency of healthcare delivery, is a potential solution to this daunting problem.

Rising Healthcare Costs

Finding a way to improve care for populations that grow increasingly chronically ill and in need of frequent medical attention is a daunting task, but the difficulty of finding ways to pay for this new standard of care is equally as concerning. In the past, patients were frequently diagnosed with diseases that could be cured with relatively little care and cost. A physician could enter the room and, within minutes, administer a shot or prescribe a medication that would relieve the patient's malady for good (Hinote, 2017). However, chronic illnesses like diabetes, heart disease, and cancer require long-term care that is exponentially more costly and often focuses on managing illness rather than curing it entirely. Health experts have highlighted the increase in spending associated with this epidemiological shift, especially in the United States. In 2019, researchers from Johns Hopkins University found that health spending in the U.S. has been growing faster than other OECD countries in spite of efforts to control spending in the U.S. Their study revealed that overall U.S. health spending increased at an average rate of 2.8 percent annually between 2000 and 2016, which is greater than the OECD median annual increase of 2.6 percent. During that time, inflation-adjusted spending per capita on pharmaceuticals also increased much more quickly in the U.S. with an increase rate of 3.8 percent per year compared to just 1.1 percent for the OECD median (JHU, 2019). These statistics are worrisome for a United States healthcare system that maintains one of the most expensive and least equitable systems among high-income countries. However, despite the validity of these statistics, there is an overarching trend of increased healthcare costs globally that is not exclusive to just the United States and this alarming development poses numerous international problems.

The 2018 World Health Organization (WHO)'s global health financing report revealed that spending on health is growing faster than the rest of the global economy, accounting for 10% of global gross domestic product (GDP). This trend shows a swift upward trajectory of global health spending, which is particularly noticeable in low- and middle-income countries where health spending is growing on average at 6% annually compared with a 4% increase for high-income countries (WHO, 2019). These economic trends are often obscured by countries with healthcare systems that control prices to lower individual patient expenditure and blunt the effects of rising healthcare costs. Prescription drug price negotiation in Germany is an example of this occurrence. Prices are established through collective negotiations between a single buyer (representing the insurers) and a single seller (the drug maker). Strong public and political pressure usually deter gridlock and encourage the two sides to come to an agreement--but if negotiations halt, the drug's price is established by an arbitration panel with representatives from each side and an appointed chair. The manufacturer can refuse the arbitrators' price and withdraw its product, but then forgoes all sales and also earns a reputation of being uncooperative in future negotiations (Robinson, 2019). More often than not, these negotiations yield drug prices that are considerably lower than those in the United States because--in our free market capitalist system--drug companies are free to set the price at whatever amount they deem justifiable.

While governmental actions like price controls may be situationally effective in keeping costs low for individual patients, they contribute to exacerbated problems in other areas of healthcare. Britain's National Health Service (NHS) demonstrates how price controls can severely hinder the performance of a healthcare system by not only veiling the reality of increased cost of care, but also creating problems like long wait times and limited patient access to treatment. According to a recent report from the Royal College of Surgeons, nearly a quarter of a million British patients have been waiting over six months to receive planned medical treatment from the NHS and more than 36,000 of those individuals have been in treatment queues for nine months or more (Pipes, 2019). Even more concerning is that patients in dire need of care are given few options for affordable care as "the target for treating cancer patients within 62 days of urgent GP referral has not been met for over 5 years," (Thorlby, 2019). Unfortunately, issues with price-controlled healthcare systems do not stop in Britain. Hospitals in Japan have seen their cost of care limited so aggressively that almost all hospitals operate in a large deficit. Similarly, German physicians and other health professionals have unified and striked for increased salaries as they feel they are not adequately compensated for their work due to their country's heavily regulated healthcare industry.

It is imperative that one understands the differences associated with the function of healthcare systems around the globe. The way in which each nation utilizes their healthcare system is important, but even more so in the context of rising healthcare costs is analyzing how a country publicizes their healthcare data. In a healthcare system like that of the United States, which avoids regulating prices and redistributing costs from patient to patient, the rise of healthcare cost over the last few decades is unmistakable. However, countries that blunt the effects of rising costs through negotiations and distribution of the burden of cost over millions of citizens make these trends less evident. Nevertheless, as expressed by the WHO's 2018 report, spending on health is increasing at a faster rate than any country's economy can continue to endure. This trend exacerbates the need for timely change in healthcare at the international level--change as widespread as it is effective. In the near future, we must find a way to redefine our healthcare systems in order to improve care for aging populations that are increasingly plagued by chronic illnesses. Even more importantly, we must achieve this goal through a method that reduces cost and ensures the long-term sustainability of affordable healthcare internationally.

The Past, Present, and Future of Electronic Health Record Use

Documenting a patient's medical history and capturing this information within a preserved record is an idea that originated long ago. In fact, translation of ancient Egyptian hieroglyphic inscriptions and papyri from 1,600-3,000 BC indicate the use of medical records thousands of years before even premodern medicine began to take shape (Evans, 2016). Despite this longstanding history of patient data collection, the utilization of medical records has drastically changed over the last century--and with this change have come new facilitators, barriers, and unknowns associated with EHR use. Until the 1920s, paper medical records were sparsely used within healthcare practices. However, by the 1960s and 1970s, a technological boom of computers and data processors quickly laid the foundation for traditionally paper charts maintained in folders to be transformed into hybrid patient charts using paper records and electronic records, known today as the Electronic Health Record. The last several decades have been revolutionary for the EHR and Health Information Exchange (HIE) as a whole, but there remains some uncertainty about their ability to increase efficiency in modern healthcare systems.

In 1992, the state of EHRs experienced profound changes thanks to affordable hardware, powerful and compact personal computers, and accelerated internet access. Suddenly, what was once a hybridization of paper and computerized data began to shift entirely electronic. As a result, academic centers began developing more functional EHR systems and clinical use skyrocketed. Medical professionals started to implement EHRs to quickly access physician notes, orders, consults, laboratory results, and more. Before long, Clinical Decision Support (CDS)--a technology designed to provide physicians and other health professionals with assistance with clinical decision-making tasks--and Computerized Provider Order Entry (CPOE)--the process of entering and sending treatment instructions via computer applications rather than paper, fax, etc.--were added to the list of possible EHR operations that further improved healthcare processes. These tools soon became two of the most important benefits associated with EHR use (Menachemi, 2011).

Since 1992, the modern era has continued to advance and expand upon the Electronic Health Record. After it became obvious that a standard communicative language between EHR systems was needed, Health Level Seven (HL7)--an international standard for transfer of clinical and administrative data--was developed and began to facilitate the interfacing of multiple EHR systems. Strides towards interoperability--interfacing on a larger scale and between more systems--also took shape as large private vendors and governments alike began to invest in improving the capabilities, functions, and fluidity of EHR systems. As of 2015, EHRs are now created, used, edited, and viewed by multiple independent entities including primary care physicians, hospitals, insurance companies, and patients (Evans, 2016). As one author states, "They [EHRs] have changed the dynamics of the patient-clinician interaction," (Evans, 2016) through clinician-patient email, virtual consults, and telemedicine.

Outside of these dynamic changes, financial savings are another positive impact associated with modern EHRs. Potential yearly savings from a reduction in the maintenance cost of paper medical records in the U.S. alone are estimated at $1.3 billion with cumulative savings of $19.9 billion over 15 years. Likewise, the cumulative potential net efficiency and safety savings from hospital systems could be nearly $371 billion with potential cumulative savings from physician practice electronic medical records (EMRs)[1] at nearly $142 billion. This estimation is calculated based on efficiency savings only; the potential net financial benefit could double if the health savings produced by chronic disease prevention and management were also included (Hillestad, 2005). Ambulatory systems also stand to benefit with savings estimated at $11 billion over the same period (Kumar, 2010).

Given these positive developments, it is clear that the EHR has become more accomplished and versatile as technology has continued to adapt and evolve. This reality has led to a number of innovations and possibilities, but it has also brought about legitimate barriers and

[1] Unlike EHRs, which include detailed patient medical history and have the potential to share this information with other providers, EMRs (Electronic Medical Records) contain only a single practice's digital health chart.

concerns. Among the top three barriers associated with EHR implementation are missing data/data error, no standards, and a loss of productivity (Kruse, 2018). One scholar details the challenges of health information technology (HIT) adoption, stressing that “we cannot yet design and deploy complex software systems that are on time, within budget, meet the specific requirements, satisfy their users, are reliable (bug free and available), maintainable, and safe,” (Karsh, 2010, pg. 617). Furthermore, even with recent strides towards interoperability, nations have been reluctant to assume wide scale adoption of the technology, a step that is absolutely necessary in order to utilize all available benefits of an interconnected and efficient EHR system.

More concerning for the outlook of wide scale EHR implementation is one author’s recent observational study which refutes the common belief that EHR implementation is associated with gains in measures of inpatient mortality, readmissions, and patient safety indicators (PSIs) (Yanamadala, 2016). In fact, data from this study of patients receiving medical and surgical care at various EHR and non-EHR system hospitals suggests that EHR implementation may actually increase the amount of time spent necessary to care for patients during clinic visits, thus contributing to clinic inefficiency. While more time with each patient may be desirable to some, this extra time was more frequently spent inputting redundant information than it was spent actually caring for the patient. Yanamadala’s article is certainly concerning for proponents of EHRs who believe federal incentives are necessary to further propagate the benefits experienced by wide scale EHR implementation. Instead of justifying calls for increased federal funding, this article insists that the associated barriers may be more challenging to overcome than initially thought.

Even with incredible technological advancements, perhaps the most daunting challenges facing the future of EHR implementation is its potential to become too knowledgeable to the point of invading personal privacy. After all, newfound technology provides EHR systems with the potential to utilize digital pathology and other sophisticated tools to manage and integrate data, laboratory results, voice recognition, barcodes, and documentation templates. Similarly, increased hardware capacity allows for entire family health histories to be entered into the EHR. Used in conjunction with big-time data and text mining, health professionals have found ways to analyze outcomes, patterns, temporal trends, and correlations within families to improve both private and public health outcomes. Even the human genome has since been decoded, sequenced, and stored within modern EHR systems (Evans, 2016). These advancements are some of the loftiest goals for techno-optimists, but they also seriously increase anxieties about the security and protection of medical histories and physician-patient confidentiality. Nonetheless, proponents of HIE continue to develop more fluid and capable EHR systems and there exists a number of ingenious yet attainable expectations for EHR technology over the next quarter century.

The ability of applications like the electronic health record to communicate, interpret, and act intelligently upon complex healthcare information is just one of a number of aggressive expectations for the progression of EHR systems in the future. Yet, while EHR and HIE has evolved considerably over the last several decades, it is more important for current EHRs to continue to meet the needs of modern medicine’s distributed systems and rapidly changing healthcare environment rather than attempt to reinvent the wheel. The fundamental role and purpose of electronic health records in the future will be:

> "...a data repository based on international standard APIs [Application Programming Interfaces] for the retrieval and storage of data. It will be coupled with facility and vendor provided, and user selected applications for data review and entry and especially CDS. In addition to health data, social, economic, behavioral, and environmental data will play a vital role in providing and especially improving healthcare. The applications will be interchangeable, not dependent on EHR versions and updates, and will facilitate innovation like the current Smart Phone applications," (Evans, 2016, p. S56).

If EHRs prove capable of effectively managing these increased functions, HIE as a whole should expect to bolster a number of design improvements and enhanced capabilities in the future. Among these changes could be EHRs with: improved interoperability, increased use of cloud technology, longitudinal (birth to death) focuses, big data storage, internationally accepted standards, foreign language translations with preserved clinical meanings, and flexible systems (Evans, 2016). Each of these functions, both the mundane and the ambitious, should be shaped by experienced clinicians with a vested interest in the functionality and efficiency of the future EHRs.

Of course, current and future EHRs will continue to have the potential to increase medical errors if used improperly; therefore, as these systems continue to change over time and improve, engineering and reengineering will be needed in order to increase their potential benefit while at the same time improving their safety. EHR safety concerns involving both unsafe technology and unsafe use will persist in the future, but the focus of this issue remains on finding solutions to prospective errors rather than systemwide punishment of electronic health records and health information exchange. Modern data and scholarly sentiment supports the continued adoption of EHR and HIE within various healthcare systems; although, a continuation of current research on the impact of EHR and HIE will continue to prove beneficial in determining whether wide scale implementation should be incentivized or scrapped.

Chapter Three: Identifying Efficiency within Healthcare Systems

Why is Healthcare Efficiency Important?

The study of health sector efficiency and related issues such as cost, effectiveness, and value for money are some of the most important dimensions of healthcare performance. These statistics portray the extent to which inputs to the health system are used to secure valued health system goals. In almost every other area of the economy, consumer preferences ensure that the most valued outputs are produced at market prices. However, all too often, this same balance is not upheld in the health sector which causes market failures and leads to dysfunction, poor quality, and inappropriate care. Health care financiers including governments, insurers, and households are interested in knowing which systems, providers, and treatments contribute the largest health gains in relation to the level of resources they consume. Especially concerning is the long-term financial sustainability of a number of different health resources and social safety net systems. In order to change the unfortunate reality of healthcare system dysfunction, the study and pursuit of efficiency should be the central objective of all parties invested in a high-functioning, healthy society and state. To achieve this goal, the study of healthcare efficiency is essential and, to that end, better instruments for measuring and understanding efficiency are absolute necessities (Cylus, 2016).

Understanding Efficiency and Inefficiency

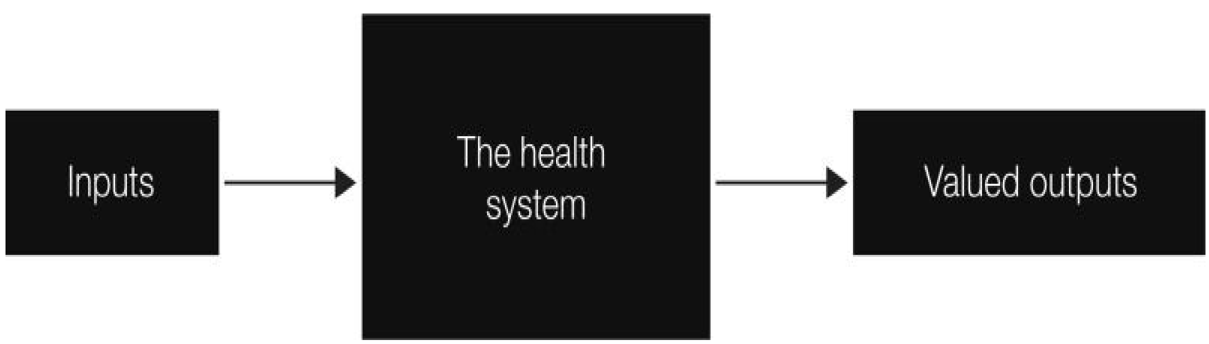
Inextricably tied to healthcare efficiency--and efficiency in general--is the idea of inefficiency. As easily as resources can be utilized wisely, they can likewise be wasted foolishly. Tackling unwise resource allocation has an important accountability value as it is essential to reassure health system backers, patients, and the general population that their money is being spent wisely and that resources are allocated optimally. These two concepts of efficiency and inefficiency may seem beguilingly simple. After all, these measures are frequently defined as a simple ratio of resources consumed to some measure of outputs that they create. Yet, despite its apparent simplicity, applying these concepts of efficiency in real-world settings can give rise to considerable complexity. This is especially true when examining efficiency in relation to the health system. All too often, measuring efficiency in this context reveals a number of complicated and interlinked processes which are difficult to evaluate and deem to be efficient or inefficient. In working with these concepts, it is helpful to start small, explain what efficiency and inefficiency mean in a certain context, and continue to expand upon an understanding of efficiency from this point. The following paragraph begins this process by outlining two very important terms in this field of research: allocative efficiency and technical efficiency.

Processes in the health system may be identified as inefficient for two distinct, but related reasons. The first reason is that health system inputs such as expenditure or other resources may be directed towards outputs that are not viewed as priorities by society. For example, high-cost end-of-life cancer treatments may be beneficial for the individuals involved, but society may see this spending as generally wasteful and believe that it could be better spent elsewhere (Cylus, 2016). Economists refer to this concept as allocative efficiency (AE) and it is often quantified using the measure of quality-adjusted life years (QALYs) as a prime cost-effectiveness criterion for determining treatment. The second reason for inefficiency within health systems is that there could be a misuse of inputs in the process of producing valued health system outputs, leading to wasteful spending. An example of this can be viewed with unnecessary duplications of patient medical tests that squander resources which could potentially be utilized more effectively elsewhere (Cylus, 2016). Economists refer to this concept as technical efficiency (TE). These comparative measures essentially indicate whether or not an entity is maximizing its outputs given a certain level of inputs. However, where AE is concerned with analyzing strategic choices of what outputs to produce or what inputs to consume, the prime interest of TE is in the operational performance of the entity. While these two forms of inefficiency may be different in their approaches, each of their analyses of health system performance is intended to offer insights into the success with which health system resources are transformed into physical outputs (i.e. patient consultations) or valued outcomes (i.e. improved health).

An Analytical Framework for Thinking about Efficiency Indicators

Now that the principles of AE and TE have been identified and explained, a simplistic viewpoint of efficiency can be established. Adopted from the European Observatory on Health Systems and Policies' 2016 "Health System Efficiency" Report, **Figure 3.1** below represents the ratio of inputs an organization consumes in relation to the valued outputs it produces (Cylus, 2016, p. 10).

Figure 3.1: *The naive view of efficiency*



In this model, efficiency is determined using an economist's "production function" mindset. A "production function" mindset is an economist's view of the transformation of inputs into valued outputs. This mindset indicates the maximum feasible level of output for a given set of inputs. Within this thought process, any failure to attain that maximum efficiency level is to some degree an indication of inefficiency. While straightforward and easy to follow, this way of thinking represents nothing more than a partial measure of efficiency because the indicator shows only a fragment of the complete transformation of resources into the desired outputs.

Especially when measuring health care systems, the majority of outputs rarely conforms to a production-line type technology in which a set of clearly identifiable outputs is used to produce a standard type of output. Instead, health care is designed to meet the specific needs of an individual patient, with various circumstances, preferences, and needs--ultimately leading to considerable variation in how inputs are consumed and outputs are produced. In light of these complexities, it is necessary to provide a framework for thinking more clearly about specific efficiency indicators and the respects in which each indicator may be informative, misleading, or partial. The five aspects of any efficiency indicator are: 1) the entity to be assessed; 2) the outputs (or outcomes) under consideration; 3) the inputs under consideration; 4) the external influences on attainment; and 5) the links with the rest of the health system (Cylus, 2016, p. 11).

The beginning of an efficiency assessment first depends on establishing the boundaries of the entity under scrutiny. At one extreme, an analysis could be as micro as a single treatment. At the other extreme, an analysis could be as macro as an entire health system. Most often, however, efficiency measurement takes place somewhere in the middle, where the actions of individuals or groups of practitioners, hospitals, or other organizations within the health system are to be analyzed and assessed. Despite this variation, almost all efficiency analyses rely on comparison--whether between entities or within a single entity for a certain time period. This means that it is of extreme importance that the entities being compared are legitimately similar. Efficiency comparison between a popular clothing firm and an internet start-up, a large hospital and a small primary clinic, and a country like the United States and that of Comoros--a volcanic archipelago off Africa's east coast--is to some extent unfavorable and suboptimal.

From this point, two fundamental issues need to be considered concerning the outputs under consideration within the efficiency analysis--specifically in regards to how these outputs should be defined and valued. It is most often agreed that health care outputs should be defined in terms of the health gains produced. These health gains are evidenced in a number of ways, but most often through diminishing rates of mortality, increasing rates of discharge, and more removed statistics like upturns in life expectancy. However, given the lack of routine information gathering and the challenging operational realities of this consensus, outputs are often defined in a different manner. In practice, analysts are often constrained to measuring efficiency on the basis of measures of activities. These measurements are frequently represented in the form of patients treated, operations undertaken, or outpatients seen. These general values are somewhat inadequate because they fail to capture the specificity, diversity, and quality of health care delivery, but there is not yet a viable alternative to using such measures.

Fortunately, determining the inputs under consideration within efficiency metrics is less problematic because they can be accurately measured and summarized in the form of costs. Nevertheless, even these agreed-upon measures can yield conceptual and practical difficulties. A fundamental decision that determines these difficulties is the level of disaggregation among the specified inputs. At one extreme, a single measure of aggregate inputs (in the form of total costs) can be used. The input side of efficiency then effectively becomes costs. This approach assumes that the entities under scrutiny are free to deploy inputs efficiently. However, in practice, some aspects of input deployment are beyond the control of the entity and can only be changed in the longer-term. This discrepancy leads to a misassessment of inputs for one or more of the entities. A similar but opposite issue occurs with labor inputs that can often be over-aggregated by different labor types depending on the circumstance (Cylus, 2016).

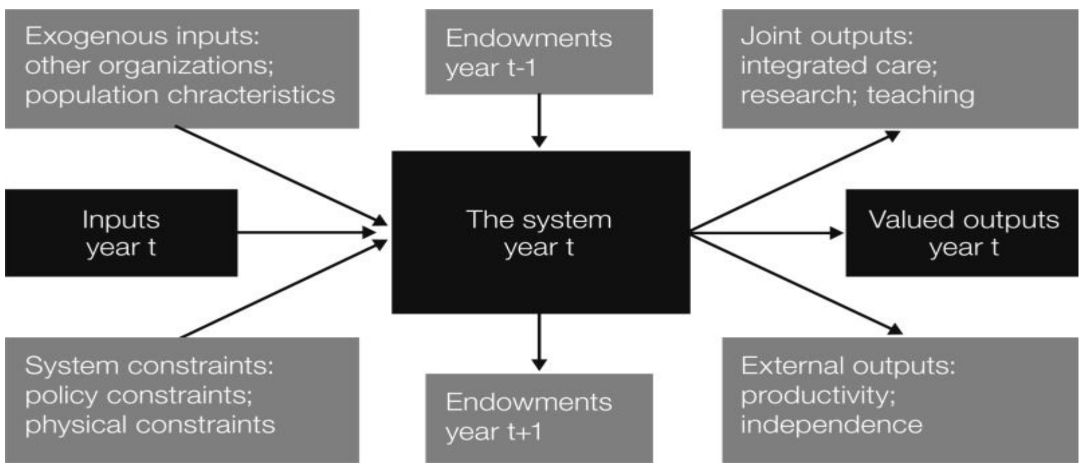
These difficulties continue with inputs of capital whose misuse can be a major source of inefficiency. Yet, incorporating these measures of capital into analyses is challenging, rudimentary, and sometimes misleading. In practice, analysts often have to be ready to resort to very crude measures of inputs such as the number of hospital beds or floor space as a proxy for physical capital. In deciding which inputs should be under consideration, it is important to remember that all efficiency metrics should be developed according to the intentions of the analysis. Doing so helps to remedy some of the aforementioned issues. If the interest is in the narrow and short-term use of existing resources, then disaggregating inputs is advantageous to the analysis as a whole. If the interest is in a less constrained and longer-term analysis, then a single measure of total costs may be perfectly adequate for indicating the physical inputs of an entity.

After satisfying these three aspects that make up what is considered a naive view of efficiency, it is important to consider two separate classes of factors that bolster efficiency analyses to make them more complete and comprehensive. One of which--the external determinants of performance--affects organizational capacity by influencing an entity beyond its control in the environment in which it must operate. These environmental factors include, but are not limited to, the severity of the disease of the patient, primary care organization structure, and local geography and settlement patterns (Cylus, 2016). There is often considerable debate as to what environmental factors are considered controllable and which should be included within an efficiency analysis. In the short-term, almost all input factors and external constraints should be fixed. In the longer-term, many can be changed depending on the level of autonomy. In many circumstances, it may be appropriate to consider efficiency metrics both with and without adjustment for external factors.

Rounding out the last aspect of any necessary efficiency indicator is the need to consider an analysis' links with the rest of the health system. This task is essential to develop a more complete efficiency analysis model. Scrutiny of a health system entity in isolation may ignore the important implications of the entity's impact on whole system efficiency. For example, if a primary care practice is held to account by only metrics of cost per patient, it might improve efficiency by shifting costs to other agencies without actually making better use of available resources (Cylus, 2016). This reality should be accounted for in any assessment of efficiency and, in principle, it should be feasible to do within the analytic framework. However, this is rarely done in practice and consequently important for determining bias in efficiency assessment.

Unfortunately, it is almost impossible to completely and perfectly accommodate each of the aspects summarized above into a single efficiency metric. Regardless, it remains important for efficiency analysts to be aware of which factors are more likely to affect the integrity of the analysis as a whole and seek to offer guidance on the implications of serious omissions and weaknesses (Cylus, 2016). This framework, in accordance with countless others, embraces the challenges and imperfections of efficiency analysis, aiming to deconstruct efficiency metrics into a manageable number of issues to propagate future research rather than remain incapable of potential efficiency comparison. **Figure 3.2** below summarizes and expands upon the more simplistic understanding of efficiency demonstrated previously by **Figure 3.1**. Similar to **Figure 3.1**, this table was adopted from the European Observatory on Health Systems and Policies' 2016 "Health System Efficiency" Report (Cylus, 2016, p. 19), but provides a more complete and complex understanding of efficiency which may be used for comprehensive efficiency metric analyses.

Figure 3.2: *A more complete model of efficiency*



Measuring Efficiency: Methods and Limitations

As mentioned previously, technical efficiency and allocative efficiency are essential for understanding inefficiency as they measure wastes of resources in their own distinct, but related manners. TE indicates whether an organization is maximizing its outputs given its chosen level of inputs, regardless of the value placed on those outputs, but AE indicates whether the value of the chosen outputs creates the maximum value to society. These economic concepts, despite their seeming complexity, offer the only current available unifying framework for assessing all the diverse objectives of health systems within an efficiency framework (Cylus, 2016). There are numerous metrics that utilize these economic concepts within their methodology to measure efficiency, but among the most common and established of these methods are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). In fact, "Over 400 published applications have used these methods within health care settings over the past 30 years," (Hollingsworth, 2016, p. 99). Both methods see efficiency as a simple relationship between inputs consumed and outputs produced and assess how effectively a unit of production, such as a hospital, uses its own inputs, such as staff and drugs, to produce outputs, such as patients treated. These analyses are especially important in the context of international healthcare efficiency because they provide perhaps the most reputable framework based on sound economic concepts and contribute transparent and potentially useful efficiency comparisons.

In efficiency analyses, the main interest is typically the connection between inputs and outputs, and often the connection between costs and outcomes. DEA is a useful efficiency metric for researchers that makes use of linear programming methods to place weights on the inputs and outputs in order to measure how efficiently an entity is converting inputs consumed to outputs produced. Measurements using DEA typically show the entities in question in the best possible light. This favorable representation should be taken into account when trying to understand the outcomes of a DEA analysis. For a multiple output or multiple input firm--like a hospital treating different types of cases using numerous nurses and physicians, various equipment, and so on--an overall measure of a hospital's TE requires summing these different inputs and outputs in some way. In other words, we must give weights to each of the inputs and outputs. Final efficiency measurements using DEA analysis metrics typically fall between 0 and 1, demonstrating the TE score for each entity. DEA is also potentially useful in measuring efficiency changes over time, often referred to as a Malmquist Index. Measuring changes over time, rather than simply providing a snapshot of efficiency, gives a more accurate picture of what is really happening across time from entity to entity (Hollingsworth, 2016).

Despite its potential successes, DEA analysis also has its fair share of shortcomings. The technique is deterministic and outlying observations are very important in determining the efficiency frontier--the threshold of entities that offer the highest expected return on inputs for a defined level of outputs. Therefore, when using DEA it is imperative to ensure like comparison between entities so as not to grossly misrepresent the outliers within question and squeue the efficiency frontier generated by the metric (Hollingsworth, 2016). Similarly, DEA is sensitive to the number of input and output variables used in the analysis. Overestimates of efficiency scores can occur if the number of units relative to the number of variables used is small. Thus, a general rule of thumb as determined by the EOHSP is that “the number of units used should be at least three times the combined number of input and output variables,” (Hollingsworth, 2016, p. 104). Still, DEA remains by far the most common method for analyzing efficiency within healthcare settings as it has now been applied successfully hundreds of times within such contexts.

Similar to DEA, SFA is a useful metric for researchers that uses its own methodology to measure the distance an entity such as a hospital is from a calculated efficiency frontier. However, rather than using mathematical programming, SFA uses a statistical regression analysis to complete such a task. In SFA, the usual statistical error term utilized in analogous regression equations is split into both inefficiency and error. Some view this distinction as a more precise measure of efficiency as it accounts for statistical noise--random irregularity researchers find in any real life data (Hollingsworth, 2016). These advantages, along with recent advances in modeling techniques and computing capabilities, are part of the reason why the use of SFA has received increased attention in the production of health care analyses over recent years. Nevertheless, as with DEA and every other known method of efficiency analysis, there are several downfalls. Estimating the production frontier of an SFA analysis requires all outputs--such as cost, for example--to be meaningfully aggregated in a single measure. However, this mix between variables and producer characteristics can skew distribution, error terms, and ultimately lead to an over- or under-estimation of efficiency (Hollingsworth, 2016).

Adding to the complexity of efficiency analyses is the brutal reality that even the most respected analyses like DEA and SFA can be very challenging in an international context. This is due in part to the seemingly endless variations across data sources and key differences in health system structures and practices. Even when this data is readily available, it can be extremely difficult to find compromises within the data that work to allow effective cross-country comparability. However, as mentioned in the EOHSP's 2016 health system efficiency report, it is:

> "almost certainly preferable to steer the health system with imperfect measures we have available, rather than to fly blind. In our view, efficiency analysis should be routinely embedded in all relevant functions of service delivery and policymaking. However, it is vital that decisions are taken in full recognition of the strengths and weaknesses of indicators, and that the search for improved metrics and better resources for comparison is pursued with vigour" (Cylus, 2016, p. 19).

In fact, any potential metric of efficiency will have its limitations depending upon its framework. This should not intimidate us as researchers, but instead motivate us to improve our measures and continue to analyze the efficiency of healthcare systems. Especially in an international context, these studies are severely lacking which in-turn limits proposals of policies that are potentially beneficial for benchmarking and gauging the efficiency of different types of healthcare delivery. These policies have the potential to remedy struggling healthcare systems and improve the lives of the citizens who rely on them; yet they continue to be overlooked. In fact, a study highlighted by EOHSP shared a 2008 review finding that out of all health care efficiency studies, only 4% were cross-country analyses (Cylus, 2016). Despite recognition that such data are desirable to capture trends in efficiency, compare changes over time, and identify the causal effects of policies, there simply remains reluctance among researchers to attempt to compare the limited cross-country longitudinal health data currently available.

Reconciling these truths--the difficulties of studying efficiency, the limitations associated with international healthcare comparisons, and the emergence of promising analytical metrics such as DEA and SFA--is a challenging but necessary task if researchers and governments alike wish to improve the current understanding of healthcare efficiency. Even more so, as worldwide populations continue to grow and resources continue to diminish, there is an increasing need for every country to maximize their overall effectiveness in healthcare delivery. The unfortunate reality is that health systems are extremely complex and there is often no consensus on which countries perform most efficiently, which method is the most appropriate, or which health outcomes should be directly attributed to certain healthcare inputs. Nonetheless, it is for the same reason that the most highly valued metrics are those which allow at least somewhat valid comparisons across countries (Cylus, 2016, p. 159).

In a perfect world, of course it would be prudent for countries to focus more on harmonizing and improving access to registry or hospital discharge level data. This is true not only at the micro level, but also at the macro level because it would allow for the control of potential confounders and ensure comparison across entities that are undoubtedly similar. It would be even more advantageous if countries could provide longitudinal data that allowed researchers to track changes in efficiency across time (Cylus, 2016). Sadly, these resources and databases simply are not available to us--at least not yet. Although, as data sources continue to gradually improve internationally, "it is only a matter of time when register-based monitoring will be a part of routine reporting and follow-up of the performance, effectiveness and efficiency of providers," (Sund, 2016, p. 73). Technical developments could likewise help to facilitate data availability in the near future, but even without these advances the appeal of international comparisons of health care efficiency is clear--despite the many challenges. Until that time, researchers should focus less on trying to develop perfect models and instead focus on robust comparisons using multiple analytical approaches.

Chapter Four: Measuring International Healthcare System Efficiency

Establishing a Comprehensive Framework for International Efficiency Analysis

In the previous chapter, the five aspects of any efficiency indicator are outlined in detail. In every efficiency analysis, it is important to remember that we must identify: 1) the entity to be assessed; 2) the outputs (or outcomes) under consideration; 3) the inputs under consideration; 4) the external influences on attainment; and 5) the links with the rest of the health system (Cylus, 2016, p. 11). In the case of healthcare efficiency analyses, we must be even more precise and consistent in our identification of these varying parameters. Each of these aspects must be outlined--whether measuring healthcare efficiency within the context of EHR and HIE or within another context--before beginning analysis in order to provide a clear and specific framework on which each efficiency indicator can be judged as informative, misleading, or partial.

Any analysis begins by establishing the boundaries of the entity under scrutiny. This entity could be as micro as a single treatment or as macro as an entire health system. For the purposes of this analysis, data will be measured from the perspective of an entire health system and on a country-by-country basis. This type of analysis focuses on entire health statistics databases such as the World Bank, World Health Organization, United Nations, and--in this instance--the Organization for Economic Cooperation and Development (OECD). However, analysis of these health system entities--and thus the databases that measure them--will predominantly focus on efficiency within the context of the hospital sector within each given country. Therefore, a hybrid approach is assumed in this analysis with a focus on hospital care to combine the benefits of the OECD's reliable data with the advantages of statistically significant findings associated with subsector-level analysis approaches.

The reason for this hybrid approach is due to the benefits and limitations associated with using DEA, SFA, or any other analysis metric in the context of healthcare efficiency. Employing these analyses with an emphasis on cross-country databases or a focus on system- or subsector-level approaches requires an understanding of how these analyses will stand in terms of internal validity, external validity, precision measurement, etc. Similar to analytic frontier methods--data analyses that establish a threshold of entities that offer the highest expected return on the inputs consumed--the factors behind these concentrations are nuanced and only increase in complexity when employed to measure efficiency internationally. To simplify the various qualities of analyses conducted with cross-country, system-, and subsector-level approaches, **Table 4.1** provides a summary of the examples, benefits, and limitations associated with each. This table is a shortened adaptation of its original version which can be found in the European Observatory on Health Systems and Policies' 2016 "Health System Efficiency" Report (Cylus, 2016, p. 160).

Table 4.1: *Summary table of international efficiency indicators*

Type	Source/example	Example indicators	Pros	Cons
Cross-country databases	• OECD Health Statistics database • WHO Europe health for all database	• Health expenditure per capita (or as a share of gross domestic product), which is often related to some broad health status measures (for example, life expectancy) • Average LOS • Bed occupancy rates	• Regularly updated time series • Databases contain some ready-made efficiency indicators or can be used to construct efficiency indicators at the system-, subsector- or disease-based level (as described below)	• Links between expenditure, inputs, outputs and outcomes are often weak (or inexistent) • Aggregate (macro) data at the national level (no disaggregation at the provider or patient level) • Limited number of outcome measures
System-level	• OECD efficiency study (Joumard, André & Nicq, 2010) • WHO efficiency study of 191 countries (Evans et al., 2001)	• Efficiency scores, often using analytical methods such as DEA, SFA or other regression-based methods	• Enables comparison of entire systems • Can control to some extent for confounders • Often assesses the entire production process from expenditure to health outcomes (that is, life expectancy)	• Usually cross-sectional • Adjustments for confounders are likely to be imprecise due to aggregation; outputs are not necessarily directly or exclusively attributable to inputs • Results sensitive to model specification and countries chosen for comparison • Often rely on cross-country databases which may inhibit external validity
Subsector-level	• Finnish and Norwegian hospitals (Linna, Häkkinen & Magnussen, 2006) • Swiss and German hospitals (Steinmann et al., 2004)	• Efficiency scores using analytical methods such as DEA, SFA or other regression-based methods	• Can better account for confounders than system-level studies because of patient similarities	• Most research is for hospitals only • Usually cross-sectional • Results sensitive to model specification and countries/facilities chosen for comparison • Often assess health care outputs (for example, discharges) instead of health outcomes

Using this table, we can establish and outline our analysis as an international comparison of the technical efficiency and productivity of the hospital subsector. Having now clearly identified the entity in question, it is imperative to identify the countries that will be measured under such a framework. For the purpose of this research project, the efficiency study assumes a fifteen country analysis. This dataset should provide an extensive look into healthcare system efficiency for each country and serve as a resourceful tool for future researchers. These countries in question are: Australia, Canada, Denmark, France, Germany, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and the United States. This analysis should be completed without making disparate or inappropriate comparisons across countries as each of these nations is comparatively modernized and industrialized with health systems that are unique, diverse, and rather high-functioning. Any two of these fifteen countries could be chosen at random and compared to the other with little difficulty as each maintains a similar quality of life, economic development, health expenditure, and much more. More importantly, each of these countries holds membership in the OECD and continuously updates database profiles that contain countless insights into the operational capacity of their respective healthcare systems. Finally, while the number of countries considered within the analysis could be increased to include other highly-developed OECD nations, we instead chose to limit the number of countries to only OECD member states with well-documented histories of EHR and HIE implementation. Much of this history was provided thanks to The Commonwealth Fund's International Health Care System Profiles in which each of the fifteen countries selected are included.

Now that boundaries have been established for the entity and respective countries under consideration, two fundamental issues need to be carefully considered regarding the outputs associated with the analysis. It is most often agreed that health care outputs should be defined in terms of the health gains produced. However, this health gain data is almost never readily available which prompts researchers to instead use inpatient days or discharges as an intermediate form of output data. This analysis will focus on data pertaining to two of the most readily available intermediate outputs: discharge and mortality. Discharge rate is generally important because it documents how many individuals are successfully moving through the health system. More specifically, heightened discharge rates in the presence of EHR and HIE could be an indication that the technology is increasing a hospital sector's capacity to treat more patients more quickly, thus increasing overall efficiency. The output of discharges is favored over inpatient days as unnecessary inpatient days may be a false indication of high hospital efficiency (Varabyova, 2013). For the purposes of this research project, discharge data is considered by diagnostic category, measured by density per 100,000 members of the population, and includes all diagnostic category causes. Mortality, the second health care output taken into consideration, captures the average in-hospital mortality rate as an additional variable to control for the potential tradeoff between inefficiency and death. Opposite to discharge rate, mortality rates are important because they provide information about how many individuals are unsuccessfully moving through the health system. This measurement represents a viable measure for hospital quality because it encompasses "effective medical interventions and [the] timely and coordinated treatment of patients," (Varabyova, 2013, p. 74). Within this analysis, the in-hospital mortality output is maintained and measures the value in terms of rate per 100,000 hospital patients. Oftentimes, a lack of routine information gathering and the challenge of arriving at a consensus of output measurements in question poses problems for efficiency analyses, but these two outputs under consideration are commonly adopted within a number of current healthcare efficiency studies.

The next phase of analysis turns to determining the inputs in question.These choices are less problematic within efficiency metrics because they are almost always accurately measured and summarized in the form of resource costs. At one extreme, a single measure of aggregate inputs (in the form of total costs) can be used. However, in this analysis the input variable of cost is adapted to accommodate a number different common hospital resources: number of beds, total hospital employment, physician employment, and professional nurse and midwife employment. First, the number of hospital beds represents a measure of total hospital resources consumed. The number of beds is “conventionally used as an approximation for the capital and technology input in a within-country hospital comparison as well as in an international context,” (Varabyova, 2013, p. 74). Next, total hospital employment represents a head count of available medical personnel within a given hospital. This data is sometimes disaggregated by skill level--especially to differentiate between the availability of physicians or nurses and midwives--but total hospital employment remains a necessary input measurement to account for healthcare systems and entities that stray away from healthcare delivery via traditional hospital personnel. Nevertheless, given this analysis’ focus on OECD database metrics, physician employment as well as professional nurse and midwife employment are both considered as separate variables to deliver a more complete count of total inputs into each hospital-sector-focused measurement.

Our analysis has now satisfied three aspects of what typically make up a naive view of efficiency: the entities, outputs, and inputs under consideration (pictured in **Figure 3.1** of Chapter Three). Now, we must also consider two separate classes of factors that enhance the validity of any efficiency analysis. One of these factors, the external determinants of performance frequently referred to as environmental variables, affects organizational capacity by influencing an entity beyond its control in its operational environment. These environmental variables often include disease severity of each patient, primary care organization structure, and local geography and settlement patterns. For the purpose of this international efficiency measure, the analysis will include: healthcare expenditure, financing of health care, income inequality, market influences, education, length of stay, health status, patient mix, and full-time employment.

The first of these external factors, healthcare expenditure, is absolutely necessary to measure as this data provides insight into not only what portion of the economy is dedicated to health funding, but also whether this dedicated funding is effectively improving healthcare system performance to justify the cost. This measure is included in environmental variables and not input variables because it is not directly involved in the care delivery process in the same manner as total hospital beds, total hospital employment, etc. Instead, this variable is beyond the control of a hospital's operational environment. In this study, healthcare expenditure is measured in terms of share of gross domestic product and includes all facets of spending--both public and private--in order to tailor the measurement to each country's economy.

Financing of health care is similarly important for complete and comprehensive analyses, especially because all OECD countries use different methods of financing their healthcare through both public and private sources. An analysis can control the effects of this mixed financing scheme by considering both the percentage of public and private financing. As mentioned by Varabyova, high levels of private spending can often lead to regressive health systems and lead to greater inequalities in health resource access (2013, p. 74). This analysis measures both of these financing methods separately, but in different ways due to limitations in data availability. Public financing is measured using the share of gross domestic product consumed by curative and rehabilitative care in hospital settings. On the other hand, private financing is measured using the share of current expenditure on health for voluntary schemes or out-of-pocket payment schemes. The units of measurements for the two variables of healthcare expenditure and financing of health care may appear to be different at first glance, but the second measure simply provides a more concentrated view of how current health expenditure is divided between public and private outlets.

The third environmental variable considered is income inequality because differences in income distribution "might affect health status and health care efficiency at the international as well as at the regional level," (Varabyova, 2013, p. 74). This variable is recorded using the Gini coefficient which assumes a value from 0 to 1 in which a higher value represents a greater degree of inequality.

Market influences are likewise included to account for competitive pressures within the health sector that could elicit faster adoption of technology or better capture economies of scale. These influences are typically measured using total hospital density as well as public hospital density to again emphasize the importance of considering mixed-scheme financing. Within the analysis, each of these measures are maintained and counted in terms of density per million population.

The remaining environmental variables to be measured are equally as important for consideration within international healthcare efficiency analyses, but differ slightly from those previously described as they focus more on country demographics and population health statistics. Education represents one of these variables and has proved to be a key contributing factor to empirical studies on health, influencing both quality of life and mortality rates (Varabyova, 2013, p. 74). As is common, this analysis measures education as the percentage of the population with a secondary education ages 25 to 64. Length of stay within hospital settings also represents another factor that differs considerably from country to country. Certain health systems may be structured so that hospital stays are less costly than others which allows providers to keep patients longer without fear of high expenses; this reality may lead to unnecessary inpatient days and a disproportionate increase in inefficiency. To help eliminate some of this nuance, average length of stay for all causes is measured in days and included in the analysis. Health status is yet another measure that controls for the heterogeneity in population health status. Therefore, life expectancy is measured in years to characterize the quality of elderly care. On the other hand, infant mortality rate is measured in deaths per 1000 live births to assess the quality of prenatal care.

The factor of patient mix is then included to continue with this demographic focus. Case-mix differences are almost always evident within empirical studies and hospital analyses should include some measure of the proportion of elderly patients. In this analysis, such a proportion is quantified by measuring the percentage of the total population 65 years old and older. Finally, full-time employment is included as the last of the environmental variables to account for what could be an overestimation of part-time labor input. This analysis takes into consideration the share of full-time employment in each country's economy to control for the difference in working hours from one OECD country to the next.

An analysis that satisfies each of these four aspects of efficiency indication provides a more complete view of efficiency. This is important within any efficiency analysis, but absolutely imperative for the validity of studies which aim to compare international healthcare systems. If any of these aspects differ to a considerable extent--the entity in question, input variables, output variables, or environmental variables--researchers will inevitably face difficulties in formulating reliable comparisons. Even having satisfied each of these components, yet another aspect must still be considered to provide an even more polished efficiency analysis model: the links an analysis shares with the rest of the health system. This aspect is important because scrutiny of a health system entity in isolation has the potential to ignore the important implications of the entity's impact on whole system efficiency. In principle, this aspect of analysis should be feasible to do within a given framework. An in-depth evaluation of health system operations within the context of EHR and HIE is provided in Chapter Six for several different countries. However, for the purposes of this research project, the analysis provided bypasses hyper-specific scrutiny of whole system efficiency to instead utilize a hybrid approach that focuses on subsector-based data made available by cross-country databases like the OECD.

Measuring Efficiency within the Context of EHR and HIE

As evidenced by preceding sections and chapters of this text, measuring efficiency from country to country is an extremely beneficial skill and useful tool for healthcare researchers, workers, and beneficiaries. To be able to measure efficiency within and between healthcare systems provides researchers with the insight they need to improve regional, national, and international care delivery. However, this understanding efficiency means very little in the context of this research project if it cannot be applied within the context of electronic health records and health information exchange.

In order to accomplish this task, I performed a data analysis--more specifically, a stochastic frontier analysis--over a period of 18 years (2000 to 2017) to determine efficiency scores for each country and year. Efficiency scores were then compared on a country-by-country basis using the year that EHRs were introduced and the most current efficiency score available (2017). In almost all cases, there is no exact point in time when EHRs were introduced on a nationwide scale for a given country. Current literature exemplifies the slow-moving nature of EHRs thanks to high cost, reluctant adoptance, and challenges in effective training and use so it is understandable that these initial dates of EHR implementation are somewhat fluid and open to educated interpretation. To accommodate for this obstacle, an estimated date was determined for each country. These dates, along with indexes of EHR adoption by country and extended explanations for how each date and index score was selected, are provided in more detail in **Table 5.5** of Chapter Five.

By comparing these efficiency scores through numerous time periods and across various countries, the hope is to gain a more precise understanding of not only whether EHRs have affected health system efficiency, but also at what point, to what degree, and in what aspects. This method represents the most inclusive analysis of EHR and HIE impact on international healthcare system efficiency. Efficiency analyses--and the scores that they determine--control for the majority of outside variables that might otherwise tarnish a study with bias. Comparing these values over time should provide a more telling representation of the impact EHRs have on each nation and the international community as a whole.

Limitations: Methods

There are countless obstacles to measuring and understanding the complex functions of healthcare and various healthcare systems, but one thing is absolutely certain: our methods can always be updated and improved. In a more perfect analysis, one might improve some of the variables under consideration--like disaggregating discharge data to classify discharges by diagnostic category. In doing so, this output could be made more extensive by including a shortlist of diagnostic categories or a global length of stay (LOS) measure. However, given the limitations of this research project, a luxury such as this had to be sacrificed. In a perfect world, it would undoubtedly be prudent to focus on harmonizing data or going the extra mile to control for potential confounders. Sadly, this reality is not always attainable, but that does not discount the versatility and usefulness of methods such as this. In the future, developments in healthcare and economic research could help to facilitate new frameworks for thinking about and analyzing healthcare system efficiency--especially as it relates to new tools provided by HIE such as the EHR--but even without these advances this methodology has proved itself both thoughtful and extensive. As mentioned previously, it is less important for researchers to focus on trying to develop perfect models and more important to instead focus on robust comparisons using diverse analytical approaches and deliberate thought processes.

Chapter Five: Data and Analysis

Justification for a Hybrid Stochastic Frontier Analysis (SFA) Approach

In Chapter Four, **Table 4.1** provides a summary of a number of different approaches for international efficiency measurements. Each of these examples--cross-country, system-, and subsector-level approaches--brings its fair share of benefits and limitations to any efficiency measurement. For the purpose of this project, the following analysis combines different aspects of each of these approaches into a hybrid approach to create a more valid and reliable assessment of international efficiency. This hybrid analysis uses cross-country data from the OECD iLibrary Data Warehouse, but does so with a system-level focus on hospital sector data to calculate an efficiency score for each country under consideration. The purpose of this mixed analysis is to combine the advantages of each type of approach and avoid some of the methods' associated disadvantages. Advantages of this hybrid approach include: regularly-updated, reliable, and comprehensive data; the capacity to control for confounding variables to some extent; and the ability to effectively compare entire health systems. Likewise, some disadvantages this analysis tries to bypass include: weak associations between inputs, outputs, and expenditures; limited external validity; and an impeded focus on health outcomes as opposed to an assessment of health outputs.

This hybrid approach to international efficiency measurement and the data associated with each of the inputs, outputs, and environmental variables under consideration is then regressed using Stochastic Frontier Analysis (SFA) in order to both understand how each input affects an associated output and to determine an overall efficiency score for each country. SFA was determined more appropriate than Data Envelopment Analysis (DEA) for several reasons.

First, DEA focuses on often complicated linear programming methods that must place weights on certain inputs and outputs. On the other hand, SFA uses statistical regression methods that combine all variables into a single aggregate measure. Additionally, SFA measures relationships between variables in ways that are often regarded as more user-friendly and easily understandable. An example of this is denoted in the Findings portion of this chapter as associated coefficients show the extent to which both the inputs and environmental variables affect each output. The last--and perhaps most influential--reason for choosing SFA over DEA was the availability of online resources and research professionals to help assist in completing such an analysis. This reality is explained in more detail in the following section; however, simply put, SFA appeared more appropriate for the purposes of this study.

The analysis portion of this research project was conducted using STATA, a general-purpose statistical software package most often used for research in the fields of economics, sociology, political science, biomedicine, and epidemiology (Stata, n.d.). I was instructed on how to use this software package for basic regression analyses, conducting t-tests, extrapolating graphs and charts, etc. in one of my undergraduate courses. However, given the hyper-specific nature of DEA and SFA analyses as well as their importance in this area of study, I thought it best to reach out to several professionals for assistance in completing my efficiency analysis. After several unsuccessful attempts to locate and secure assistance from faculty, I solicited the help of a third-party postdoctoral researcher who aided my completion of the SFA analysis. More information on this endeavor is located within the **Acknowledgements** section of my thesis.

Findings: Output 1

Table 5.1 and **Table 5.3** show the results of this analysis as each table presents the Input and Environmental Variables' coefficient scores in relation to Output 1 and Output 2. Similarly, **Table 5.2** and **Table 5.4** represent efficiency scores for each country in relation to Output 1 and Output 2. These efficiency scores represent technical efficiency benchmarks where 1.000 is completely efficient (more favorable) and 0.000 is completely inefficient (least favorable). Both the data used to inform these STATA commands as well as the accompanying Do Files used to complete them can be located in the Appendix chapter. The findings resulting from this data analysis using these commands are found below. Agains, the results of Output 1 are important because discharge rate more or less documents how many individuals are successfully moving through the health system. In the case of EHR and HIE, heightened discharge rates could be an indication that the technology is increasing a hospital sector's capacity to treat more patients more quickly, thus increasing overall efficiency.

Table 5.1: *Stochastic Frontier Analysis Coefficients, Output 1*

Stochastic Frontier Analysis Output 1: Log Discharge Rate By Diagnostic Category, All Causes (Per 100,000 Population)		
	VARIABLES	**COEFFICIENT**
	INPUTS	
1)	Total hospital beds (per 1000 pop.)	0.081***
2)	Total hospital employment (per 1000 pop.)	-0.012***
3)	Physicians employed in hospitals (per 1000 pop.)	0.154***
4)	Professional nurses and midwives employed (per 1000 pop.)	-0.004***
	ENVIRONMENTAL VARIABLES	

1)	Health expenditure (share of GDP)	0.006
2)	Expenditure on curative and rehabilitative care (share of GDP)	0.064
3)	Household out-of-pocket payments (share of health exp.)	-0.005*
4)	Income inequality (Gini coeff.)	4.335***
5)	Total hospitals (per million pop.)	0.007***
6)	Publicly owned hospitals (per million pop.)	-0.002
7)	Upper secondary education (per 1000 pop.)	-0.000
8)	Average length of stay, all causes (days)	0.054***
9)	65 years old and over (% of total pop.)	-0.020***
10)	Life expectancy at birth (years)	-0.022
11)	Infant mortality (deaths per 1000 live births)	-0.071*
12)	Incidence of full-time employment (share)	-0.004

Notes: ***Significant at the 1% level; *Significant at the 10% level

When working with data analysis of any type, one factor is always important in determining the validity of a given set of results: statistical significance. As evidenced by the table above, all four input variables were found statistically significant in influencing Output 1, the discharge rate. Given this information, we can confidently move on to analyzing our coefficient score to better understand how each of these variables influences Output 1. Examining the coefficient score for Input 1, one can resolve that if the total number of hospital beds increases by 1 bed per 1000 population, the discharge rate increases by .081 discharges per 100K population. Likewise, if the number of physicians employed increases by 1 physician per 1000 population, the discharge rate increases by .154 discharges per 100K population. However, one can also conclude that the total hospital employment and the number of nurses and midwives employed decrease the discharge rate significantly. While this only occurs to a very marginal degree, (.012 and .004, respectively) this information is still meaningful in determining how one variable impacts another. Switching focus to the environmental variables, one can conclude that income inequality, total hospitals, and average length of stay each significantly influence efficiency in a positive manner (by 0.043, 0.007, and 0.054 coefficient points respectively). On the other hand, a higher proportion of older people and a higher infant mortality seem to reduce efficiency (by .020 and .071 coefficient points, respectively). Meanwhile, other variables such as the number of total hospitals is significant at the 10% level. While this determination may still influence our view of how certain variables impact the rate of discharges or the overall efficiency, it is not economically meaningful and should not be included in the findings of more comprehensive and conclusive efficiency analyses.

Table 5.2: *Efficiency Scores by Country and Year, Output 1*

STOCHASTIC FRONTIER ANALYSIS OUTPUT 1: EFFICIENCY SCORES BY COUNTRY AND YEAR										
Country	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Australia										
Canada						0.631				
Denmark		0.897	0.901	0.908	0.916	0.910	0.908	0.904	0.895	0.918
France	0.761	0.745	0.734	0.734	0.739	0.743	0.746	0.734	0.742	0.762
Germany	0.781	0.789	0.802	0.874	0.881	0.881	0.899	0.926	0.947	0.954
Israel	0.972	1.000	0.987	0.988	0.944	0.971	0.999	0.972	0.960	0.967
Italy				0.826	0.825	0.804	0.802	0.777	0.767	0.756
Japan										
Netherlands	0.567	0.564	0.577	0.603	0.631	0.647	0.641	0.652	0.674	0.697
New Zealand										
Norway			0.937	0.972	0.959	0.962	0.975	0.950	0.953	0.997
Sweden										
Switzerland				0.811	0.823	0.827	0.847	0.865	0.890	0.883
United Kingdom										
United States	0.925	0.943	0.973	1.000	0.996	0.990	0.987	0.970	0.997	0.996

STOCHASTIC FRONTIER ANALYSIS OUTPUT 1: EFFICIENCY SCORES BY COUNTRY AND YEAR (CONT.)									
Country	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Overall**
Australia									
Canada		0.629					0.633	0.638	0.633
Denmark	0.914	0.908		0.874	0.895	0.876	0.845	0.834	0.878
France	0.771	0.761	0.760	0.752	0.746	0.743	0.858	0.852	0.780
Germany	0.961	0.971	0.980	0.983	0.996	0.996	1.000	0.991	0.985
Israel	0.978	0.974	0.983	0.957	0.927	0.919	0.900	0.879	0.939
Italy	0.735	0.713	0.700	0.680	0.667	0.661	0.647	0.639	0.680
Japan									
Netherlands			0.730	0.610		0.632	0.621	0.604	0.639
New Zealand									
Norway	1.000	0.975	1.000	0.989	0.980	0.976	0.973	0.951	0.981
Sweden									
Switzerland	0.875	0.873	0.861	0.865	0.875	0.878	0.874	0.864	0.871
United Kingdom									
United States	0.954								0.954

Table 5.2 provides efficiency scores for each of the countries under consideration for any given year between 2000 and 2017. In cases where efficiency scores are missing, it is due to a lack of data available to complete the statistical regression. This data is most often lacking in the Input category, but is occasionally absent for environmental variables as well. This hindrance is explained in more detail in the Limitations section of this chapter. Nevertheless, it appears as though both the United States and Norway exhibit the highest overall efficiency scores for any country examined within the analysis--although, it is important to note that the last seven years are missing efficiency measures for the United States. Therefore, it remains somewhat unclear whether the United States can be viewed as more efficient than Norway, Israel, or a handful of other countries within the analysis. Additionally, it is remarkable that several countries achieved a maximum efficiency score of 1.000 and were considered at the benchmark efficiency level for healthcare efficiency over any extended period of time. However, given the number of efficiency scores missing within this portion of the analysis, it can be concluded that the measure possesses a rather weak validity.

Findings: Output 2

Table 5.3 was arranged using the same methods as **Table 5.1**. Thus, the values found within this table can be interpreted in a similar manner. The only difference worthy of notation for interpreting these coefficient scores is the switch from Output 1, measuring the discharge rate, to Output 2, measuring the average in-hospital mortality rate.

Table 5.3: *Stochastic Frontier Analysis Coefficients, Output 2*

Stochastic Frontier Analysis Output 2: Log Average In-Hospital Mortality Rate (Per 100,000 Patients)		
	VARIABLES	**COEFFICIENT**
	INPUTS	
1)	Total hospital beds (per 1000 pop.)	0.013***
2)	Total hospital employment (per 1000 pop.)	-0.003
3)	Physicians employed in hospitals (per 1000 pop.)	-0.128***
4)	Professional nurses and midwives employed (per 1000 pop.)	0.022**
	ENVIRONMENTAL VARIABLES	
1)	Health expenditure (share of GDP)	-0.000
2)	Expenditure on curative and rehabilitative care (share of GDP)	-0.000
3)	Household out-of-pocket payments (share of health exp.)	-0.000
4)	Income inequality (Gini coeff.)	0.000***
5)	Total hospitals (per million pop.)	0.000*
6)	Publicly owned hospitals (per million pop.)	0.000
7)	Upper secondary education (per 1000 pop.)	-0.000
8)	Average length of stay, all causes (days)	-0.000***
9)	65 years old and over (% of total pop.)	0.000*

10)	Life expectancy at birth (years)	-0.000***
11)	Infant mortality (deaths per 1000 live births)	-0.000**
12)	Incidence of full-time employment (share)	0.000

Notes. ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

As evidenced by the table above, the number of hospital beds and the number of physicians employed significantly influence the average in-hospital mortality rate. If the total number of hospital beds increases by 1 bed per 1000 population, the mortality rate increases by .013 mortalities per 100K population. However, if the number of physicians employed increases by 1 physician per 1000 population, the mortality rate decreases by 0.128 mortalities per 100K population. Therefore, investing in human resources in hospitals such as physicians employed is very important. Unfortunately, when we observe relationships among the environmental variables, it is clear that the analysis does not hold the same internal validity as that of Output 1--and it is even less likely to maintain any sort of external validity. This low level of internal validity is likely due to large collinearity, missing values, and an overall low sample size of panel data available. Ultimately, while some of these input and environmental variables are found to be significant, none of them are economically meaningful at the three decimal point level and cannot be included in any comprehensive efficiency analysis.

Table 5.4: *Efficiency Scores by Country and Year, Output 2*

STOCHASTIC FRONTIER ANALYSIS OUTPUT 2: EFFICIENCY SCORES BY COUNTRY AND YEAR						
Country	**2000**	**2005**	**2010**	**2015**	**2017**	**Overall**
Australia						
Canada		0.998				0.998
Denmark	0.998	0.998	0.998	0.998		0.998
France	0.998	0.998	0.998	0.998		0.998
Germany	0.998	0.998	0.998	0.998		0.998
Israel	0.998	0.998	0.998	0.998		0.998
Italy		0.998	0.998	0.998		0.998
Japan						
Netherlands	0.998	0.998		0.998		0.998
New Zealand						
Norway		0.998	0.998	0.998		0.998
Sweden						
Switzerland		0.998	0.998	0.998		0.998
United Kingdom						
United States	0.998	0.998	0.998	0.998		0.998

The abundance of variables exhibiting almost no correlation displayed within the findings of **Table 5.3** forecast the rather meaningless efficiency scores provided in **Table 5.4**. These efficiency scores do not differ at all at the three decimal point level. While they do differ at lower levels, this variation is almost completely insignificant. It is clear that the efficiency analysis for this outcome is neither statistically nor economically meaningful. A detailed explanation for this adverse outcome is provided in the Limitations section below.

Findings: Understanding Efficiency Scores in the Context of EHR and HIE

Given the unfavorable results highlighted in **Table 5.4** of this data analysis, measurement of the effects of EHR and HIE on international healthcare system efficiency will proceed using only the efficiency scores found in **Table 5.2**. Of course, as mentioned previously, these effects will be calculated by measuring the change in efficiency over time for each of the countries under consideration. The first date used in measuring the difference in efficiency scores will be determined using the initial date of EHR program or legislation implementation in each country. Therefore, this date will vary by country and may be open to interpretation in certain circumstances. The second date used in measuring the difference in efficiency scores remains fixed for the year 2017--the most up-to-date efficiency score capable of being measured given available OECD data. Each of the initial dates for EHR implementation for each respective country is outlined in **Table 5.5** below. In addition to this date, the table provides the respective name of the EHR program or legislation as well as an index score for each country. Similar to the task of determining the initial date of EHR implementation, the index score is determined in a manner that is somewhat open to interpretation. However, justifications for each score are provided within the table. Each of these decisions were informed by current literature as well as an assessment of current EHR adoption relative to other countries considered within the analysis.

Table 5.5: *EHR Index, Implementation, and Adoption by Country*

Countries	Date of Implementation	Name of EHR Program/Legislation	Reasoning for Index Score
Australia	**2012**	**My Health Record**	➢ **Currently beginning opt-out due to security concerns**
Canada*	**2001**	**Infoway**	➢ **Lacking adoption in hospitals**
Denmark	**2007**	**E-Journal**	➢ **Does not exist as a national EHR, but instead as a means of data empowerment**
France*	**1998**	**Carte Vitale**	➢ **High interoperability, adequate adoption rates, and plans to extend to social sector in the future**
Germany	**2004**	**EHC, GMG**	➢ **Does not exist as an EHR, but instead as a smart card**
Israel	**2012**	**-**	➢ **Strong implementation with plans for increased interoperability**
Italy	**2012**	**InFSE**	➢ **Average implementation with plans to slowly connect interregional EHRs**

Japan*	**2002**	**-**	➢ **Very little progress in implementing a non-experimental national EHR**
Netherlands	**2011**	**AORTA**	➢ **Plans to grow eHealth programs continue to remain in developmental stages**
New Zealand	**1980**	**Health Information Platform (HIP)**	➢ **Four regional systems that operate independently without interoperability**
Norway	**2008**	**Summary Care Record (SCR)**	➢ **History of high adoption, usage, and consistent improvement**
Sweden	**2009**	**National Patient Summary (NPÖ)**	➢ **All 21 regions have provided citizens with access to a national EHR since EHR was adopted**
Switzerland	**2015**	**LCIP**	➢ **Recently implemented with anticipation of slow adoption**
United Kingdom*	**2015**	**NHS App**	➢ **EHR abandoned early, patient record now linked only through NHS App**
United States*	**2009**	**HITECH Act**	➢ **Development of Meaningful Use standards, eightfold increase in use since EHR establishment**

Notes: *Countries outlined in Chapter Six: Case Studies by Country; Legend located below.

Very Strong Implementation	**Strong Implementation**	**Average Implementation**	**Weak Implementation**	**Very Weak Implementation**

Now that each country has an identified date of initial EHR program or legislation implementation, the efficiency change over time can be measured and analyzed. The results for this calculation are provided in **Table 5.6** below.

Table 5.6: *Change in Efficiency Over Time*

Country	Initial Year ; Efficiency Score	2017 Efficiency Score	Change in Efficiency
Australia	2012 ; N/A	N/A	Undetermined
Canada	2001 ; N/A	0.638	Undetermined
Denmark	2007 ; 0.904	0.834	- 0.070
France	1998 (~2000) ; 0.761	0.852	+ 0.091
Germany	2004 ; 0.881	0.991	+ 0.110
Israel	2012 ; 0.983	0.879	- 0.104
Italy	2012 ; 0.700	0.639	- 0.061
Japan	2002 ; N/A	N/A	Undetermined
Netherlands	2011 (~2009) ; 0.697	0.604	- 0.093
New Zealand	1980 ; N/A	N/A	Undetermined
Norway	2008 ; 0.953	0.951	- 0.002
Sweden	2009 ; N/A	N/A	Undetermined
Switzerland	2015 ; 0.878	0.864	- 0.014
United Kingdom	2015 ; N/A	N/A	Undetermined
United States	2009 / 0.996	N/A	Undetermined

These results are admittedly suboptimal in the grand scheme of determining the long-term effect that EHRs and HIE have on international healthcare system efficiency. Of the results, two of the countries--France and Germany--show positive increases in efficiencies over an 18 and 14 year time period, respectively. Conversely, six of the countries--Denmark, Israel, Italy, Netherlands, Norway, and Switzerland--demonstrate negative declines in their efficiencies with an average time period of almost 8 years between EHR implementation and current modern-day use. The remaining countries under consideration--Australia, Canada, Japan, New Zealand, Sweden, the United Kingdom, and the United States--all remain undetermined in terms of measuring their change in efficiency over time. Two of these nations--Canada and the United States--provided a handful of efficiency scores over the 2000 to 2017 time period, but each of the other countries yielded no results for any of the years in question. Explanations for these deficiencies are outlined in the following section and Chapter Seven. However, this data analysis seems to raise more questions about both the long-term efficacy of EHRs and the feasibility of performing international healthcare efficiency analyses than it does affirm optimistic sentiments about health information technology as a whole.

Limitations: Findings

There are a number of limitations that could and should be addressed in an analysis such as this to improve its validity and comprehensiveness for the future. One can begin at the very beginning with the difficulties in measuring a rather new topic such as electronic health records and health information exchange. As with any new technology, there are limitations in measuring when it was implemented, to what degree, and to what level of success. Even more complicated is the fact that the idea of EHR implementation has been an issue that numerous countries have wrestled over for years. Some countries have even moved forward with EHR implementation for a number of years before deciding to abandon the program entirely--examples of these actions are touched on and explained in detail in Chapter Six with the cases of the United Kingdom and Australia.

Continuing on with the limitations of this data analysis, it is important to think back again on the limitations of efficiency study in the first place. There is almost no consensus on how exactly it should be carried out, which entities should be included, or what variables should be under consideration. Even more troubling is the prospect of conducting an efficiency analysis from an international perspective where even more challenges and nuance begin to intertwine with each step of the analysis. Countries must be proven--at least to some degree--demographically, politically, and economically similar. Without satisfying this requirement, the data input into any analysis can be skewed or tarnished with bias altogether.

If each of these fundamental prerequisites are satisfied, the most insurmountable obstacle of them all--data availability and collection--waits in the wings for researchers to battle fruitlessly. Data availability and collection are impediments that researchers must deal with in almost every investigative or analytical scenario, but even more so in the case of international analyses of healthcare and healthcare efficiency. Data sources are often numerous, but frequently lack comprehensive longitudinal data for even a third of the countries around the globe that could otherwise be more appropriately studied and understood. When this data is rarely available, it almost never satisfies the needs of programs that demand thousands of observations in order to determine causality, prove statistical significance, and yield acceptable standard deviations. For example, even in the case of Output 1, which provided the most significant results of this analysis, there remain a myriad of missing values in the dataset. As a result, more than a third of the available efficiency scores are missing within this study--and five of these countries are missing scores in their entirety.

Even when these countries and a majority of their input, output, and environmental variables are accounted for and reported, there still remains a serious statistical issue of small sample size. Statistical regressions, especially those of the more complex variety like SFA and especially DEA, rely on large sample sizes in order to calculate statistically significant values like the coefficient and efficiency scores. In the case of this analysis, 15 countries were measured using 4 input variables, 2 output variables, and 12 environmental variables over an 18 year period (2000-2017). Altogether, these variables numbered more than 270 unique observations. Even with somewhat large sects of missing data, no variable within the data set ever contained less than 153 observations. In fact, only three of the variables ever dipped below 195 individual observations--and still, the analysis calls for more data. This reality only brings about additional nuance and unforeseen complications as there exists only a handful of always unfavorable solutions: add more variables, include more countries, or measure more years. Yet, adding more variables would increase the potential for collinearity--a problem that would only bias efficiency estimates and unintentionally increase standard deviations. Similarly, measuring over a longer time period would be equally difficult because of the lack of data. In almost all scenarios, if data is not available from 2000 to 2017, there is little chance it will be available from 1980 to 2000. Lastly, including more countries would draw attention back to the fundamental requirement of only measuring countries comparable in likeness. Additionally, this impractical solution would only augment the difficulties of assessing EHR implementation and environmental variables within the country which allow each healthcare system to be financed, operated, and improved.

The study of international healthcare efficiency appears to be fighting an uphill battle on many different fronts. From understanding new technological implementation standards to developing and defining standards for healthcare efficiency to locating and analyzing large amounts of data that arrive at statistically significant findings, there seems to exist no limit on the number of obstacles healthcare researchers and professionals must overcome in order to arrive at meaningful conclusions. Even pre-existing analyses to use as a basis for comparison are almost entirely outdated or impossible to find. Still, insightful research in any and all areas of healthcare remains absolutely necessary in the coming years and decades in order to overcome future health challenges and dissipate some of the nuance surrounding some of healthcare's most convoluted spheres. In the following section, some of this nuance is tackled head-on by outlining specific EHR implementation histories and outcomes for 5 of the 15 countries under consideration.

Chapter Six: Case Studies by Country

As evidenced by the data measured and analyzed in the previous chapter, each of the 15 countries included in this study demonstrate varying levels of increasing or decreasing technical efficiency within their respective healthcare systems. The majority of these countries actually show indeterminate results regarding their healthcare systems' gains and losses in efficiency as the result of implementation and utilization of EHRs and HIE, proving the efficacy and future of these technologies somewhat inconclusive. However, one thing is certain: each nation employs this technology differently.

Some countries began experimenting with the foundational basics of an EHR early on by incentivizing their patients to access and update their medical information through the internet. Others still face challenges in implementing these technologies due to issues with interoperability, security concerns, and decentralized healthcare systems. These country-to-country variations are to be expected in international comparisons, but it remains important to highlight these differences to show how this technology is being employed differently to yield effective or ineffective results. Five countries--Canada, Japan, France, the United Kingdom, and the United States--are chosen from the comparison not only to serve as representations of the group as a whole, but also to provide distinct examples of these varying levels of EHR implementation. In addition to their own distinct healthcare systems, each of these countries possesses a unique history of EHR adoption, utilization, and effectiveness. An understanding of these characteristics may help countries better identify how to implement these health records more efficiently--or not at all--both now and in the future.

Case Study 1: Canada

When thinking of Canada's contributions to the world, it seems difficult to stray away from popular topics like maple syrup, hockey, and Tim Hortons--but in the realm of healthcare, Canada has quite a bit to offer healthcare researchers. The nation is representative of many of the countries utilized within this analysis and uniquely highlights both an interesting healthcare system and history of EHR use. Canadian healthcare was founded and designed so that "all insured persons have access to medically necessary hospital and physician services on a prepaid basis," (Government of Canada, 2011). Similar to the United States, this insurance system is financed both publicly and privately. An estimated 69.8% of total health spending in Canada comes from public sources (CIHI, 2016). These expenses are funded primarily through the federal government's contributions to the provinces and territories on a per capita basis. Nevertheless, private insurance is quite common as well and nearly ⅔ of Canadians maintain coverage for services typically excluded from public reimbursement like vision, dental, and rehabilitative care (Canadian Life and Health Insurance Association, 2015).

Canada's experiences with electronic health records began at the turn of the century. In an effort to improve both the patient experience and unlock sources of value for the health system, the Canadian government made the decision in 2001 to create Canada Health Infoway Inc. (Infoway). This not-for-profit private corporation describes its role as that of a "strategic investor" to accelerate the development of electronic health records across the country. Infoway was specifically charged with developing and implementing several types of digital health solutions including laboratory information systems, diagnostic imaging and drug information systems, and interoperable electronic health registries and records. By March 31st, 2009, Infoway had spent nearly $615 million and committed another $614 million (approximately $1.2 billion in total) to the EHR initiative (Office of the Auditor General of Canada, 2010). Fortunately, the venture has proven fruitful for the Canadian government. A 2009 report from the Auditor General of Canada found that Infoway's EHR initiative showed "due regard" for taxpayers' money and outlined a number of pathways to continue to improve the program. Even more indicative of Infoway's success was a recent study done to test the initiative's effectiveness. This study by PricewaterCoopers LLC found that, between 2006 and 2012, the increased use of electronic medical health records saved $1.3 billion--nearly $800 million in administrative efficiencies and $584 million in health system benefits (avoiding duplicate diagnostic tests, improving chronic disease management, improving communication across providers, etc.) (CBC News, 2013).

Canada Health Infoway's success is certainly praiseworthy--and some countries may find its success deserving of use as a blueprint for the development of other EHR systems--but there remains no national strategy for implementing EHRs. Instead, each province's systems remain somewhat divided in collecting data and sharing it interoperably throughout the country. And while EHR use more than doubled from 2006 to 2012 (CBC News, 2013), by 2014 only 42% of general practitioners reported using EHRs to enter and retrieve clinical notes and 38% still claimed to use a combination of paper and electronic charts. In the same survey, 87% of general practitioners reported that their patients do not have access to their own personal health record and only 6% of patients have the ability to request appointments online (Allin, n.d.). Compiled with the fact that hospital setting implementation of EHRs remains abysmally low, it appears as though Canada is still struggling with its fair share of problems with health information exchange implementation. This may be evidenced by Canada's overall efficiency score of 0.633, ranking second to worst behind the Netherlands of the ten countries displaying overall scores. Even taking into consideration the fact that Canada only exhibited scores for four of the eighteen years, it is disappointing that the country only showed a 0.007 increase in efficiency from the year 2005 to 2017. Nevertheless, given the country's recent history of financial success utilizing HIE, Canada provides an optimistic outlook for the future of EHR development and certainly has more to provide international healthcare researchers than a tasty coffee and doughnut.

Case Study 2: Japan

With an incredibly developed and industrialized society as well as an increasingly aging population of more than 127 million people, Japan provides one of the most prudent healthcare system examples in the world. The Japanese possess what is known as a Statutory Health Insurance System (SHIS) that provides universal primary coverage and comprises more than 3,400 noncompeting public, quasi-public, and employer-based insurers. The national government sets provider fees and subsidizes care through general tax revenue and insurance contributions. Primary care is typically provided in private nonprofit hospitals which account for approximately 80% of beds while public hospitals round out the other 20% (Matsuda, n.d.). This combination of funding and treatment options have boded well for the nation. The government has long boasted the affordability and first-class nature of its healthcare system. In fact, Japan has consistently remained atop the world rankings with its high life expectancy. In 2017, the OECD ranked the average lifespan in Japan first in the world at 84.2 years. This area of care delivery is where Japan's future in healthcare becomes truly intriguing--and, frankly, worrisome.

In addition to the country's excellent life expectancy, Japan's healthcare system is also regarded as one of the world's most favorable because it maintains rigorous price controls on cost of care, medications, and surgical procedures to protect its citizens. The country upholds a strict requirement that hospitals remain nonprofitable so the majority of public hospitals continually operate at a deficit. Some might see little problem with this arrangement, but Japan's increasingly aging population appears to be placing the nation's already strained system under more pressure than ever. In an article from The Japan Times, one writer highlights how Japan ranks third highest in health spending as a percentage of GDP, trailing only the United States and Switzerland. Quoting Yusuke Tsugawa, a physician and research associate at Harvard University specializing in health care economics, the article adds that "...while the government controls the cost of medical goods and services, it doesn't control the volume of the services provided...This has fostered a culture in Japan of patients seeking more care than necessary because access is unlimited," (Otake, 2017). Unfortunately, as the Japanese population continues to grow and the nearly 26% of its citizens aged 65 or older grows to nearly 33% by 2050 (ILC Japan, 2013), healthcare system sustainability is only going to grow increasingly more uncertain.

One might certainly find Japan's healthcare worries a prime opportunity to implement innovative technology like EHRs and HIE to help solve this potentially costly development. In fact, looking to get ahead of problems looming on the horizon, Japan initially attempted EHR adoption in the latter half of the 1990s, but it was not until 2002 that the EHRs became more widespread (Tanaka, 2007). EHRs have been developed and experimented in select areas in the years following this movement, but since momentum faltered around 2006 a national system has yet to be established or implemented on a comprehensive scale. Unsurprisingly, interoperability between providers at the local and regional levels was also overlooked. The government maintains that experiments are currently underway to make HIE available to patients and providers via cloud computing which would give patients access to features like unique identifier numbers and Social Security and Tax Number Systems. Initiated in 2016, these efforts were scheduled to be phased into healthcare delivery networks by 2018 (Matsuda, n.d.). Supporters of EHR systems may find this news promising, but the reality remains that Japan is very far-removed from meaningful health information exchange.

The turbulent nature of Japan's EHR history and the lack of information regarding the country's healthcare efficiency score lends little information as to why Japan continues to demonstrate interest in reviving its once-failed healthcare technology. After all, their attempts appear more like efforts to resuscitate a lifeless EHR program than they do pursuits to bolster an already effective healthcare tool--which begs the question why Japan has continued to invest in EHR and HIE? This persistent, albeit lackluster, endeavor could exist thanks to techno-optimist sentiment in one of the world's most technologically advanced countries. Perhaps these actions may be the result of the foresight of policy experts and medical professionals who visualize the looming threat of population aging on the horizon. Or, as some researchers claim, this may be due to Japan's historic compulsion to maintain the "status quo" and avoid the embarrassment of failing to "maintain the high standards of medicine now in use in Japan," (Yoshihara, 1998). Justification for each of these speculative reasons remains somewhat unfounded; yet, it remains clear that EHR and HIE technologies are tools that countries like Canada and Japan continue to invest in despite their questionable practicalities and benefits.

Case Study 3: France

It is nearly impossible to have a conversation about electronic health records and health information exchange without discussing France. The country first began experimentation with an EHR in 1998 when it launched the Carte Vitale, a health insurance card intended to allow patients to settle directly with the medical arm of the social insurance system (Brieu, n.d.). Since then, the country has led the charge internationally in health information exchange by attempting to expand upon its original Carte Vitale with the Carte Vitale 2--a similar smart card carrying a picture for identification and the ability to store electronic documents. Even more impressive was the country's lofty goal to expand computer-based medical efforts in 2004 with its "Dossier Médical Personnel, DMP" (known as the "Dossier Médical Partagé" since 2015) which is a "digital health booklet that stores and secures your health information...It allows you to share them with the health professionals of your choice, who need to care for you" (DMP France, 2020). The DMP was created with the hope that an EHR system would help increase communication and transparency and improve overall quality of care, but it was not long until France ran into problems with longitudinal paper records and patient security. The project looked defeated when the government failed to make the DMP fully operational by its goal of 2007, but soon gained new life when the French national legislature and Ministry of Health relaunched the project with full support in 2011 (Stone, 2014). The system has since grown in operational ability and approval.

Admittedly, EHR adoption rates in France were only measured at 67% for physicians (Stone, 2014). However, the capabilities of the DMP make it one of the most adept in the world. With the Dossier Médical Partagé, patients not only have access to their own unique electronic identifier number, the ability to make appointments easily online, and a personalized patient portal, but they also have the ability to allow any health professional or facility access to their medical record for consultancy and treatment of any kind. This level of unparalleled interoperability is ensured through the chip on each patient's Carte Vitale health card and endorsed thanks to France's centralized top-down driven governmental system.

France has a stronger hold on privacy laws than most other nations which allows the country to bypass rules and regulations that would normally overemphasize privacy concerns (Stone, 2014). This governmental structure provides the perfect foundation for future EHR systems to successfully connect and operate with advanced capabilities like increased interoperability and clinical decision support (CDS). Interoperability between health and social care professionals has not yet been permitted (Durand-Zaleski, n.d.), but this level of exchange of information is unheard of elsewhere in the world and appears to have yielded dividends for France's healthcare efficiency as of late. This is evidenced by the country's 0.091 increase in efficiency over the eighteen year period and the 0.115 increase from 2015 to 2016, in particular. While these increases have only been witnessed recently, this development is promising for the future of EHR in France and elsewhere throughout the world. France's recent success in EHR gains and continued pursuit of HIE diversification exemplifies why other nations like the United States should look to France for help in creating more robust, adaptable, and interoperable HIE systems for the future.

Case Study 4: United Kingdom

Created in 1948 following the end of World War II, the United Kingdom's National Health Service (NHS) represents the world's oldest universal healthcare system (Brain, n.d.). Since it was founded, the NHS has prided itself on providing free coverage at the point of need to all eligible citizens. These services are traditionally financed through taxes, and citizens have experienced increased taxation for health services since the 1980s as health expenditure has continued to trend upward. Today, the NHS promises more information, resources, and healthcare employees for patients while continuing to combat long wait times, high accident and emergency (A&E) department costs, and a fast-aging population.

The United Kingdom's history with EHRs is equally as interesting as it is complicated. In 2002, the UK government launched the development of the NPfIT otherwise known as NHS Care Records Service. This program was intended to deliver an EHR system that could store and share patient records from across the UK. However, there were soon numerous problems relating to poor user accessibility, failures in addressing patient confidentiality, overambitious timescales, and enormous cost overruns. In 2008, the Summary Care Record (SCR) was introduced and headed by the NHS with the intention of its use as an EHR in emergency or out-of-hours care settings. By 2011, the NPfIT was dismantled almost entirely and the SCR was named the focus of the NHS. However, shortly after, the SCR also dealt with similar shortcomings and the UK abandoned their pursuit of a national EHR and instead shifted focus from HIE implementation on a national scale to management and use by individual general practitioners (GPs).

Since April 2015, these GP practices have been obligated to offer patients the option to book appointments and request prescriptions online. These requirements were expanded in 2018 to include offering patients information about their diagnoses, medications, treatments, immunizations, and test results. An NHS App was even developed and rolled out in January 2019 (NHS England, 2019). The app is designed to give patients an additional resource to access their medical records, book appointments, refill prescriptions, and manage their long-term conditions (Australian Digital Health Agency, n.d.). Despite these successes, SCR records are never linked between GPs or other providers and the UK still lags far behind their goal of reaching digital maturity for their patients. NHS patients continue to find themselves unable to secure digital copies of their health records, and while the NHS aimed to make primary, urgent, and emergency services paperless by 2018--and all other NHS services paperless by 2020--the general consensus appears to be that these targets are still years away (Thorlby, n.d.).

Analogous to the struggle of implementing an effective EHR and making all NHS services paperless is the United Kingdom's shortcoming in failing to maintain a sufficient longitudinal record of health data. This information deficiency--particularly within the OECD iLibrary Data Warehouse--is what makes the UK one of five countries within the analysis that produces no efficiency scores for any of the eighteen separate time periods. For this reason and others previously outlined, future plans for the establishment of an interoperable EHR system in the UK appear rather bleak. However, the NHS App and its success in offering patients useful electronic resources is yet another testament to the advantages of different forms of health information technology and exchange.

Case Study 5: United States

For the longest time, the United States healthcare system has been one of the most well-known and frequently discussed care networks in the world--for all of the wrong reasons.

Healthcare coverage in the United States has lived in infamy for decades for its hyper-privatization, severe disparities in health delivery, and abysmal rates of uninsured individuals. Even more abhorrent than these disappointing attributes is the grim reality that the country has continually maintained exceptionally high healthcare costs without experiencing comparable gains in population health. One might even consider this the legacy of the United States healthcare system: spend more, and get less in return.

With the emergence of the internet and web-based software at the turn of the century, many within the government believed technological innovation could pose a potential solution to some of the dilemmas plaguing the healthcare system. During President George W. Bush's time in the Oval Office, the budget for healthcare IT projects doubled and a new sub-cabinet position of National Health Information Coordinator was created (University of Scranton, n.d.). At the start of President Barack Obama's tenure in the White House, an even more progressive move towards the adoption of healthcare technology was proposed with the American Recovery and Reinvestment Act (ARRA) and its subtitle, the Health Information Technology for Economic and Clinical Health (HITECH) Act. Signed into law in February of 2009, both of these laws were enacted to "promote the adoption and meaningful use of health information technology...and address the privacy and security concerns associated with the electronic transmission of health information," (U.S. Department of Health and Human Services, 2017). A portion of this legislation was dedicated to strengthening the criminal enforcement of HIPAA (Health Insurance Portability and Accountability Act) passed by Congress in 1996, but the HITECH Act was equally dedicated to constructing an electronic health record system and encouraging industry-wide adoption within the decade. Both the ARRA and HITECH Act led to significant investments in HIE--more than $30 billion--and established financial incentives for physicians and hospitals to adopt EHR systems under what is now known as the EHR Incentive Program (The Commonwealth Fund, n.d.).

A well-established and high-functioning electronic health record in the United States was hypothesized to lead to a number of improvements in the healthcare system--not only from the perspective of cost, but also of quality of care delivered to each and every patient. The ability to access and update medical information remotely made an electronic method of keeping records very appealing and ultimately justified both physicians' decisions to invest in EHRs to improve their practice and the government's decision to subsidize some of these implementation costs. Unique to other countries examined, the United States went a step further to ensure that professionals choosing to adopt these systems implemented them in an effective and economical manner. Thus, the concept of "Meaningful Use" was established under the EHR Incentive Program with three different Meaningful Use stages: Meaningful Use Stage 1, Meaningful Use Stage 2, and Meaningful Use Stage 3.

The first of these stages includes meeting 14 to 15 out of 20 core requirements and 5 out of 10 menu requirements such as the ability to record demographics, use computerized order entry (COE) for medication orders, send reminders to patients for preventative/follow-up care, and implement simple clinical decision support (CDS) suggestions (HealthIT, 2012). The second stage of Meaningful Use expanded upon Stage 1 to encourage improved functionality of EHR systems--that is, meeting more than 15 core requirements and more than 5 menu requirements. In October 2015, the Centers for Medicare and Medicaid Services (CMS) released requirements for achieving Stage 3 of Meaningful Use, which focused on EHR systems improving health outcomes and care delivery by 2018 (CDC, 2019). While researchers have yet to receive results on this data, it is clear that EHR adoption in the United States has drastically increased since the beginning of its implementation. As of 2015, 84% of physicians use some form of EHR system and three out of four hospitals (76%) have adopted some basic form of EHR system. This represents an eightfold increase in EHR implementation since 2008 (The Commonwealth Fund, n.d.). The ARRA, HITECH Act, and EHR Incentive Program were all designed to gradually raise the threshold for EHR implementation and functionality across the United States. Up to this point, these initiatives seem to be achieving their goal in that regard.

The differences between continued improvement in the United States; partial success in Canada; and ranges of ineffective implementation in countries like Japan and the United Kingdom depend on variables such as history of EHR use; current level of implementation; outlook for the future; and much more. While Canada has saved hundreds of millions with initial EHR systems, their implementation rates among physicians and hospitals remain considerably lower than those in the US. More importantly, where countries like Japan and the United Kingdom appear rather content in maintaining the health information systems they currently have in place, the United States is continuously demanding more from EHR systems and improving the functionality of the technology as a result. Woefully, our analysis is unable to corroborate this assessment due to missing efficiency scores of the United States' healthcare system from 2011 to 2017. Therefore, whether or not the US has succeeded in increasing the quality of care, health outcomes, and efficiency of their healthcare system through the use of EHR and HIE remains to be determined.

Chapter Seven: Conclusion

Ephemeralization is a term intimately linked with the concept of efficiency and it is especially relevant in the context of our increasingly modernizing world. This term, coined by R. Buckminster Fuller, refers to the ability of technological advancement to do "more and more with less and less until eventually you can do everything with nothing," (Fuller, 1938). Fuller's vision was that ephemeralization could continue to rectify ever-increasing standards of living with an ever-growing population despite a finite supply of resources. This subsidiary of efficiency may seem like nothing but a pipe dream. After all, basic concepts as elementary as the laws of conservation of energy and mass state very clearly that something cannot be created out of nothing. However, attaining higher levels of efficiency within our daily lives and governmental systems is absolutely imperative as populations continue to grow and societies continue to develop.

As with any large transformative process, some sectors of life and government have already begun to take the leap of increasing their efficiency by adopting increasingly dynamic methods of production. Food systems have developed farming and agricultural methods that grow produce and livestock bigger and faster and transportation systems have evolved to move more people over longer distances in shorter amounts of time than ever before. Healthcare systems have likewise adapted to changes in population and technology growth. Innovations such as artificial intelligence, virtual reality simulations, and three-dimensional printers are just a handful of a seemingly endless number of cutting-edge technologies that have helped healthcare professionals today improve their quality of care and do more with less--but can innovations like these alone slow the tide of much greater problems soon to be brought about by the epidemiological shift of our modern era? This transition from treating patients with one-time, acute illnesses to dealing with older, more obese, and increasingly immunocompromised victims of chronic disease has already placed a heightened strain on healthcare systems around the world that will only intensify as time passes. It is precisely for this reason that new technological advancements in healthcare delivery should be both broadly explored and meticulously assessed.

One innovation in particular--the electronic health record (EHR)--shows promising signs of the ability to improve healthcare delivery and thus increase entire health system efficiency. Electronic health records are defined as ‘a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports,’ (Menachemi, 2011, p. 48). The three functionalities that make EHRs so attractive as a potential solution to health system inefficiency rising healthcare costs are clinical decision support (CDS) tools, computerized physician order entry (CPOE) systems, and health information exchange (HIE) capabilities (Menachemi, 2011). Yet, despite these dynamic functions, EHRs are also frequently critiqued by those skeptical of their practicality and efficacy in healthcare settings because they can be expensive, difficult to implement effectively, and even lead to burnout among healthcare workers (Brown, 2019). This contrasting sentiment about the influentiality of EHRs begs the question whether this recently implemented medical technology has affected the health system efficiency of countries choosing to implement this tool--and if so, to what end and extent?

In order to answer this research question, the idea of efficiency was first defined in a number of ways. It proved important to identify both a general definition of efficiency--to produce desired results with little or no waste of time or materials--and apply this definition to better more broadly in order to understand the concept of healthcare efficiency--the extent to which inputs to the health system are used effectively to secure valued health system goals. After accomplishing this task, this knowledge was used in coordination with the different terms of allocative and technical efficiency to provide a naive framework for thinking about healthcare system efficiency. This framework was then enhanced by explaining the different inputs and outputs under consideration within a health system as well as highlighting several environmental variables like governmental constraints, population aging, etc. which help control for potential confounding variables within any efficiency study. Such a comprehensive framework not only provided an exemplary foundation for future efficiency studies, but also took into account studies of efficiency at the international level. Thankfully, this model mitigated many of the difficulties surrounding the nuance of a fifteen country healthcare efficiency analysis. Where other blueprints struggle to compensate for the number of differences in healthcare and governmental policies, the aforementioned framework effectively compared any and every country so long as they were determined to be reasonably alike.

Having established this comprehensive framework for modeling international healthcare system efficiency, all that remained of the study was to decide upon each of the fifteen countries under consideration, select the appropriate analytical method for determining healthcare efficiency scores for each country, and effectively calculate and interpret the analysis' results. The first of these undertakings was rather easy to complete as each of the fifteen countries chosen is comparatively modernized and industrialized with a health system that is unique, diverse, and rather high-functioning. Even more important was the fact that each of these countries holds membership in the OECD and continuously updates database profiles which contain countless insights into the operational capacity of their respective healthcare systems. Nevertheless, despite the ease with which this first task was accomplished, the following demonstrated considerably more difficulty.

Unfortunately, there are countless reasons why completing healthcare efficiency analyses prove so burdensome. One of the main reasons for this difficulty is the lack of consensus on which analytical method to utilize to perform such an analysis. Two of the more favorable methods that have grown in popularity over the last several decades are known as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). Over 400 published applications have used these methods within health care settings over the past 30 years (Cylus, 2016, p. 99). Both methods see efficiency as a simple relationship between inputs consumed and outputs produced and assess how effectively a unit of production, such as a hospital, uses its own inputs, such as staff and drugs, to produce outputs, such as patients treated. However, where DEA often focuses on complicated linear programming methods that place weights on certain inputs and outputs, SFA uses statistical regression methods that combine all variables into a single aggregate measure. SFA measures relationships between variables in ways that are frequently regarded as more user-friendly and easily understandable. This fact--compiled with the reality that online resources and research professionals were more easily available to assist in a study using a SFA approach--made the decision to utilize SFA a rather easy decision.

Even with the help of online resources and research professionals, completing the Stochastic Frontier Analysis was assuredly the most difficult portion of the entire research project. An immense amount of time was consumed to identify reliable databases, create and organize datasets, and locate individuals to assist in completing the analysis. The largest of these delays occurred due to a lack of information and resources available both online and through the university. While there were several individuals who provided assistance in other areas of the project, few had the expertise to contribute to a DEA or SFA analysis pertaining to the healthcare sector. In the future, my personal recommendation for students is to either consider using simpler regression methods in STATA from the onset of their project or plan on hiring third-party research experts on platforms such as Upwork for assistance in completing more complex analytical approaches. Although, even this action may not yield findings considerably more pragmatic than those previously outlined in Chapter Five.

Ultimately, almost all of these actions--defining efficiency, contextualizing this understanding of efficiency within the healthcare sector, highlighting the difficulties of international country comparisons, explaining analytical approaches to healthcare efficiency analysis, and performing a Stochastic Frontier Analysis--produced little conclusive data in determining the impact EHRs and HIE have had on international healthcare system efficiency. Fortunately, **Table 5.1** and **Table 5.2** provide some practicable information on the effectiveness of certain input variables to the hospital sector--most notably, the positive effect of increasing the number of physicians employed in hospitals. Perhaps the most useful findings relating to the current state of EHR and HIE use are located within **Table 5.5**, which provides the initial dates of EHR implementation and an index score for each respective country as well as each EHR implementation's respective names. This data, along with a number of other findings, is certainly useful information that could contribute to the advancement of future studies.

More importantly, it is imperative to emphasize the significance of this study even without validating its findings--regardless of how limited they may be. The reality of all international healthcare analysis is that researchers are already fighting an uphill battle when they make the decision to attempt to study such complex and varying systems. As proven by the explanations provided in this research project, performing efficiency studies of any degree can be a complicated process, but even more so in the context of healthcare--and especially at the international level. More complex methods of analysis using statistical programming like DEA only further complicate these matters and make arriving at results as well as statistical significance even more difficult to determine. Even when data is readily available, such a challenging field of study requires highly specialized and knowledgeable professionals to make sense of such information. Nevertheless, the truth remains that the nuance surrounding the evaluation of healthcare systems and their efficiency does not disappear despite the seemingly insurmountable obstacle of arriving at conclusive results. Instead, national and global researchers alike should continue to push forward to develop new and improved metrics and measures in order to find solutions to these increasingly complex problems. While this analysis may fall short in determining the abiding effects of international EHR and HIE implementation today, perhaps the information presented can prove helpful in determining the outlook of such technology for the future.

Admittedly, this data analysis seems to raise more questions about both the long-term efficacy of EHRs and the feasibility of performing international healthcare efficiency analyses than it does affirm optimistic sentiments about health information technology as a whole. However, this ambiguous conclusion seems quite poetically just for a topic surrounded by such immense debate and uncertainty. With each and every passing week, new information is brought forth deeming EHRs the savior of healthcare efficiency, the bane of every physician's existence, and everything in between. Despite this extraordinary ambivalence, it is clear that--for one reason or another--EHRs and HIE is absolutely here to stay for the foreseeable future. After all, the quest for efficiency is a pursuit that has consumed the thoughts of governments around the world for generations; and while the concept of ephemeralization might be too utopic for some world leaders to bear, the need for healthcare systems to improve their quality of care for patients who continue to grow older, more obese, and increasingly afflicted with chronic diseases is an obligation that will not disappear anytime soon.

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Appendix

Entry 1: STATA Do File Command

```
*Provided by Upwork Freelancer Deni Mazrekaj*

***STOCHASTIC FRONTIER ANALYSIS***

clear
import excel "/Users/davidpfaehler/Desktop/Thesis - Extended Data Sheet
>  STATA.xlsx", sheet("Efficiency") firstrow
drop tdum*

**FIRST OUTPUT**
gen logov1 = log(ov1)
global y logov1
global x iv1 iv2 iv3 iv4
global z ev1 ev2 ev3 ev4 ev5 ev6 ev7 ev8 ev9 ev10 ev11 ev12

*Remove Missing observations*
/*For a cleaner analysis you can drop the missings, but the problem of convergence will occur
due to a small sample*/
*drop if
missing(logov1,ov2,iv1,iv2,iv3,iv4,ev1,ev2,ev3,ev4,ev5,ev6,ev7,ev8,ev9,ev10,ev11,ev12)

*Cross-sectional Stochastic Frontier Analysis*
sfcross $y $x, distribution(tnormal)
/*overall efficiency*/
predict effcross1, bc
/*Efficiency by country*/
bys country: egen effbycountry1 = mean(effcross1)
tab effbycountry1 country
/*Efficiency by country and year*/
br country year effcross1
/*effect of environmental variables:
Ideally you would do this in a single stage, however problems of converge occur, so it's in two
stages here*/
reg effcross1 $z

*Panel Stochastic Frontier analysis
/*For a more correct analysis, a panel model should be performed as below,
however convergence problems occur as the data is not suitable for this analysis*/
*xtset country year
*sfpanel $y $x, distribution(tnormal)
*predict effpanel1, bc
```

```
*sum effpanel1
*reg effpanel1 $z

**SECOND OUTPUT**
gen logov2 = log(ov2)
global y logov2

*Cross-sectional Stochastic Frontier Analysis*
sfcross $y $x, distribution(tnormal)
/*overall efficiency*/
predict effcross2, bc
/*Efficiency by country*/
bys country: egen effbycountry2 = mean(effcross2)
tab effbycountry2 country
/*Efficiency by country and year*/
br country year effcross2
/*effect of environmental variables:
Ideally you would do this in a single stage, however problems of converge occur, so it's in two stages here*/
reg effcross2 $z

*Panel Stochastic Frontier analysis
/*For a more correct analysis, a panel model should be performed as below,
however convergence problems occur as the data is not suitable for this analysis*/
*xtset country year
*sfpanel $y $x, distribution(tnormal)
*predict effpanel2, bc
*sum effpanel2
*reg effpanel2 $z
```