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Do Medical Technology and Healthcare Spending Affect Health Outcomes?

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DO MEDICAL TECHNOLOGY AND HEALTHCARE SPENDING AFFECT HEALTH OUTCOMES?

by

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ABSTRACT

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Healthcare expenditures have been on the rise for many countries, especially for the developed countries. As of 2009, Japan, Australia and Canada are spending around 8 to 10% of their total GDP on healthcare, while the United States is currently up to 16%. One of the major factors contributing to increased expenditures on healthcare is the emergence of medical technology.

Using data from the Organization for Economic Co-operation and Development (OECD), I empirically investigate the effects of medical technologies and healthcare expenditure on health outcomes for a group of 17 countries. Medical technology is measured by the number of MRI machines, CT scanners, mammography machines and radiation therapy equipment and their usage. Health outcomes are measured by life expectancy at birth, life expectancy at age 65 separated by males and females, infant mortality rate, and potential years of life lost (PYLL), also classified by males and females. Health expenditures are separately measured at both the public and private level. I employ a cross-country regression analysis and control for the number of hospital beds and physicians, GDP per capita, percentage of GDP spent on healthcare and lifestyle factors such as tobacco and alcohol consumption.

The results show that increases in most medical equipments are associated with higher life expectancies and lower mortality rates. A higher share of public spending on health care is associated with increased mortality rates and lower life expectancies for males and females.

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CHAPTER ONE:

INTRODUCTION

Healthcare spending in the United States has increased dramatically over the past few decades. As of 2009, 17.6% of total Gross Domestic Product (GDP) was spent on healthcare, an estimated $2.1 trillion nationally. This is an increase from the 16.2% of GDP spent on healthcare in 2008. The Center for Medicare and Medicaid Services (2010) projects healthcare spending to reach $4.3 trillion by 2018, around 19.5% of GDP. Comparing these values to other OECD (the Organization for Economic Co-operation and Development) countries, which are similar in development status, one can see that these countries spend considerably less on healthcare. For example, Figure 1 shows the percent of national GDP spent on healthcare for the following countries: Australia, Canada, Denmark, Finland, Iceland, Japan, Netherlands, United Kingdom and the United States.

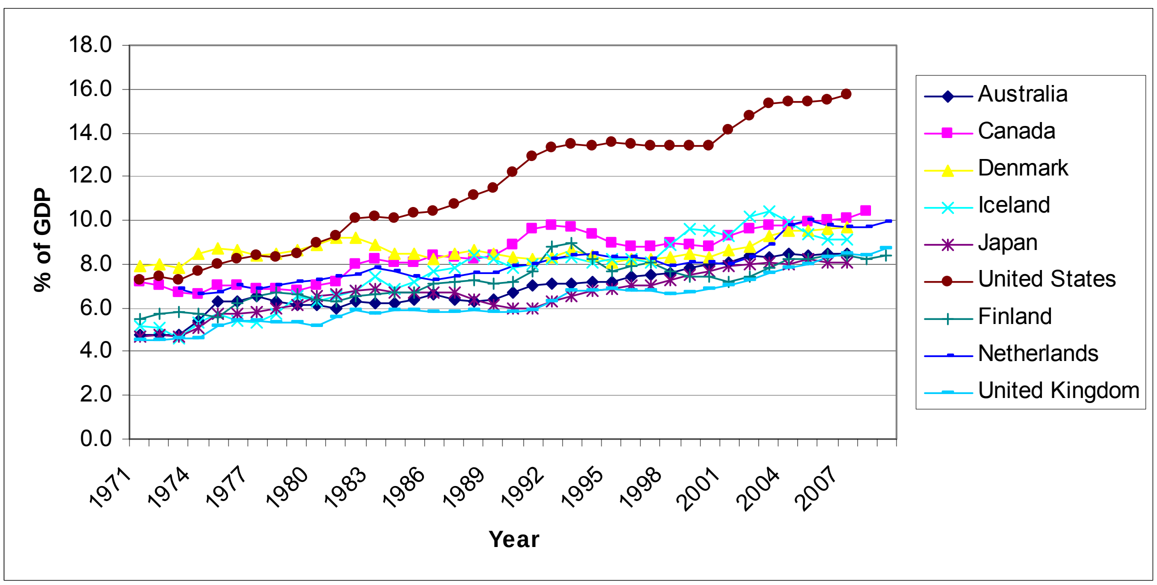

Figure 1: Percent of GDP spent on healthcare from 1971 to 2009
Source: OECD Health Data 2010

As seen in Figure 1, the United States is an outlier as it spends a higher proportion of its GDP on healthcare than all of the other OECD countries selected. Prior to the 1970s,

all of the countries pictured had similar trends in healthcare spending. With the introduction of Medicare, Medicaid and other federal and state-funded programs, total healthcare spending in the United States has risen at a constant rate.[1]

Rising health expenditures are a concern for many countries, including the United States, which spending trillions of dollars annually towards healthcare. The analysis in this thesis seeks to build upon previous studies that have looked at healthcare spending and its effects on health indicators by incorporating medical technology as a focus for further investigation. I have considered as health outcomes four main indicators as discussed in previous studies: life expectancy at birth and at age 65, infant mortality, and PYLL (potential years of life lost) (Or, 2000 and Papageorgiou *et al.,* 2007). Overall health of populations have improved as indicted by rising trends in life expectancies throughout the time period 1970 to 2009, but it is unknown to what extent other factors, such as rising healthcare expenditures and accumulation of medical technology, are contributing to this improvement.

Comparing the effects of healthcare expenditure on health outcomes, in this cross-country analysis, healthcare expenditure is divided into public and private sources. They are expressed as separate values indicating percentage of total healthcare expenditure funded through public sources[2] and through private sources[3]. As of 2008, 46.5% of total health expenditure in the United States is obtained from "public funds" and 53.5% from

[1] Medicare and Medicaid spending are sources of government funds, paid for by the federal government. Medicare provides healthcare insurance to individuals age 65 and over who meet certain criteria. Medicaid is a health insurance program for families with low incomes and resources with joint funding provided by federal and state budgets. In the context of this thesis, both Medicare and Medicaid are accounted for in "public expenditure".

[2] The term "public sources" includes state, regional and local government bodies and social security programs (*OECD Health Data, 2010*).

[3] The terms "private sources" include out-of-pocket payments by patients (both over-the-counter and cost-sharing), private insurance programs, charities and occupational health care. (*OECD Health Data, 2010*).

“private funds”, or “non-public” sources (*OECD Health Data, 2010*). Many other developed nations have adopted single-payer healthcare systems, involving a greater percentage of healthcare expenditures to be paid for by public sources, such as Japan with 81% from public and 19% from private. Canada, which functions under a nationalized health system, collects 70% from public sources and 30% from private as of 2009. The United Kingdom’s health system acquires 82.6% from public funds and 17.4% from private, mainly out-of-pocket payments. In 2009, the country with the lowest population and the highest share of public funding is Luxembourg, with 91.1%, and only 8.9% from private sources (*OECD Health Data, 2010*). A potential difference in types of payment structures with regard to health indicators could help determine ways to improve existing healthcare systems to produce higher life expectancies and lower mortality rates.

Figure 2 shows the percentage of total healthcare expenditure from public funds compared to life expectancies at age 65 for the entire population in the year 2005 for 17 OECD countries. Japan covers over 80% of its healthcare costs with public funds, and experiences nearly 20 years of life expectancy at the age of 65. The Czech Republic collects approximately 90% of healthcare funds through public expenditure and gained 15.5 years of life expectancy in 2005. Compared to the United States, all other countries depicted in Figure 2 have higher rates of public expenditure; however the US experiences average rates of life expectancy of approximately 17.6 years. Figure 2 does not show a definitive correlation between increased public expenditure, roughly capturing nationalized healthcare systems, yielding higher rates of life expectancy at the age of 65 for the whole population. This Figure indicates that other factors are influencing health outcomes, rather than healthcare expenditure alone.

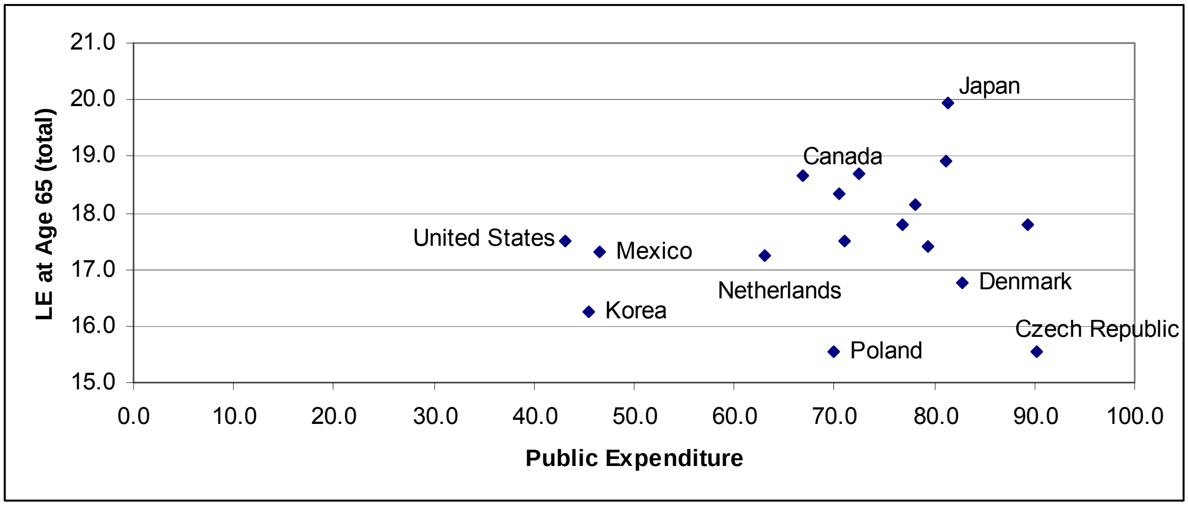

Figure 2: Percent of Public Expenditure on Healthcare vs. Life Expectancy at Age 65 for total population in the year 2005.
Source: OECD Health Data 2010

A. A Focus on Medical Technology

Increased spending on healthcare in countries around the world can be attributable to a variety of sources. According to Kimbuende, *et al.* (2010), several key factors to consider that contribute greatly to healthcare spending are: prescription drugs, care for chronic diseases, aging of the population, the development and allocation of medical technology, and administrative costs. About half of the increases in medical spending over the past decade are attributable to changes in medical care made possible by advances in medical technology (Baker *et al.*, 2008). The focus of this thesis is on overall healthcare spending and medical technology, and their effects on health outcomes of a country. Technological change is causing strains on healthcare resources through the increased intensity in the utilization of existing technologies, the introduction of new technologies, and diffusion of new technology.

Several technological components that I focus on are medical devices, including: magnetic resonance imaging (MRI) machines, computer tomography (CT) scanners, mammography machines, and radiation therapy equipment. All of these medical

technologies are used as diagnostic tools to help detect damaged or malignant tissues and organs in the human body. MRI machines, for example, can scan body parts to detect injury in soft tissues such as the brain, muscles, and heart. MRIs are particularly useful for imaging deteriorated tissues and on organs and muscles. CT scanners serve the same basic purpose as a diagnostic tool, to create three-dimensional images of the head, heart, abdomen and extremities with multiple x-ray type images. Typically, CT scans are run to detect heart disease, tumors, abdominal bleeding/injury and fractures in extremity bones. The cost to run a CT scan is less expensive than MRI scans; however it is less precise and produces more false positives (*RadiologyInfo,* 2010). MRI machines cost more and take longer to scan; thereby one MRI machine will scan fewer patients per day than a CT scanner therefore each patient ends up paying more for an MRI than they would a CT scan.

Mammography machines are primarily used to diagnose breast tissue abnormalities such as breast cancer. Radiation therapy equipment includes x-rays, other low-resolution images as well as a technique known as brachytherapy, which is a treatment for certain types of cancers with radiation treatment to shrink tumors and kill cancer cells (*RadiologyInfo,* 2010). If any of these techniques are employed early as diagnostic tools, the cost to treat or cure diseases can be significantly reduced.

Incorporating health outcomes with health expenditure and medical technology, Figure 3 shows data for the year 2000. The horizontal axis shows the percent of GDP spent on healthcare, the vertical axis represents total life expectancy at age 65, and the size of the "bubble" indicates the number of MRI machines per 1 million members in the population. The United States spends a significant proportion of GDP on healthcare (13.4% in 2000);

however life expectancy is approximately average amongst the 17 countries, and the number of MRI machines is closer to the higher end of the distribution.

This could potentially be an issue of improper utilization or underutilization of medical resources, or no correlation between amount of technology and spending on life expectancies. This is the question I address in this thesis, whether the amount of technology and its usage have an impact on life expectancies and other health indicators. Several variables that I control for in the empirical model are medical resources and lifestyle factors. By controlling for the capacity of the healthcare system, through medical resources, I control for the availability of physicians and hospital beds as the United States has lower physician per 1,000 population ratios than the median OECD rates, and growth rate is also slower than most other countries. As of 2009, the US had 2.43 physicians per 1,000 population compared to the OECD average of 3.1 physicians per 1,000 (*OECD Health Data*, 2010). The supply of doctors remains relatively constant throughout the years because of the high barriers to entry into medical schools, the length of time required to receive training, and the financial burden of receiving a medical education (Kling, 2006). Hospital beds experienced an overall decrease across all countries; specifically the US has 3.1 hospital beds per 1,000 people while the OECD average for 2009 is 5.4.

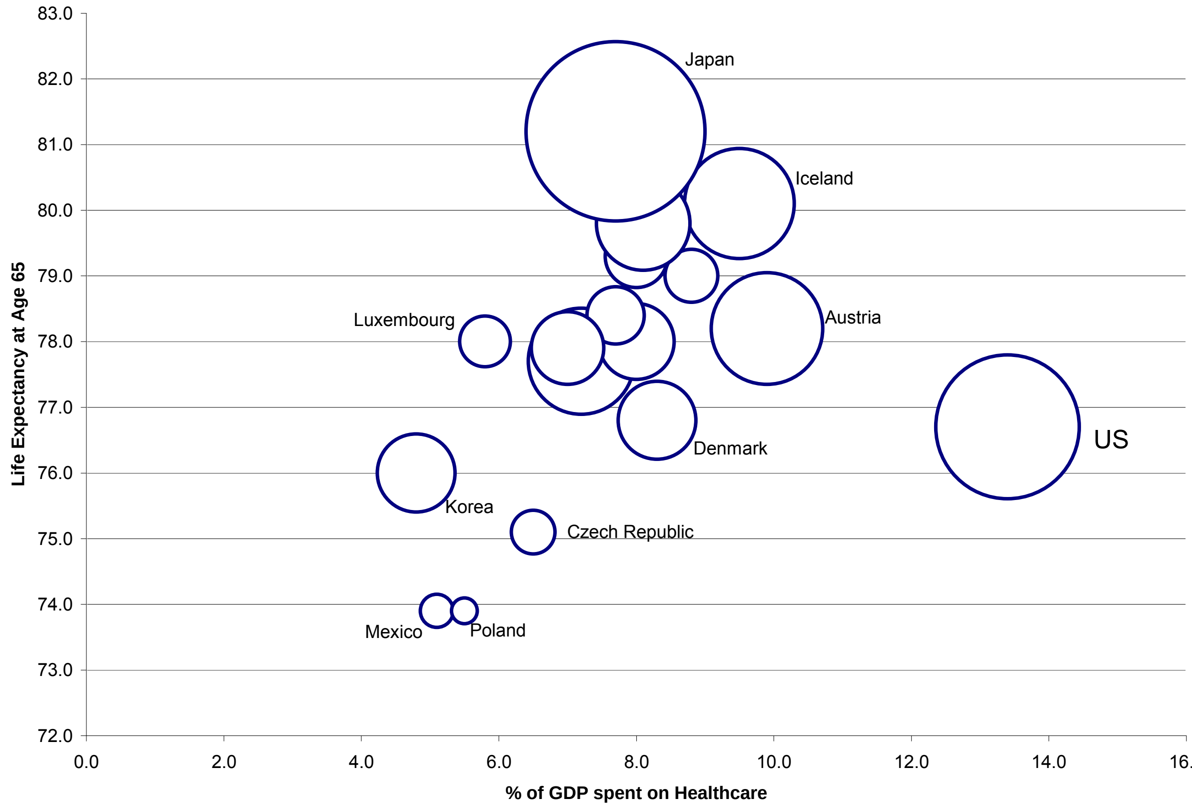

Figure 3: Healthcare Expenditure as a Percent of GDP vs. Life Expectancy at age 65 in 2000. Size of bubble indicates number of MRI machines per 1 million population.
Source: OECD Health Data 2010

B. Contributing Factors to Increased Healthcare Expenditure and Technology Use

Increased spending on medical technology, as previously stated, is one of the larger components of healthcare expenditure. "As medical technology continues to advance at an accelerated pace, the cost and demand for each one of these technologies skyrockets" (*Sick Around the World, 2008*). The rising demand of new technology usage is prevalent by both the patients and the providers. Sometimes, easily identifiable, yet costly technologies (i.e. transplantations and surgeries) receive a large amount of political and media attention, while frequently used and less costly items (i.e. routine X-ray) may consume more resources but receive little public attention. "Artificial" patient demand increases due to availability of these treatments involving more expensive, newer medical technologies.

Artificial patient demand is defined by the generation of consumer demand for more intense, costly services even if they are not necessarily cost-effective (Savedoff, 2003). The overall national spending total increases; however there is a discrepancy in that only a select population, those who can afford these treatments, will demand and receive care with the expensive equipment. Lower utilization does not necessarily imply less effective care; however this could lead to differences in access translating to biases in health outcomes across a population.

Wealthier countries tend to spend more on healthcare because they can afford to do so (Gerdtham and Jönsson, 2000). About 90% of the observed cross-national variation in health spending across the OECD countries in 2001 can be explained simply by GDP per capita. An estimated bivariate relationship between GDP per capita and per capita health spending predicts a US per capita health spending level of $3,435 for 2001. The actual level, $4,887, is $1,452 or 42% higher than the predicted level.

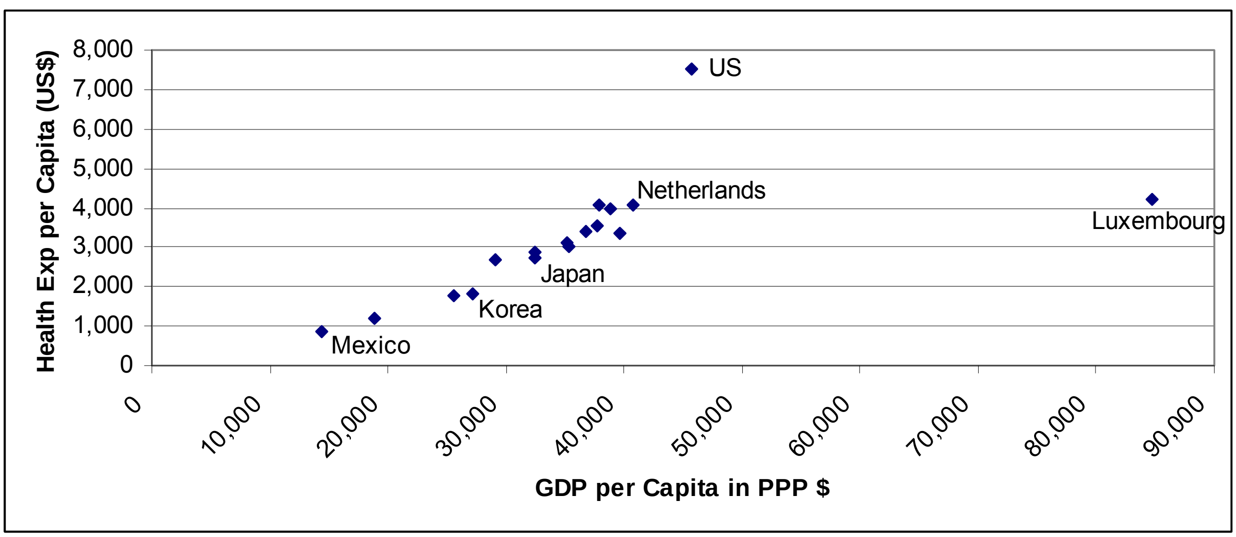

Figure 4: GDP per capita vs. Health Expenditure per capita in the year 2001.
Source: OECD Health Data 2010

Figure 4 shows a strong relationship between GDP per capita of these countries (a rough measure of ability to pay for healthcare services) and per-capita health spending (Reinhardt, 2008). For this reason, GDP per capita is included as an independent variable to control for the effect of higher GDP, leading to higher health expenditures.

GDP growth is not the only factor that is associated with growth in healthcare spending. Higher prices for the same goods and services are being charged in the US. Japan is the second richest country in the world with a capitalist economy; however, spends half as much on healthcare per capita than the US, $2,700. A partial reason for this is the lower cost of medical services provided by hospitals and physicians. For example, an MRI machine costs $1,200 on average in the United States, while in Japan it costs $98. Doctors and hospitals are reimbursed less for their services, with an overnight stay in the hospital totaling $10 per night in a room with four patients and $90 per night for a private room (*Sick Around the World*, 2008).

Previous studies have shown that spending on healthcare rises with income levels (Baker *et al.*, 2008 and Or, 2000). Usage of medical care also increases with income; as people become wealthier, they have the ability to spend more on their healthcare needs, providing an encouraging market for more medical innovation and technology. With a focus on medical devices, I explore the effect of medical devices usage levels such as MRI machines and CT scanners on overall health outcomes. Figure 5 shows the relationship between rises in average income levels for the 17 OECD countries from the years 2000 to 2009, and the usage of medical devices in terms of number of MRI or CT scan exams per 1,000 people in the population for each year. The positive relationship suggests that

increased income levels have contributed to higher utilization rates of these technologies, which directly gives rise to higher healthcare expenditures.

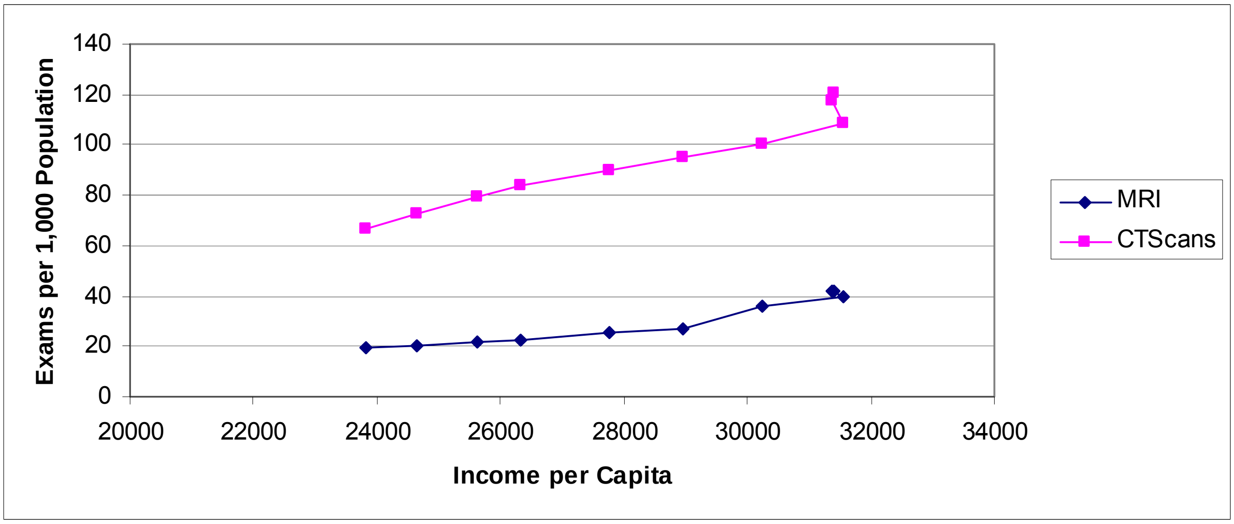

Figure 5: Income per Capita vs. Usage of MRI machines and CT Scanners, measured by exams per 1,000 per year for the years 2000 to 2009.
Source: OECD Health Data 2010

A common effect associated with rising levels of total income is an increase in the demand for goods. The income effect suggests as the world population's income increases, their tendency to spend more on healthcare also increases. It is widely accepted that a wealthier person who can afford more medical goods and treatment is generally healthier. Therefore, we see unequivocal variations in demand, since these treatments are mostly available to upper-class and middle-class consumers who have the financial means to demand these services (Dewar, 1997). A similar effect takes place with education levels; generally, those with higher levels of education lead healthier life styles and have higher incomes to demand more medical treatment. According to Goldman and Smith (2002), "differences by education in patient adherence to prescribed treatment explained a significant component of the health gradient", depending on how difficult the treatment plan was to adhere to and who actually receive the treatment. Individuals with higher

socioeconomic status more quickly adopted medical technologies, giving them at least a temporary advantage in improved health (Goldman and Smith 2002, p. 236).

C. Defensive Medicine

Increases in medical technology usage are not only demanded from the patient's side, but also by healthcare providers, who tend to recommend more expensive procedures due to fear of malpractice lawsuits. This practice is commonly known as "defensive medicine". Higher insurance reimbursement rates also provide an incentive for recommendations towards greater amounts of expensive procedures. Physicians are often stakeholders in technology, as they own a large percent of diagnostic centers, radiation therapy centers, ambulatory surgery centers, and clinical laboratories (Hekman, 2005). In some areas, physicians perform nearly twice as many tests per patient and charge twice as much. Under a fee-for-service model, provider-induced demand for technological services has caused a huge increase in the overall spending with the incentive of profit-maximization (Dewar, 1997).

D. Impact of Expenditure and Technology on Health Outcomes

Competition among providers is a driving force for acquiring more advanced technology. Even with an oversupply of hospitals in an area, many providers increase the use of technological services to maintain market share, thereby increasing overall spending due to overutilization of medical devices. Figure 6 shows number of MRIs and CT scanners for the year 2000 compared to share of health expenditure covered by public sources. There seems to be no apparent correlation between public expenditure and number

of machines per 1 million population. Countries with high rates of public spending, such as the Czech Republic and Luxembourg have relatively low numbers of MRI machines and CT scanners. This suggests that a higher portion of their health expenditure is spent towards other types of treatment, pharmaceutical drugs, administrative costs and hospital care, rather than purchases of these medical devices. Japan has a much higher number of CT scanners however, its percentage of public expenditure is 81% compared to the United States with a public expenditure value of 43% but higher rates of MRI and CT scanners, 18.3 and 26.8, respectively.

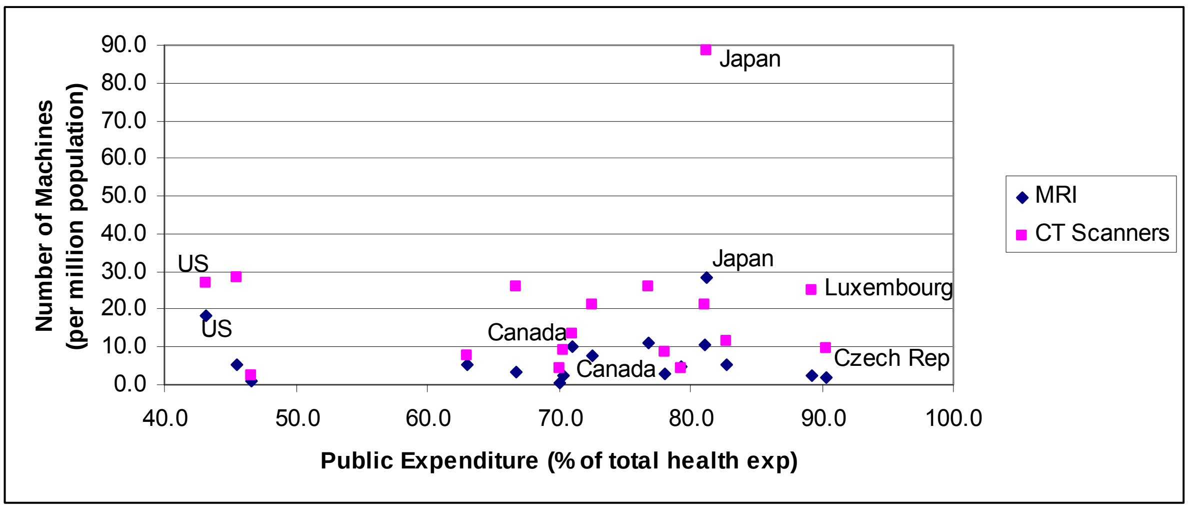

Figure 6: Share of Public Expenditure vs. Number of MRI machines and CT scanners for the year 2000.
Source: OECD Health Data 2010

E. Payment Structures for Healthcare Systems

Even though patients on average enjoy prolonged lives and improved quality of life, the added clinical benefits of new medical technologies and services should be weighed against the additional costs before they are implemented into common medical practice. As "newer, more expensive diagnostic or therapeutic services are sometimes used in cases in

which older, cheaper alternatives could offer comparable outcomes for patients" (Baker *et al.,* 2008). Managed care has been increasingly popular among privately and publicly insured individuals, creating an integrated delivery of care. Managed care organizations (MCOs) are slower and more cautious in the adoption of particularly costly technology (Isakkson and Hg, 2006). With this system, there are gatekeepers at the primary care level who are focused on more the cost-effective medical treatment reigns.

As previously discussed, the United States has a highly fragmented organization of financing for the healthcare system, including the presence of multiple third-party payers from both public and private sources. This highly complex and fragmented payment system weakens the demand side of the health sector and entails high administrative costs, a typical characteristic seen in the United States (Reinhardt, 2004). The United States spends a significant amount of healthcare expenditure on R&D aimed towards medical treatments and technologies.[4]

Other countries also have government-funded health insurance programs. For example, Japan has a social insurance system, where every citizen must sign up for health insurance either through their work company or the community. The patient assumes 30% of their healthcare expenditure, known as private costs, while the government covers most of the remaining costs, known as the public costs (*Sick Around the World,* 2008). The Japanese Health Ministry exhibits tight control over health costs and the Japanese people are highly satisfied with their system. Unlike in the United States, physicians in Japan are

[4] Most of the healthcare dollars the United States is spending are invested in vaccines, drugs and medical equipment. The United States allocates a higher rate of investment in research and development (R&D) towards pharmaceuticals, vaccinations and clinical trials. This money spent translates indirectly to other countries as they benefit from medical breakthroughs found in the US, without having spent the initial R&D cost. This idea, developed by Papageorgious *et al.* (2007), is one of the main reasons for exponential increases in US spending as we see a steadier rate of growth in healthcare spending for many other developed nations.

not employed to earn large profits, since price regulation by the Health Ministry has hit physician pay the hardest. Another downside to this system of healthcare is that 50% of Japanese hospitals are functioning in a financial deficit since the Japanese population spends “too little” on medicine, therefore not compensating hospitals enough for their services (*Sick Around the World,* 2008).

Canada has a population with similar rates of disease, environmental factors, and medical resources to the United States. Canada experiences overall lower healthcare expenditures, due to lower administrative costs, lower hospital costs and lower physician fees. Like Japan, Canada practices a nationalized healthcare delivery, in that all healthcare treatment is regulated and covered through government-run insurance plans. Canada’s government possesses a great deal of control over the utilization and distribution of medical resources (Dewar, 1997). The US spends more per capita than Canada, $7,439 per capita compared to $5,514 per capita; even though both countries’ life expectancies are similar, Canada’s infant mortality is lower by 15% (CMS, 2010). The single payer reimbursement methodology is simpler and works well for countries such as Canada and the United Kingdom.

Expenditures per hospital admission are higher in the US than Canada since US hospitals have a more complicated, diverse case mix of patients.[5] Also, the Canadian system only has a few large hospitals capable of providing specialized procedures and tertiary care, so as to maximize efficiency and usage of specialized equipment and physicians (Dewar, 1997). Services are used in limited scope in order to constrain costs.

[5] This was analyzed by the measure of DRGs, diagnosis-related groups, which is a system of classifying hospital cases into one of 500 groups expected to have similar hospital resource use, originally developed for Medicare billing purposes.

F. Measuring the Effects of Medical Technology

The main areas of concern for healthcare can be narrowed down to three fundamentals: cost, quality and access, as they ultimately relate to health outcomes. Relatively, it is simple to decrease costs; however, the difficult task is to not reduce quality or access simultaneously. The ultimate healthcare goal is to decrease costs while increasing quality and access. In an effort to "measure" the benefits of healthcare and its quality, a few variables are generally used. Health status is one of the fundamental variables for economic development. For example, "over the period 1950–2000, life expectancy increased by 3.7 years per decade in Latin America, by 6 years in East Asia, by 4.5 in South Asia, and by 3.4 years in Sub-Saharan Africa (prior to the reversal due to AIDS since 1990)" (Papageorgiou *et al.,* 2007). Health indicators can show a nation's welfare as a function of population variables, such as life expectancy, mortality rates, and percentage of population affected with a certain disease.

Chapter 1 concludes with this description on the following chapters. Chapter 2 presents a literature review of previous research studies that have been conducted regarding medical technology and resources. Chapter 3 describes the empirical methodology and linear regression model that was used to analyze the cross-country panel data from 21 OECD countries. It defines the dependent and independent variables, control variables and instruments. Chapter 4 explains findings and empirical results, and Chapter 5 provides concluding statements.

CHAPTER TWO:
LITERATURE REVIEW

This chapter provides a review of existing literature pertaining to healthcare spending, medical technology and their effects on health indicators. These studies utilize empirical models for measuring these relationships which are discussed in this chapter.

As of 1993, the United States spent only 5% of healthcare expenditures on technology; however, today it is one of the two leading factors of healthcare, along with pharmaceutical spending (Guidon and Contoxannis, 2008). According to Baker *et al.* (2008), technological advances in the field of medicine are defined as “changes in clinical practice that enhance the ability of providers to diagnose, treat, or prevent health problems; examples include: new drugs, devices, or services, as well as new clinical applications of existing technologies”. Medical technology is one of the leading causes of increased healthcare spending around the world; however recent advances in technology are shown to have a marginal yet positive impact on health outcome measures (Guidon and Contoxannis, 2008 and Papageorgiou *et al.*, 2007). I focus on the medical devices definition of medical technology, through numbers of MRI, CT scanners, mammography machines and RT equipment as well as usage levels of MRI machines and CT scanners. A variety of studies have been conducted focusing on different aspects of medical technology to explore further knowledge of efficiency gains or cost-benefit analysis.

To analyze possible determinants of health outcomes, Or (2000) took a multidisciplinary approach to include several environmental and lifestyle factors that have an indirect impact on health outcomes. These include: medical, social, economic and institutional factors, as part of a pooled, cross-country, time-series analysis. A “within-

country" approach to answer a question regarding national healthcare expenditure and healthcare satisfaction was conducted by Adang and Borm (2007), comparing 15 European Union countries with data from the OECD health database and Eurobarometer survey. Results concluded that there was little to no correlation between amount of expenditure spent on healthcare and perceived satisfaction of citizens. A notable conclusion by Adang and Borm (2007) is that a better healthcare system strives to optimize the relationship between life expectancy, infant mortality rates, physician density and total health expenditure, as these were variables utilized in their study.

A. Medical Technology: "Pharmaceutical Expenditure"

Well-known and widely used medical technologies include vaccinations, pharmaceutical drugs, and medical equipment. Previous research has spanned all of these realms, including the effects of pharmaceutical spending and its effects on health outcomes (Guindon and Contoxannis, 2008). Health outcome variables observed were: male and female life expectancies at birth and at age 65, and infant mortality rates. Pharmaceutical spending was used as a proxy for pharmaceutical use, while controlling for total non-pharmaceutical health expenditure, income, tobacco expenditure, alcohol expenditure, food, poverty, and population density. Empirical analyses supported the conclusion that a high correlation exists between pharmaceutical spending and health outcomes, particularly for infant mortality and life expectancy at age 65.

B. The Health Production Function

The health production, utilized by many studies generalizes the relationship between health outcomes and determinants that have an effect, is:

$$H = f(M, E)$$

H is health outcomes, taking the form of a number of variables, for example, life expectancy, infant mortality, incidence of disease, and mortality from a particular disease/illness. M is an indicator of medical resources and E represents the vector of non-medical social, economic and lifestyle indicators. Economic analyses performed by Or (2000), Arah *et al.* (2005), and Guindon *et al.* (2008) utilize the technique of controlling for lifestyle factors, as a result of various epidemiological studies leading to the awareness about a strong relationship between health factors and lifestyles.

C. Health Expenditure and Health Outcomes

Utilizing the fixed-effects model, a previous study focusing on public health expenditure hypothesized that increased health expenditure leads to lower mortality rates and PYLL (Arah *et al.*, 2005). This analysis examined a cross-sectional time series data set for 18 OECD countries with mortality rates and PYLL chosen as determinants of health outcomes. The regression results indicated that preventative medicine has the greatest impact on lower mortality rates, where nutritional factors and public health expenditure led to decreased mortality rates as well. Emphasized in the discussion, Arah *et al.* (2005) mentioned substantial concerns that threaten overall health gains for many countries, including: addictive behavior for alcohol and tobacco and poor nutritional lifestyle, degrading environmental quality and less-than-adequate health investments. Inefficient means of

investment in medical technology contributes to lower benefits as opposed to purchasing optimal quantities of medical devices to have substantial gains in health outcomes. Additional studies have explored this issue, determining if large amounts of medical technology or healthcare expenditure contribute to improvements in life expectancies and decreased mortality rates.

D. Medical Technology and Health Outcomes

Most of the existing empirical studies use a linear regression analysis to analyze medical technology's impact on health outcomes. Papageorgious *et al.* (2007) utilized multiple models of linear regression analysis, each with a different standard health outcome as the dependent variable, such as life expectancy, mortality rates and infant mortality rates. Per capita medical imports, foreign research and development expenditures, and the number of foreign-trained medical students were the explanatory variables. Control variables included were: total population, GDP per capita in PPP dollars, physicians per thousand people, female illiteracy rate, calorie intake, access to clean water, and sanitation. This paper hypothesizes that medical technologies resulting from R&D (research and development) in advanced economies have beneficial effects on health status in all countries, under the assumption that spending on medical technology imports influences life expectancy (Papageorgious *et al.*, 2007). As the empirical results suggest, the main finding is that imports of medical goods improve health statuses for all of the countries included in the analysis.

Another linear regression model compared usage of calcium channel blockers and ACE inhibitors used to treat hypertension against the independent variable education level.

Covariates included: age, gender, marital status, education class, mean cholesterol levels, blood sugar levels, and obesity (Goldman and Smith, 2002). Results showed that there was no significant different in adoption rates of new drugs with respect to education levels. All people in population surveyed, from the homogeneous New England town of Framingham, had similar patterns to adoption of new drugs introduced on the pharmaceutical market.

Standard health outcome variables used by numerous studies include infant mortality rate, life expectancy at birth and age 65, and mortality rate. Comprehensive variables that have been calculated using these values are PYLL, potential years of life lost, and QALY, quality adjusted life year. A QALY is the number of life years left after a medical intervention has been made, combining both quantity and quality of life remaining. Each year is assigned a value, ranging from 1.0 being a person in full health and 0.0 being death. For example, if someone requires the use of a wheelchair for the remainder of their life, they would not receive a full year for every year of life left; it would be some fraction of a year, to incorporate living condition and quality of life. Or (2000) explains the PYLL as a preferred measure of premature mortality, as it treats the year of life saved as the unit of output. PYLL deaths are weighted according to a base age, typically age 70. This gives more of a weight to those individuals who die earlier, as opposed to conventional mortality rates that have the same weight for all deaths irrespective of age. Or (2000) also introduced a different variable for medical consumption, PPP or purchasing power parity. It is used as a comparable measure for volume of health resources. Two problems are associated with this adjustment. First, the number of products associated with this 'medical basket of goods' is limited and the weighing method of importance of goods is subjective, and thus biased.

E. Medical Devices and Future Spending

Focusing on the medical equipment definition of medical technology, Baker *et al.* (2008) discuss the use of renal dialysis procedures for kidney failure, bone marrow (stem cell) transplantation, neonatal intensive care, joint replacement, diagnostic imaging (MRIs, CT scanners), and angioplasty, pacemaker and bypass surgery. These medical factors are compared to national healthcare spending for selected industrialized countries during the time period 1975 to 2005. "Health economists came to a general consensus that growth in real healthcare spending was principally the result of the emergence of new medical technology and services and their adoption and widespread diffusion by the U.S. healthcare system" (Baker *et al.* 2008, p. 2).

How much should countries spend on healthcare? This question of optimally spending valuable dollars and whether public or private spending should work in balance does not have an easy answer. Some economists have made progress to addressing these concerns. Spending on healthcare can be addressed through four approaches: Peer Pressure, Political Economy, Production Function, and Budget (Savedoff, 2003). Incorporating the qualifications to this simple question results in a final inquiry: "How much should my country spend on health, given our current epidemiological profile relative to our desired level of health status, considering the effectiveness of health inputs that would be purchased at existing prices, and taking into account of the relative value and cost of other demands on social resources?" (Savedoff, 2003, p. 3) Utilizing economic analyses to answer this question will have to keep in mind the scarcity of resources as well, and the three aspects of healthcare which must be kept in balance: cost, access and quality.

CHAPTER THREE:
METHODOLOGY

This chapter discusses the linear regression model and a description of the source data from the OECD Health Data 2010. Descriptive statistics are also presented for health indicators and independent variables.

A. Data

This study uses cross-country data from 1970 to 2009 from 17 OECD countries obtained from *OECD Health Data 2010*.[6] The linear regression economic model is as follows:

$$HI = \beta_0 + \beta_1 D_i + \beta_2 T_t + \beta_3 PUB_{it} + \beta_4 GDP\_CAP_{it} + \beta_5 HEALTH\_GDP_{it} + \beta_6 MRI_{it} + \beta_7 CTSCAN_{it} + \beta_8 MAMM_{it} + \beta_9 RTEQUIP_{it} + \beta_{10} MRI\_USAGE_{it} + \beta_{11} CTSCAN\_USAGE_{it} + \beta_{12} PHY_{it} + \beta_{13} HOSPBEDS_{it} + \beta_{14} TOB_{it} + \beta_{15} ALC_{it} + \varepsilon_{it}$$

where ε_{it} is the error term.

A fixed-effect regression model is used in this analysis to control for extraneous variables. For each country and time period, fixed effects dummies are used in the panel data regression for each country and year that the included independent variables do not account for. Fixed country effects and fixed time period effects are represented in the linear regression equation by the vectors D_i and T_t, respectively.[7]

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[6] Due the availability of complete data, I chose a selection of 17 countries from the OECD database. Several other countries were missing larger "chunks" of values in their data sets. I believe that I still captured an accurate representation of the world, with a diverse range of countries according to size, population, health systems, progress of development and economic environment with regards to availability of data for medical devices.

[7] The variable D_i is the fixed effect for countries, as there is no time component depicted by *t*. D_i represents all factors affecting a particular country's health outcomes that do not change over time, for example its geography. T_t is the time-varying fixed effect variable because it represents unobserved factors that change over time for all countries. The use of a fixed effects model is to control for all of the unobserved factors that do not appear in the regression equation above.

Dependent Variables:

HI is indicative of Health Indicator measurements as the dependent variable in each regression output. The following describes these measurements and their significance. All of these values are at the national level and cover the time period 1970 to 2009.

LEB is the life expectancy of the total population at the time of birth, measured as the expected number of total years to be lived without reduced functioning due to illness or disability (*OECD Health Data, 2010*). *LE65* is the life expectancy after the age of 65 for the total population, separated into males and females (*LE65FEM* and *LE65MALE*). *INFMORT* is the infant mortality rate, calculated by the deaths of children under the age of 1 that occurred in a given year per 1,000 live births. Potential years of life lost, or PYLL, is a measurement of premature mortality, which provides an explicit way of weighting deaths occurring at younger ages, which are, a priori, preventable. Mortality rates were not used in this study, as they are in absolute terms, whereas PYLL values give more weight to the death of a younger person.[8] For each country, the comprehensive value each year is established by the total number of PYLL of 100,000 people in the population. This variable is divided into males and females, *PYLLFEM* and *PYLLMALE*.

Independent Variables:

Two types of healthcare spending are captured by the *PUB* variable. Private spending is the percentage of total healthcare expenditure funded by private sources, specifically out-

[8] The calculation of PYLL involves summing up deaths occurring at each age and multiplying this with the number of remaining years to live up to a selected age limit, age 70. PYLL determines the average number of years a person would have left if they had not died prematurely. Generally, an upper reference age is established, in this study a standard of 70 years old was used, and all ages of those who died are compared to this number. For example, a person who died at age 15 would receive a weight of 55 while a person who died at age 65 would receive a weight of 5.

of-pocket payments (both over-the-counter and cost-sharing). *PUB* is the percentage of total healthcare expenditure incurred by public funds, including: state, regional and local government bodies and social security programs. *PUB* and *PRIV* represent the entire source of healthcare funding, as they add up to 100% for each country for any specific year. A third component to healthcare spending is not included as a separate healthcare spending variable as its sources are classified under private expenditure. It represents the reference group and encompasses informal payments extracted by medical care providers above the conventional fees, to over-the-counter prescriptions and to medical services not included in a third-party payer formulary or nomenclature of reimbursable services as well as fund received through private insurance programs, charities and occupational health care. Public (*PUB*) and private expenditures, whose relationship can be inferred through the values obtained through the *PUB* variable, are differentiated to capture the effect of the healthcare payment systems that vary across the 17 countries chosen for this analysis. Countries with a nationalized health system tend to have a greater portion of their healthcare covered through government programs, which is included in public expenditure.

Control variables include GDP per capita and income per capita to account for the economic environment and income levels. However, due to multicollinearity issues, income per capita was removed as an independent variable. *GDP_CAP* is the total GDP of the nation, converted to US dollars in the year 2000, divided by the population, therefore giving GDP per person for all 17 countries. The magnitude of total expenditure as a proportion of national spending is represented by percentage of GDP spent on healthcare, *HEALTH_GDP*. Healthcare resources are controlled for by including number of hospital beds per 1,000 people (*HOSPBEDS*) and number of physicians (*PHY*) in the population per 1,000 people.

The term ‘physician’ includes all individuals who have completed medical school, are licensed to practice medicine and deliver medical care to patients including interns, residents and practicing physicians. To try to control for lifestyle and health factors, two variables are included: TOB is the amount of tobacco consumption measured in percentage of the population (above the age of 15) who are daily smokers, and ALC is the amount of alcohol consumption measured in annual consumption of pure alcohol per person in liters for persons above the age of 15.

Medical technology is indicated with four commonly-utilized devices. *MRI* captures the number of MRI (magnetic resonance imaging) machines per million population. *CTSCAN* is the total number of computer tomography scanners per million population. *MAMM* is the total number of mammography machines designed specifically for taking mammograms per million population, and *RTEQUIP* is the total number of radiation therapy equipment per million population, involving x-rays or radionuclide, more specifically linear accelerators, Cobalt-60 units, Caesium-137 therapy units, low to orthovoltage x-ray units, high dose and low dose rate brachytherapy units and conventional brachytherapy units. Usage levels for MRIs and CT scanners are represented by *MRI_USAGE* and *CTSCAN_USAGE*, calculated by the number of diagnostic exams per 1,000 population. Comprehensive data for usage levels for mammography machines and radiation therapy equipment was not available for this study.

All variables include data from 17 OECD countries whose applicable data was available through *OECD Health Data 2010*. These countries include: Australia, Austria, Canada, Czech Republic, Denmark, Finland, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Poland, United Kingdom, and United States. Rationale

for choosing these specific countries is simply due to availability of data. I also try to sample countries with a variety of healthcare systems, from nationalized healthcare systems to a mix of private and public expenditure on medical care. For example, larger countries with nationalized healthcare systems are Canada, the United Kingdom and Japan, while countries that have a smaller proportion of healthcare expenditure funded through public sources are Mexico, Korea and the United States.

B. Descriptive Statistics

Table 1 shows descriptive statistics for the dependent variables, including their means, standard deviations, minimum and maximum values. Life expectancy at birth (*LEB*) ranges from 60.9 years in Mexico from 1970 to 82.7 in Japan in 2009, with an average of 75.01 for all countries accounting for all years 1970 to 2009. Mean life expectancies for females and males differ where females have an average of 18.09 years of life remaining after the age of 65 with a standard deviation of 1.81 while males have 14.40 years with a standard deviation of 1.89.

Infant mortality rates average to 11.46 deaths per 1,000 newborns under the age of one year old with a standard deviation of 10.29, indicating a wide distribution of infant mortality from 1.4 to 68.9. Potential years of life lost are essentially treated as a mortality rate, therefore the larger the value, the greater the number of people who have died prematurely. Males and females also differ in PYLL averages. Males have a higher average, 7595.73 years of life lost, in comparison to females with an average of 4092.25. Distributions for each gender differ as well, with males having a standard deviation of 3104.61 and females with 1871.48.

Table 1: Descriptive Statistics for Health Indicators

	Mean	Standard Deviation	Minimum	Maximum	N
LEB	75.01	3.68	60.9	82.7	680
LE65 Female	18.09	1.81	14.3	23.6	680
LE65 Male	14.40	1.89	10.2	18.6	680
Infant Mortality	11.46	10.29	1.4	68.9	680
PYLL Female	4,092.25	1,871.48	1,585	16,638	680
PYLL Male	7,595.73	3,104.61	2,736	22,909	680

Note: Data was taken from the years 1970 to 2009 from the 17 OECD countries. Most of the data is present for all of the countries for the listed years, with the exception for a few countries missing data from 2009.

Shown in Table 2 are the descriptive statistics for the independent variables. Healthcare expenditure is represented by public and private expenditure. On average, countries spend more from public sources, 70.87% of total healthcare expenditure, and an average of 19.11% from private sources, mainly out-of-pocket payments and private insurance programs. Percent of GDP spent on healthcare is approximately 7% with a 2.11% standard deviation. MRI and radiation therapy equipment have similar averages, 6.56 and 6.87 machines per million people. CT scanners and mammography machines have similar average as well with 17.49 and 16.26 machines per million people, respectively. CT scanners have a large standard deviation of 18.14 indicating a widely distributed data set. MRI usage has an average of 27.10 diagnostic exams per 1,000 people ranging from 1.30 to 72.30. CT scanner usage is relatively higher, 91.72 exams per 1,000, and is a wider distribution with a standard deviation of 36.31.

Expected signs for the anticipated empirical results of the independent variables are indicated in Table 2. It is expected that increased spending, both through public and private sources, would increase health indicators (such as life expectancy at birth and life expectancy at age 65 for males and females). Consequently, I expect public and private spending to be negative for mortality rates, captured by infant mortality rates and PYLL, as spending on healthcare increases overall, health outcomes are predicted to improve. GDP per capita and

percentage of GDP spent on healthcare are expected to follow the same trend as public and private spending. Medical technology as indicated by medical devices, MRI machines, CT scanners, mammography machines and radiation therapy equipment as well as usage of MRIs and CT scanners are expected to improve health indicators. Increased ownership of technology and its usage should translate to higher life expectancies and lower mortality rates. Physicians and hospital beds per 1,000 population are indicators of medical resources that are also expected to improve health outcomes. The life style indicators chosen to capture for consumption of alcohol and tobacco are expected to decrease health outcomes, as smoking and drinking alcohol are indicative as detrimental to one's health, thus reducing life expectancies and either increasing mortality rates or reducing quality of life at the end of life.

Table 2: Descriptive Statistics for Independent Variables

	Mean	Standard Deviation	Minimum	Maximum	Expected Signs (LEB, LE65)	N
PUB EXP	70.87	18.06	15.80	97.40	+	680
GDP_CAP	17290	12406	612	89732	+	680
HEALTH_GDP	7.03	2.11	3.10	16.00	+	680
MRI	6.56	7.68	0	43.10	+	365
CT SCAN	17.49	18.14	0	97.30	+	376
MAMM	16.46	10.05	0.70	56.00	+	352
RTEQUIP	6.87	5.00	0.20	28.00	+	337
MRI_USAGE	27.10	16.55	1.30	72.30	+	156
CTSCAN_USAGE	91.72	36.31	28.8	175.5	+	148
PHY	2.22	0.80	0.18	4.68	+	680
HOSPBEDS	6.80	4.02	0.96	19.4	+	680
TOB	32.08	8.71	12.9	59	--	680
ALC	9.84	2.84	3.8	18.5	--	680

Note: Data was taken from the years 1970 to 2009 from the 17 OECD countries. Most of the data is present for all of the countries for the listed years, with the exception for a few countries missing data from 2009.

C. Correlation Matrices

Multicollinearity is an issue where explanatory variables are highly linearly related that could potentially affect the sample data in this multiple regression model. Multicollinearity indicates a strong correlation between two or more independent variables, indicating either they capture the same regression effect or one variable causes the other. The precision of the coefficients, β values, are lowered in the presence of multicollinearity than if the explanatory variables were uncorrelated with each other. To address this issue, correlation matrices are shown in the following tables.

Table 3 shows all variables representing medical devices: MRI machines, CT scanners, mammography machines, radiation therapy equipment and usage levels for MRIs and CT scanners. From the correlation matrix, several of these variables are highly correlated, such as MRI and CT scanners as well as MRI and CT scanner usage, therefore to avoid any issues of multicollinearity, these variables will also be regressed individually, controlling for all other independent variables.

Table 3: Correlation Matrix for Medical Equipment

	MRI	*CTSCAN*	*MAMM*	*RTEQUIP*	*MRIUSAGE*	*CTSCANUSAGE*
MRI	1					
CTSCAN	0.7907	1				
MAMM	0.4198	0.4404	1			
RTEQUIP	0.0372	-0.1361	-0.026	1		
MRIUSAGE	0.7354	0.2618	-0.3403	0.2764	1	
CTSCANUSAGE	0.6336	0.4505	0.0424	0.0266	0.8995	1

Table 4 includes the remaining independent variables, the control variables. A possible concern is high correlation between GDP_CAP and medical resources, as it is likely that if patients have overall more to spend on medical care, the amount of medical resources, such as number of physicians and hospital beds, present in the population would correspond

to those increases. HEALTH_GDP poses the same potential problem. Looking at Table 4, however, alleviates that concern as correlation values between GDP_CAP and medical resources are 0.5618 for number of physicians and -0.145 for number of hospital beds. Similarly, HEALTH_GDP has a correlation value of 0.6153 with number of physicians per 1,000 population and -0.0931 for number of hospital beds per 1,000 population.

A high correlation is seen between GDP per capita and income levels per capita, with a 98.39% similarity in data trends. Therefore, I run regressions removing income levels from the empirical analysis. Public and private expenditures have a relatively high correlation, of 73.92%, however since I would like to see their effects to health outcomes; they will not be used in the same regression to be analyzed separately.

Table 4: Correlation Matrix for Control Variables

	PUBEXP	*PHY*	*HOSPBEDS*	*TOB*	*ALC*	*GDP_CAP*	*HEALTH_GDP*
PUBEXP	1						
PHY	0.3736	1					
HOSPBEDS	0.5232	0.3077	1				
TOB	0.2012	-0.575	0.4022	1			
ALC	0.2247	0.2084	0.2801	0.1477	1		
GDP_CAP	0.1388	0.5618	-0.145	-0.6216	0.0769	1	
HEALTH_GDP	-0.1125	0.6153	-0.0931	-0.4307	-0.0428	0.5792	1

CHAPTER FOUR:
EMPIRICAL ANALYSIS

This chapter presents the results of the regression analysis. It is divided into two sections. The first focuses on healthcare expenditure, both public and private, controlling for economic environment, medical resources and lifestyle factors. The second incorporates medical technologies and controls for public spending, economic environment, medical resources and lifestyle factors.

For each of the models, I present the results from the regression analysis using fixed effect regression models.[9] Each dependent variable is noted in the top row of each table, with R^2 values, number of observations, time periods and number of countries included shown at the end of each table. The availability of data is a barrier for most regressions controlling for multiple factors, especially for medical technology, therefore time periods and number of observations vary for each regression within the tables presented. Data statistics are presented at the end of each table, where most data from the years 1970 to 2009 is presented for the 17 countries.

A. The Effects of Healthcare Expenditures on Health Indicators

Estimates for the regression model of public and private spending on life expectancy at birth are shown in Table 5. Public expenditure is included in Columns 1, 2 and 3. Column 1 indicates a significant increase in life expectancy at birth with an increase of public expenditure as a portion of total healthcare expenditure. Controlling for GDP per capita and

[9] The regression outputs for a non-fixed effect model, which does not incorporate dummy variables for fixed-country and fixed-time period, are not included in this thesis. There is little significance and difference in the statistical significance levels of the included independent variables, therefore they are not included or discussed.

percentage of GDP spent on healthcare, public expenditure continues to have a positive impact on life expectancy at birth. However, after controlling for medical resources and lifestyle factors, there is no significance in public expenditure. Overall healthcare spending, as a percentage of GDP, causes a decrease in life expectancy at birth with a 1% increase resulting in 0.000019 year decrease in life expectancy, estimated to a few hours in one year. With a mean of 7.03% of GDP spent on healthcare and a standard deviation of 2.11, it is unlikely that *HEALTH_GDP* will change drastically to cause a significant impact on life expectancy.

Table 5: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Life Expectancy at Birth

	Life Expectancy at Birth		
Independent Variables:	(1)	(2)	(3)
Expenditure			
PUBEXP	0.0235 (4.779)**	0.0468 (7.258)**	-0.0011 (-0.064)
GDP_CAP		0.0334 (4.659)**	-0.0022 (-0.117)
HEALTH_GDP		0.000034 (6.256)**	-0.000019 (-3.367)**
Health Resources			
PHY			0.0009 (0.627)
HOSPBEDS			-0.4837 (-2.880)**
Lifestyle Factors			
TOB			-0.0585 (-2.113)*
ALC			-0.8951 (-6.002)**
Constant	16.4812	13.6135	-48.084
F-stat	93.792	83.192	96.45
R^2	0.809	0.813	0.813
Adj R^2	0.812	0.824	0.824
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%			

Table 6 shows the estimates for public and private spending on infant mortality rates. No significant relationship is seen between either of these variables, even when controlling for healthcare resources and lifestyle factors. In addition, lifestyle factors and medical resources are not significant in affecting infant mortality rates. There is likely some other factor that has more of an effect on this dependent variable which is not included in these regressions.

Table 6: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Infant Mortality Rates

	Infant Mortality Rate		
Independent Variables	(1)	(2)	(3)
Expenditure			
PUBEXP	136.329 (1.193)	-793.73 (-1.912)	139.111 (0.3381)
GDP_CAP		98.4769 (0.151)	-734.991 (-1.131)
HEALTH_GDP		464.402 (2.142)*	306.381 (1.241)
Health Resources			
PHY			-6723.92 (-3.120)*
HOSPBEDS			-3837.81 (-2.234)
Lifestyle Factors			
TOB			13.358 (1.412)
ALC			5.188 (1.236)
Constant	338.67	370.45	721.7
F-stat	38.01	76.82	143.88
R^2	0.812	0.869	0.896
Adj R^2	0.826	0.876	0.889
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Life expectancy at age 65 is divided by gender, to explore a possible difference among males and females, as average life expectancies at age 65 are 18.14 years for females and 14.40 years for males. Table 7 shows the estimates for the fixed-effect model of healthcare expenditure on life expectancy at age 65 for females. Public expenditure provides a significant decrease in life expectancy in Column 1. However, controlling for other factors indicates that a 1% increase of percentage of GDP spent on healthcare increases life expectancy of females by 0.2527 years, approximately 90 days or 3 months. Inference about the private expenditure effect on life expectancies could suggest that private expenditures also have no significant relationship to life expectancies. It raises further concerns about allocation of resources and inequality in quality of care provided by either public or private sectors of the healthcare market. This is likely not the case, however further investigation could be conducted to address this question.

Table 7: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Life Expectancy at Age 65 for Females

	Life Expectancy at Age 65 (Female)		
	(1)	(2)	(3)
Expenditure			
PUBEXP	-0.1318 (-2.987)**	0.0998 (0.425)	-0.2081 (-1.751)
GDP_CAP		1.0009 (1.943)	0.2527 (0.706)
HEALTH_GDP		0.1679 (1.830)	0.3709 (4.731)**
Health Resources			
PHY			-4.8615 (-3.826)**
HOSPBEDS			0.2123 (0.318)
Lifestyle Factors			
TOB			0.0027 (0.699)
ALC			-0.0004 (-0.238)
Constant	75.841	57.239	145.68
F-stat	278.76	239.82	297.92
R^2	0.888	0.827	0.847
Adj R^2	0.885	0.833	0.847
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Table 8 shows the results from the cross-country regression for life expectancy at age 65 for males. Columns 1, 2 and 3 provide no statistical significant results for public spending, however overall percent of GDP spent on healthcare provides an increase in life expectancy for males by 0.3334 years, or approximately 4 months.

Table 8: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Life Expectancy at Age 65 for Males

	Life Expectancy at Age 65 (Males)		
	(1)	(2)	(3)
Expenditure			
PUBEXP	-0.0665 (-1.545)	-0.1464 (-0.716)	0.2467 (1.415)
GDP_CAP		-0.827 (-1.845)	-0.2227 (-0.651)
HEALTH_GDP		-0.141 (-1.776)	0.3334 (4.447)**
Health Resources			
PHY			3.4670 (2.854)*
HOSPBEDS			-0.3754 (-0.588)
Lifestyle Factors			
TOB			-0.0004 (-0.118)
ALC			-8.50E-05 (-0.051)
Constant	18.768	36.39	-28.773
F-stat	210.44	173.45	229.13
R^2	0.785	0.826	0.898
Adj R^2	0.781	0.820	0.896
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Tables 9 and 10 show the regression results for the same independent variables against the dependent variables PYLL for females and males, respectively. Both females and males experience a similar trend for significant levels of public spending. There seems to be no significant correlation between level of public spending and potential years of life lost for males and females.

Table 9: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Potential Years of Life Lost for Females

PYLL (Females)			
	(1)	(2)	(3)
Expenditure			
PUBEXP	0.0161 (1.078)	0.0481 (0.917)	0.0787 (1.101)
GDP_CAP		0.2147 (1.987)	0.2745 (2.273)
HEALTH_GDP		0.0009 (0.062)	-0.0136 (-0.577)
Health Resources			
PHY			0.5821 (1.643)
HOSPBEDS			0.0634 (0.342)
Lifestyle Factors			
TOB			-0.0007 (-0.686)
ALC			-0.00006 (-0.124)
Constant	7.3221	4.6932	-4.558
F-stat	40.873	117.87	219.28
R^2	0.829	0.864	0.896
Adj R^2	0.837	0.869	0.895
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%			

Table 10: Estimates for the Fixed-Effect Model Regressions of Healthcare Expenditure on Potential Years of Life Lost for Males

	PYLL (Males)		
	(1)	(2)	(3)
Expenditure			
PUBEXP	-0.0252 (-0.431)	-0.1237 (-1.445)	-0.0148 (-0.157)
PRIVEXP			
GDP_CAP		0.1776 (1.322)	0.2844 (2.196)
HEALTH_GDP		-0.1231 (-2.758)*	-0.1116 (-2.332)*
Health Resources			
PHY			1.8538 (3.615)**
HOSPBEDS			0.1235 (0.304)
Lifestyle Factors			
TOB			-0.0022 (-0.964)
ALC			0.0009 (0.884)
Constant	5.764	5.4523	-26.348
F-stat	31.04	179.43	228.27
R^2	0.806	0.855	0.878
Adj R^2	0.827	0.860	0.884
Num of Obs:	680	680	680
Years:	1970-2009	1970-2009	1970-2009
No. of Countries	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%			

B. The Effects of Medical Technology on Health Indicators [10]

Results for a linear regression analysis for the dependent variable life expectancy at birth (*LEB*) are reported in Table 11. Controlling for GDP per capita, medical resources and lifestyle indicators, each medical device is part of a separate regression, to avoid issues of multicollinearity. Medical technology variables that do not have high correlation values are included in regression results later in this chapter, Tables 17 - 21, and are tested for joint

[10] I have performed regressions on MRI, CT scanners, mammography machines and radiation therapy equipment as medical devices with their data as a 2-year lag on the health outcomes. For example, with a similar set-up to Table 11, data points for MRIs in the years 1990-2007 are regressed against the life expectancies at birth for the years 1992-2009, instead of the years 1990-2009 as done in Table 11. These are not included in the empirical analysis section as the results did not differ in a major way from the tables displayed in the text, Tables 11-16.

probability. MRI machines and CT scanners provide significant increases in life expectancies at birth. For example, a change in number of MRI machines of 7.68, the standard deviation, increase life expectancy by 5 days for life expectancy at birth. This is not a large improvement for an entire population's life expectancy and likely not a good investment if target is to improve life expectancy at birth, since MRI machines average to 6.56 machines per million population. The number of CT scanners experiences an even smaller, but significant, improvement for life expectancy at birth. A one unit increase in CT scanner usage would make a greater improvement, as an addition diagnostic exam per 1,000 people increases life expectancy by approximately 25 days. Radiation therapy equipment also is significant, providing a 0.1369 year improvement in life expectancy at birth, approximately 50 days. This is less attainable, as the average for RT equipment is 6.87, with a standard deviation of 5.00. Perhaps since the distribution of RT equipment is widely distributed, it is less likely to obtain an additional RT machine per 1 million population.

Table 11: Estimates for the Fixed-Effect Model Regressions of Medical Technology on Life Expectancy at Birth

	Life Expectancy at Birth					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	-0.7196 (-3.535)**	-0.0012 (-0.069)	-0.0175 (-0.295)	-0.0013 (-0.069)	0.0288 (0.501)	-0.0022 (-0.120)
GDP_CAP	-0.7172 (-3.458)**	-0.0009 (-0.049)	-0.0035 (-0.192)	-0.0013 (-0.069)	0.0038 (0.201)	-0.0022 (-0.120)
HEALTH_GDP	0.0442 (1.245)	0.0566 (1.751)	0.0275 (0.851)	0.0096 (0.332)	0.0363 (1.093)	0.0086 (0.336)
Med Technology						
MRI	0.002 (2.385)*					
CTSCAN		0.000374 (2.335)*				
MAMM			-0.014 (-0.1573)			
RTEQUIP				0.1369 (6.674)**		
MRIUSAGE					0.0156 (1.018)	
CTSCAN USAGE						0.0748 (9.572)**
Health Resources						
PHY	0.1194 (2.480)*	0.0442 (1.216)	0.0643 (1.423)	-0.0186 (-0.563)	0.0263 (0.702)	-0.0492 (-1.646)
HOSPBEDS	-0.4407 (-5.670)**	-0.0273 (-4.617)**	-0.0295 (-5.283)**	-0.0327 (-6.194)**	-0.0254 (-4.269)**	-0.0216 (-4.706)**
Lifestyle Factors						
TOB	1.2696 (2.406)*	0.0054 (1.000)	0.0079 (1.025)	0.0067 (1.419)	0.0085 (1.573)	0.0034 (0.800)
ALC	-1.3570 (-2.050)*	1.1722 (2.296)*	1.527 (2.827)*	1.6227 (3.997)**	1.7930 (3.800)**	1.7791 (4.909)**
Constant	69.0406	-7.5285	6.8976	-4.9087	-7.4682	-4.4631
F-stat	193.83	197.86	48.701	251.75	191.78	316.66
R^2	0.835	0.880	0.814	0.884	0.880	0.887
Adj R^2	0.906	0.925	0.797	0.901	0.914	0.904
Num of Obs:	177	177	177	177	177	177
Years:	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009
No. of Countries	17	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%						

Table 12 shows the regression output for life expectancy for females at age 65. One MRI machine increase in a population of one million people has a positive impact on life expectancy for females, extending life by 0.2239 years, approximately three months. CT scanners have a negative impact for females, as a one unit increase for CT scanners decreases life expectancy by 0.05 years. Public expenditure decreases life expectancy for females at age 65 for all columns in Table 8. For example in Column 1, a 1% increase in public expenditure decreases life expectancy of older females by 0.777 years, or 10 months. This was not an expected result; however it is consistent with every regression conducted with this dependent variable. Public expenditure does not benefit older women with additional years of life gained after the age of 65.

Regression results for the fixed-effects model are shown in Table 13 for medical technology on life expectancy at age 65 for males. MRI machines in Column 1 cause an increase in life expectancy by 0.2995 years, approximately three months, similar to females in Table 12. For all regressions, Columns 1 through 6, public expenditure has a negative relationship to life expectancy for males.

Table 12: Estimates for the Fixed-Effect Model Regressions of Medical Technology on Life Expectancy at Age 65 for Females

	Life Expectancy at Age 65 (Females)					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	-0.7774 (-22.615)**	-0.8427 (-23.804)**	-0.8287 (-24.704)**	-0.8773 (-17.569)**	-0.9005 (-15.903)**	-0.7838 (-18.927)**
GDP_CAP	0.8421 (4.708)**	0.9136 (4.714)**	0.8367 (4.499)**	0.1932 (0.983)	0.1626 (0.7213)	0.5132 (2.351)*
HEALTH_GDP	0.0214 (0.738)	0.1749 (6.285)**	0.1148 (4.182)**	0.0089 (0.224)	0.0480 (0.245)	0.2139 (6.794)**
Med Technology						
MRI	0.2239 (13.87)**					
CTSCAN		-0.0562 (-2.431)*				
MAMM			0.0405 (0.962)			
RTEQUIP				0.0026 (0.300)		
MRIUSAGE					-0.0067 (-0.218)	
CTSCAN USAGE						-0.1607 (-0.295)
Health Resources						
PHY	0.1087 (1.075)	0.1673 (1.518)	0.0927 (0.896)	0.4695 (3.066)**	0.4207 (2.510)**	0.2602 (2.105)*
HOSPBEDS	0.5729 (1.842)	0.4079 (1.262)	0.6807 (2.074)*	-0.1440 (-0.329)	-0.3847 (-0.836)	0.3305 (0.871)
Lifestyle Factors						
TOB	-0.4063 (-1.237)	0.4250 (1.281)	0.1455 (0.449)	-0.4445 (-1.120)	-0.4318 (-1.087)	0.8888 (2.273)*
ALC	0.0632 (0.222)	-0.1210 (-0.397)	-0.1958 (-0.676)	-0.0587 (-0.195)	0.0683 (0.2813)	-0.1519 (-0.443)
Constant	39.7150	43.612	28.204	102.49	119.668	41.965
F-stat	702.99	715.22	787.15	1870.73	1797.13	436.38
R^2	0.851	0.872	0.892	0.898	0.873	0.886
Adj R^2	0.889	0.890	0.901	0.908	0.887	0.894
Num of Obs:	276	276	276	276	276	276
Years:	1980-2009	1980-2009	1980-2009	1980-2009	1980-2009	1980-2009
No. of Countries	17	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%						

Table 13: Estimates for the Fixed-Effect Model Regressions of Medical Technology on Life Expectancy at Age 65 for Males

	Life Expectancy at Age 65 (Males)					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	-0.8912 (-2.183)**	-0.9327 (-4.218)**	-0.8832 (-5.812)**	-0.9381 (-6.337)**	-0.8824 (-4.924)**	-0.8021 (-5.123)**
GDP_CAP	-0.0009 (-0.049)	-0.0035 (-0.192)	-0.0013 (-0.069)	0.0038 (0.201)	-0.0022 (-0.120)	-0.0040 (-0.206)
HEALTH_GDP	-0.000019 (-1.335)	-0.000019 (-1.410)	-0.00002 (-1.407)	-0.000018 (-1.099)	-0.000018 (-1.211)	-0.000019 (-1.210)
Med Technology						
MRI	0.2995 (9.196)**					
CTSCAN		0.0101 (1.339)				
MAMM			-0.0032 (-0.695)			
RTEQUIP				0.0049 (1.201)		
MRIUSAGE					0.0177 (1.531)	
CTSCAN USAGE						0.0006 (0.276)
Health Resources						
PHY	0.0008 (0.528)	0.0004 (0.279)	0.0010 (0.671)	0.0003 (0.181)	0.0002 (0.135)	0.0008 (0.476)
HOSPBEDS	0.4785 (2.842)**	0.4546 (2.692)**	0.4993 (2.942)**	0.4719 (2.809)**	0.5145 (3.056)**	0.4729 (2.726)**
Lifestyle Factors						
TOB	-0.0664 (-2.233)*	-0.0687 (-2.399)*	-0.0599 (-2.153)*	-0.0814 (-2.424)*	-0.0682 (-2.411)*	-0.0548 (-1.861)
ALC	-0.8985 (-15.983)**	-0.8883 (-15.85)**	-0.8976 (-15.985)**	-0.8872 (-15.772)**	-0.9058 (-16.141)**	-0.8936 (-15.563)**
Constant	-48.520	-47.395	-48.278	-47.899	-49.046	-47.829
F-stat (p-value)	442.36	446.29	442.18	445.19	448.01	434.21
R^2	0.891	0.856	0.861	0.831	0.865	0.871
Adj R^2	0.898	0.909	0.878	0.858	0.879	0.880
Num of Obs:	276	276	276	276	276	276
Years:	1980-2009	1980-2009	1980-2009	1980-2009	1980-2009	1980-2009
No. of Countries	17	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%						

Output for the regression analysis for medical technology on infant mortality rates is shown in Table 14. CT scanners and their usage provide decrease infant mortality rates. CT scanners are mainly diagnostic tools for children and adults; however the relationship between infants and CT scanners is surprising. Infant mortality rates are a component measure of overall population health, therefore having this improvement in mortality rates is beneficial to the population as a whole. With a mean of 91.72 and standard deviation of 36.31, an increase in CT scan exams decreases infant mortality by approximately 2.65 deaths per 1,000 life births. Mammography machines and radiation therapy equipment also provide decreases in infant mortality rates. Unlike previous analyses, public expenditure does not have a correlation with infant mortality rates.

These significant results of medical technology on infant mortality rates are likely incorporating some other effect, as infants are not the primary demographic for these types of medical devices. I hypothesize that this relationship is capturing the number and types of vaccines given to newborns or the number of diagnostic exams performed on an infant up to 1 year of age. Due to this inference, infant mortality rates are not included in subsequent regression analyses.

Table 14: Estimates for the Fixed-Effect Model Regressions of Medical Technology on Infant Mortality Rates

	Infant Mortality Rates					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	1.2882 (0.044)	-3.347 (-1.163)	-5.2139 (-0.536)	-1.5814 (-0.049)	-1.6323 (-0.049)	-1.5600 (-0.047)
GDP_CAP	-2.874 (-1.027)	-4.1207 (-2.285)	1.3078 (0.102)	-5.3447 (-0.933)	-6.5235 (-1.201)	-6.5489 (-1.197)
HEALTH_GDP	0.0393 (1.344)	0.0191 (1.199)	-0.0054 (-0.320)	-3.5756 (-2.093)	-0.0016 (-0.092)	-0.0022 (-0.135)
Med Technology						
MRI	-0.0427 (-1.443)					
CTSCAN		-0.0000418 (-5.298)**				
MAMM			-0.0414 (-3.462)**			
RTEQUIP				-0.2397 (-9.467)**		
MRIUSAGE					0.0134 (1.673)	
CTSCAN USAGE						-0.0155 (-3.005)**
Health Resources						
PHY	0.0259 (1.341)	0.0383 (2.140)*	0.0112 (0.580)	-0.0558 (-0.444)	0.0203 (1.030)	-0.0695 (-1.013)
HOSPBEDS	-0.0032 (-1.038)	-0.0062 (-2.152)*	-0.0056 (-1.805)	-0.0383 (2.224)*	-0.0038 (-1.244)	-0.03693 (-2.096)
Lifestyle Factors						
TOB	0.0031 (1.103)	0.0056 (2.134)*	0.0032 (1.174)	0.1001 (0.997)	0.0023 (0.835)	0.1270 (1.246)
ALC	0.5775 (2.235)*	1.0536 (4.186)**	0.4827 (2.039)*	0.2376 (0.668)	0.3815 (1.536)	0.6165 (1.200)
Constant	12.958	15.421	16.500	12.784	15.562	16.375
F-stat	172.41	204.46	184.62	131.88	173.29	180.98
R^2	0.823	0.860	0.828	0.834	0.841	0.892
Adj R^2	0.842	0.875	0.853	0.848	0.883	0.902
Num of Obs:	177	177	177	177	177	177
Years:	1997-2009	1997-2009	1997-2009	1970-2009	1997-2009	1997-2009
No. of Countries	17	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%						

Medical technology regressed against the dependent variables PYLL for females and males is shown in Tables 15 and 16. Public expenditure does not have a significant impact on PYLL for both genders. CT scanners and their usage decrease PYLL for females from Columns 2 and 4 in Table 15. These are significant but small increases in PYLLs; for example an increase in one CT scanner per million population causes a decrease in PYLL by 25.32 years for a population of 100,000. Similarly, one additional diagnostic exam per 1,000 with a CT scanner causes a decrease in PYLL for females by 15.29 years. Radiation therapy equipment is seen to decrease PYLL by 12.32 years with a one unit increase per million population. Regression results for PYLL for males are shown in Table 12. The output indicates increases in MRI machines and usage cause decreases in PYLL for males by 15.85 years and 12.47 years, respectively.

Table 15: Estimates for the Fixed-Effect Model Regressions of Medical Technology on PYLL for Females

	PYLL (Females)					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	0.0958 (1.440)	7.1612 (0.578)	1.9528 (0.827)	1.6641 (1.096)	0.8478 (0.686)	0.8387 (0.657)
GDP_CAP	0.3804 (2.466)	-0.9153 (-0.069)	0.7348 (0.055)	0.6539 (0.482)	-0.5085 (-0.038)	1.7152 (0.124)
HEALTH_GDP	0.0030 (0.114)	0.025 (1.624)	-0.000084 (-0.021)	0.0103 (0.6557)	0.0147 (0.912)	0.0093 (0.609)
Med Technology						
MRI	-1.1168 (-0.619)					
CTSCAN		-25.3281 (-3.269)**				
MAMM			-4.3123 (-1.375)			
RTEQUIP				-12.3151 (-2.239)*		
MRIUSAGE					3.8462 (0.513)	
CTSCAN USAGE						-15.2914 (-3.280)**
Health Resources						
PHY	0.0028 (0.158)	0.0090 (0.522)	0.5808 (0.532)	-0.0073 (-0.405)	0.0004 (0.023)	-0.0148 (-0.824)
HOSPBEDS	-0.0025 (-0.867)	-0.0045 (-1.586)	-0.0199 (-0.163)	-0.0040 (-1.450)	-0.0027 (-0.963)	-0.0020 (-0.715)
Lifestyle Factors						
TOB	0.0083 (3.184)**	0.010 (3.945)**	0.0349 (1.751)	0.0086 (3.379)**	0.0083 (3.171)**	0.0094 (3.704)**
ALC	0.2363 (0.992)	0.6392 (2.626)**	0.4246 (1.069)	0.2987 (1.345)	0.2619 (1.141)	0.2683 (1.232)
Constant	18.488	17.125	16.382	17.776	17.288	17.918
F-stat	155.88	167.54	198.21	161.11	155.74	167.62
R^2	0.835	0.846	0.826	0.821	0.874	0.867
Adj R^2	0.849	0.851	0.832	0.829	0.899	0.891
Num of Obs:	177	177	177	177	177	177
Years:	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009
No. of Countries	17	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%						

Table 16: Estimates for the Fixed-Effect Model Regressions of Medical Technology on PYLL for Males

	PYLL (Males)					
	(1)	(2)	(3)	(4)	(5)	(6)
Expenditure						
PUBEXP	-24.3312 (-0.124)	-1.3294 (-0.069)	-12.5712 (-0.082)	10.327 (0.544)	4.4536 (0.242)	-13.1770 (-0.162)
GDP_CAP	0.0477 (2.031)*	0.0401 (1.660)	0.0390 (1.618)	0.0446 (1.783)	0.0410 (1.757)	0.0463 (1.843)
HEALTH_GDP	0.000099 (1.381)	0.000092 (1.221)	0.000093 (1.345)	0.000098 (1.316)	0.000015 (1.604)	0.000082 (1.054)
Med Technology						
MRI	-15.8507 (-3.086)**					
CTSCAN		6.9218 (0.701)				
MAMM			2.1275 (1.268)			
RTEQUIP				2.8338 (0.541)		
MRIUSAGE					-12.470 (-3.243)**	
CTSCAN USAGE						3.048 (0.018)
Health Resources						
PHY	0.0002 (0.093)	0.0006 (0.287)	0.0007 (0.392)	0.0005 (0.261)	-0.0010 (-0.518)	0.0007 (0.345)
HOSPBEDS	-0.8571 (-4.072)**	-0.8645 (-3.953)**	-0.8477 (-3.889)**	-0.8773 (-4.036)**	-0.9661 (-4.576)**	-0.8760 (-3.930)**
Lifestyle Factors						
TOB	0.0531 (1.430)	0.0876 (2.361)*	0.0978 (2.737)**	0.0812 (1.869)	0.0689 (1.942)	0.0898 (2.374)*
ALC	0.4924 (7.006)**	0.4701 (6.480)**	0.4689 (6.504)**	0.4701 (6.457)**	0.5031 (7.150)**	0.4860 (6.589)**
Constant	-24.617	-21.859	-21.873	-22.219	-24.882	-23.53
F-stat	302.48	284.20	286.46	283.80	304.48	281.03
R^2	0.887	0.846	0.896	0.907	0.846	0.868
Adj R^2	0.895	0.863	0.910	0.892	0.862	0.872
Num of Obs:	177	177	177	177	177	177
Years:	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009	1997-2009
No. of Countries	17	17	17	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

General results for impacts of medical technology coincide with results found in previous studies, where increases in medical technology cause improvements in health outcomes (Or, 2000 and Papageorgiou, 2007). By investigating gender effects and incorporating various types of medical equipment, more specific questions can potentially be answered through these regression results.

C. Effects of Multiple Medical Technology Variables on Health Indicators

Tables 17 - 21 show empirical results for each health indicator with multiple medical technologies included in each regression. These are chosen by comparing correlation values from Table 3 and grouping technologies based on their low correlation values. In Table 17, the medical technology combinations do not have a significant effect on life expectancy at birth.

Table 17: Estimates for the Fixed-Effect Model Regressions of Multiple Medical Technologies on Life Expectancy at Birth

	Life Expectancy at Birth				
	(1)	(2)	(3)	(4)	(5)
Expenditure					
PUBEXP	0.1015 (1.338)	0.0482 (0.913)	0.0719 (1.306)	0.0528 (1.122)	0.0679 (1.228)
GDP_CAP	0.0018 (0.192)	0.0210 (0.373)	0.0142 (0.099)	0.0012 (0.041)	0.0189 (0.129)
HEALTH_GDP	-0.1872 (-1.518)	-0.2016 (-1.892)	-0.2910 (-1.972)	-0.1036 (-1.238)	-0.1642 (-1.819)
Med Technology					
MRI	-0.7102 (-1.179)				
CTSCAN		-0.1182 (-0.101)		0.9191 (1.103)	
MAMM	-0.7227 (-0.819)	-0.6182 (-1.117)	-0.1922 (-0.282)	-0.4726 (-0.824)	-0.4384 (-0.838)
RTEQUIP	1.3116 (1.752)	1.4201 (1.129)	0.1928 (0.993)		0.6726 (1.153)
MRIUSAGE				0.0826 (0.264)	
CTSCAN USAGE					0.0822 (1.157)
Health Resources					
PHY	0.0102 (0.847)	0.0281 (1.064)	0.0174 (0.961)	0.0192 (1.458)	0.0233 (0.935)
HOSPBEDS	0.0603 (3.396)**	0.0592 (3.283)**	0.0165 (3.283)**	0.0503 (3.585)**	0.0598 (3.864)**
Lifestyle Factors					
TOB	-4.1927 (-3.291)**	-4.1284 (-2.920)**	-4.2745 (-3.176)**	4.3391 (3.453)**	4.7261 (3.354)**
ALC	0.6388 (1.031)*	0.5778 (1.935)	0.5271 (1.898)	0.5397 (1.769)	0.5432 (1.607)
Constant	92.884	67.226	62.573	94.572	42.367
F-stat	192.56	212.87	182.68	197.83	195.27
R^2	0.837	0.86	0.786	0.887	0.827
Adj R^2	0.853	0.893	0.833	0.899	0.859
Num of Obs:	177	177	177	177	177
Years:	1990-2009	1990-2009	1990-2009	1990-2009	1990-2009
No. of Countries	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%					

Table 18 displays regression results for life expectancy at age 65 for females, with radiation therapy equipment having a significant effect shown in Column 3. A value of 1.8994 implies that a one unit increase in radiation therapy equipment per million population increases life expectancy for females by approximately 1.89 years with the presence of mammography equipment utilized in the population. Similarly, CT scanners cause approximately a one year increase in life expectancy for women above the age of 65 for a one unit increase in CT scanners per million population. These values indicate that at least one of the variables for each combination of medical technologies has a significant impact on life expectancy at age 65 for females.

Table 18: Estimates for the Fixed-Effect Model Regressions of Multiple Medical Technologies on Life Expectancy at Age 65 for Females

	Life Expectancy at Age 65 (Females)				
	(1)	(2)	(3)	(4)	(5)
Expenditure					
PUBEXP	0.0741 (1.848)	0.0728 (1.814)	0.0720 (1.799)	0.0657 (1.596)	0.0779 (1.926)
GDP_CAP	0.0084 (0.240)	0.0101 (0.284)	0.0049 (0.142)	0.0050 (0.141)	0.0003 (0.009)
HEALTH_GDP	-0.2076 (-1.923)	-0.1836 (-1.772)	-0.1720 (-1.680)	-0.1836 (-1.717)	-0.1770 (-1.727)
Med Technology					
MRI	-0.7333 (-1.034)				
CTSCAN		-0.7482 (-0.769)		0.9382 (2.092)*	
MAMM	-0.4028 (-0.681)	-0.6182 (-1.032)	-0.5139 (-0.882)	-0.2214 (-0.421)	-0.4307 (-0.733)
RTEQUIP	1.4640 (1.802)	1.7328 (1.397)	1.8994 (2.193)*		0.7900 (1.293)
MRIUSAGE				0.0913 (0.385)	
CTSCAN USAGE					0.0011 (1.053)
Health Resources					
PHY	0.0154 (0.901)	0.0149 (0.873)	0.0166 (0.980)	0.0179 (1.043)	0.0146 (0.8620)
HOSPBEDS	0.0529 (3.636)	0.0541 (3.693)**	0.0530 (3.640)**	0.0499 (3.466)**	0.0523 (3.600)**
Lifestyle Factors					
TOB	-4.5746 (-3.378)	-4.0121 (-2.822)**	-4.372 (-3.262)**	4.6033 (3.380)**	4.3147 (3.218)**
ALC	0.5970 (1.981)*	0.5340 (1.792)	0.519 (1.778)	0.5297 (1.757)	0.5788 (1.947)
Constant	86.4755	44.093	41.7532	43.970	39.401
F-stat	172.14	231.57	190.64	243.77	203.84
R^2	0.818	0.878	0.812	0.877	0.881
Adj R^2	0.836	0.897	0.846	0.882	0.896
Num of Obs:	177	177	177	177	177
Years:	1990-2009	1990-2009	1990-2009	1990-2009	1990-2009
No. of Countries	17	17	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Life expectancy for males at age 65 is shown in Table 19 with regression estimates for multiple technologies in each Column. According to the estimated model, an additional 5.00 increase in radiation therapy equipment per million population causes a 1.14 year increase in life expectancy with the presence of CT scanners used as diagnostic equipment as well. Column 4 shows that one unit increase in CT scanners will increase life expectancy of

males by 0.89 years controlling for all other factors including mammography machines and usage of MRI machines.

Table 19: Estimates for the Fixed-Effect Model Regressions of Multiple Medical Technologies on Life Expectancy at Age 65 for Males

	Life Expectancy at Age 65 (Males)				
	(1)	(2)	(3)	(4)	(5)
Expenditure					
PUBEXP	-0.0371 (-0.968)	-0.0369 (-0.965)	-0.037 (-0.980)	-0.0381 (-0.977)	-0.0382 (-0.988)
GDP_CAP	0.0948 (2.817)**	0.0921 (2.700)**	-0.0953 (-2.855)**	-0.0916 (-2.684)**	-0.0947 (-2.804)**
HEALTH_GDP	0.2153 (2.084)*	0.2130 (2.154)*	0.2203 (2.259)*	0.2024 (1.995)*	0.2210 (2.255)*
Med Technology					
MRI	-0.1044 (-0.1539)				
CTSCAN		-0.4793 (-0.516)	0.8140 (1.467)	0.8946 (1.981)*	
MAMM	0.8298 (1.466)	0.7472 (1.308)		0.5937 (1.190)	0.8028 (1.429)
RTEQUIP	-1.0556 (-1.357)	-0.6020 (-0.508)	1.1360 (1.979)*		-1.1212 (-1.918)
MRIUSAGE				0.0701 (0.311)	
CTSCAN USAGE					-0.0001 (-0.148)
Health Resources					
PHY	0.0013 (0.082)	0.0004 (0.026)	0.0014 (0.093)	0.0001 (0.008)	0.0017 (0.107)
HOSPBEDS	0.0371 (2.666)**	0.0363 (2.602)*	0.0371 (2.674)**	-0.0346 (-2.534)*	-0.0370 (-2.658)**
Lifestyle Factors					
TOB	-1.6306 (-1.259)	-1.8901 (-1.394)	-1.6594 (-1.299)	-2.1208 (-1.642)	-1.6517 (-1.287)
ALC	0.1931 (0.670)	0.1851 (0.663)	0.1820 (0.654)	0.2119 (0.741)	0.1739 (0.611)
Constant	40.7982	35.930	34.431	35.833	34.749
F-stat	142.34	123.07	206.47	214.58	179.33
R^2	0.837	0.86	0.786	0.887	0.827
Adj R^2	0.853	0.893	0.833	0.899	0.859
Num of Obs:	177	177	177	177	177
Years:	1990-2009	1990-2009	1990-2009	1990-2009	1990-2009
No. of Countries	17	17	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Table 20 shows decreases in female PYLL for MRI machines and radiation therapy equipment (Column 1) in the presence of mammography machines. Column 2 also controls for mammography machines and indicates decreases in PYLL for CT scanners and radiation therapy equipment.

Table 20: Estimates for the Fixed-Effect Model Regressions of Multiple Medical Technologies on PYLL for Females

	PYLL (Females)				
	(1)	(2)	(3)	(4)	(5)
Expenditure					
PUBEXP	-0.0212 (-2.201)*	-0.0221 (-2.287)*	-0.0229 (-2.284)*	-0.0288 (-2.837)**	-0.0232 (-2.290)*
GDP_CAP	-0.0055 (-0.653)	-0.0030 (-0.350)	-0.0084 (-0.959)	-0.0069 (-0.786)	-0.0081 (-0.917)
HEALTH_GDP	0.0062 (0.239)	0.0236 (0.944)	0.0357 (1.395)	0.0168 (0.639)	0.0360 (1.401)
Med Technology					
MRI	-0.6082 (-3.566)**				
CTSCAN		-0.7834 (-3.337)**		-0.0507 (-0.431)	
MAMM	0.1709 (1.201)	-0.0304 (-0.210)	0.0788 (0.540)	0.2061 (1.586)	0.0738 (0.5004)
RTEQUIP	-0.6717 (-3.436)**	-1.0761 (-3.595)**	0.2034 (1.349)		0.2099 (1.367)
MRIUSAGE				-0.1216 (-1.079)	
CTSCAN USAGE					-0.00007 (-0.251)
Health Resources					
PHY	0.0040 (0.981)	0.0032 (0.780)	0.0049 (1.171)	0.0056 (1.317)	0.0050 (1.187)
HOSPBEDS	0.0065 (1.869)	0.0077 (2.199)*	0.0066 (1.810)	0.0054 (1.516)	0.0066 (1.812)
Lifestyle Factors					
TOB	0.1071 (0.328)	-0.4378 (-1.276)	-0.0608 (-0.181)	-0.0868 (-0.258)	-0.0573 (-0.170)
ALC	0.3233 (4.460)**	0.2638 (3.737)**	0.2581 (3.538)**	0.2857 (3.838)**	0.2550 (3.414)**
Constant	39.062	4.4201	1.9698	4.2545	2.1109
F-stat	279.60	276.63	264.51	260.65	255.81
R^2	0.837	0.86	0.786	0.887	0.827
Adj R^2	0.853	0.893	0.833	0.899	0.859
Num of Obs:	177	177	177	177	177
Years:	1990-2009	1990-2009	1990-2009	1990-2009	1990-2009
No. of Countries	17	17	17	17	17
t-statistics shown in parentheses; * significant at 5%, ** significant at 1%					

Table 21 shows the effects of multiple medical technologies on PYLL for males. In Column 2, the model estimates decreases in PYLL with an increase in CT scanners and radiation therapy equipment with the inclusion of number of mammography machines in the population. These are small reductions in PYLL, as one unit increase in CT scanners and radiation therapy equipment causes a decrease in PYLL by 3.66 and 4.28 years for 100,000 males in the population.

Table 21: Estimates for the Fixed-Effect Model Regressions of Multiple Medical Technologies on PYLL for Males

	PYLL (Males)				
	(1)	(2)	(3)	(4)	(5)
Expenditure					
PUBEXP	0.0052 (0.110)	0.0052 (0.114)	0.0088 (0.186)	-0.0002 (-0.005)	0.0088 (0.184)
GDP_CAP	0.0753 (1.821)	0.0562 (1.380)	0.0815 (1.968)	0.0605 (1.450)	0.0814 (1.945)
HEALTH_GDP	0.2572 (2.026)*	-0.2511 (-2.126)*	0.1941 (1.605)	0.1847 (1.490)	0.1941 (1.598)
Med Technology					
MRI	1.2982 (1.558)				
CTSCAN		-3.6672 (-3.309)**	0.6989 (1.016)	0.7137 (1.292)	
MAMM	0.5022 (0.722)	1.2101 (1.774)		0.1307 (0.214)	0.6996 (1.004)
RTEQUIP	-1.2005 (-1.256)	-4.2855 (-3.033)**	-0.2006 (-0.282)		-0.2015 (-0.278)
MRIUSAGE				0.4134 (1.504)	
CTSCAN USAGE					0.000091 (0.007)
Health Resources					
PHY	-0.0981 (-4.917)**	-0.1042 (-5.348)**	-0.0960 (-4.800)**	0.1015 (5.081)**	0.0961 (4.754)**
HOSPBEDS	-0.0002 (-0.011)	-0.0058 (-0.348)	-0.0002 (-0.017)	0.0062 (0.373)	-0.0003 (-0.018)
Lifestyle Factors					
TOB	-0.7560 (-0.475)	1.3670 (0.844)	-0.3971 (-0.251)	-0.2540 (-0.161)	-0.3979 (-0.250)
ALC	0.9997 (2.822)**	1.1137 (3.343)**	1.1378 (3.301)**	1.2804 (3.663)**	1.1383 (3.230)**
Constant	-87.490	-19.765	-8.297	-20.340	-8.3168
F-stat	205.22	217.90	208.55	207.45	201.61
R^2	0.837	0.86	0.786	0.887	0.827
Adj R^2	0.853	0.893	0.833	0.899	0.859
Num of Obs:	177	177	177	177	177
Years:	1990-2009	1990-2009	1990-2009	1990-2009	1990-2009
No. of Countries	17	17	17	17	17

t-statistics shown in parentheses; * significant at 5%, ** significant at 1%

Table 22: Joint Probability Estimates for Regression Analysis - The F-Test/Wald Test

	(1)	(2)	(3)	(4)	(5)
	MRI, MAMM, RTEQUIP	CTSCAN, MAMM, RTEQUIP	MAMM, RTEQUIP	CTSCAN, MAMM, MRIUSAGE	MAMM, RTEQUIP, CTSCANUSAGE
Health Indicator					
LEB	12.2603 (0.0007)**	0.9761 (0.3290)	4.1746 (0.0021)**	1.4561 (0.1454)	1.0648 (0.2871)
LE65FEM	13.1908 (0.0006)**	409.27 (0.0000)**	498.37 (0.0000)**	402.18 (0.0000)**	31.2881 (0.0000)**
LE65MALE	12.3243 (0.0008)**	93.8384 (0.0000)**	188.176 (0.0000)**	104.263 (0.0000)**	91.173 (0.0000)**
PYLLFEM	3.4708 (0.0543)	3.787 (0.0120)*	64.401 (0.000)**	3.0784 (0.0299)*	51.0576 (0.0000)**
PYLLMALE	2.2603 (0.1298)	0.0748 (0.9734)	4.1746 (0.0166)*	2.7451 (0.0452)*	6.0612 (0.0006)**

Note: One-sided F-test statistic shown with p-value in parentheses. Each F-test has 3 numerator degrees of freedom and 173 denominator degrees of freedom.
* significant at 5%, ** significant at 1%

For the medical technology variables that do not have multicollinearity issues, mentioned in Tables 17 - 21, joint probability tests are conducted under a fixed-effect model to test whether a group of medical technology variables have an effect on health outcomes. An F-test indicates whether there is a joint probability between the coefficients of the variables selected, by imposing multiple restrictions in the model. The null hypothesis (H_0) is that the selected group of medical technology variables has no effect on the health indicator, given that countries and time periods are controlled for.

For example, in Table 18 Column 2, to test whether there is joint significance between CT scanners, mammography machines and radiation therapy equipment, an F-test is performed. The null hypothesis is H_0: $\beta_1 = \beta_2 = \beta_3 = 0$, where β_1, β_2 and β_3 are coefficients for CTSCAN, MAMM and RTEQUIP, respectively. The alternative hypothesis is H_1: H_0 is false. The F-statistic, with a value of 409.27 (indicated in Table 22, Column 2), is significant and the null hypothesis is rejected, meaning at least one of the coefficients for the selected medical technologies has an effect on life expectancy at age 65 for females. Other joint probability statistics are indicated in Table 22, designated with significance levels.

Another example of CT scanners, mammography machines and MRI usage (CTSCAN, MAMM and MRIUSAGE), shown in Table 22, Column 4, has an F-value that is not statistically significant for life expectancy at birth. The F-value for this combination of medical technology variables in a joint probability test is 1.4561. These variables are jointly insignificant and can be considered to be dropped from the empirical model as they do not have a joint impact on life expectancy at birth.

CHAPTER FIVE
CONCLUSION

This chapter summarizes the main findings from this study, and provides discussion on the impact of health expenditure and technology on healthcare systems. Furthermore, potential investigation and analyses for future research and their implications on health outcomes are proposed.

A. Summary of Findings

Using cross-sectional data from *OECD Health Data 2010*, this study investigates whether healthcare spending and medical technology have an impact on health outcomes. In addition to previous literature, this thesis examines the effect of public spending, MRI machines, CT scanners, mammography machines, and radiation therapy equipment against health indicators, including: life expectancy at birth, infant mortality rates, life expectancy at age 65 and PYLL, distinguished by gender.

This thesis finds that increased public expenditures lead to decreased life expectancies for females over the age of 65. On average, increased number and usage of selected medical technologies improve health outcomes, either by increasing life expectancy or decreasing mortality rates. The types of technology that impact each specific health outcome vary throughout the regression outputs as discussed in the "Empirical Analyses" section. When multiple types of medical devices are regressed in the model together, the joint probability of their impact is significant for most of the combinations used in the analysis.

There is no direct explanation for a relationship between health expenditure, medical technology, and health outcomes. Observations and results are highly sensitive to the choice of indicators for health outcomes and resources to control for (Or, 2000). Every model is a

simplification of the reality of medical technology and spending. By including estimates to represent the economic environment or medical resources, empirical studies try to extrapolate explanations for trends seen in healthcare. By investigating these possible relationships with cross-country data, analysis can be done to understand specific facets of the healthcare system, and improvements can be made through existing models of healthcare that are producing better health outcomes.

B. Alternatives to Current Healthcare Spending Practices

Predictions for our current healthcare spending rise suggest that it will plateau to 30% of GDP in 2050 (Baker *et al.*, 2008). This is due to a variety of reasons, including: the rising healthcare costs due to advances in medical technology and knowledge, rising expectations and demands from customers, advances in medical technology and pharmaceutical drugs, rising provider expenses administrative costs, and a rapidly aging population which will pose greater demand on health resources in the future (Price Waterhouse Coopers, 2002). With regard to medical technology, increased spending on diagnostic services (MRI and CT included) is attributable to two primary reasons: higher costs per treatment and patients living longer so they remain in treatment longer (Baker *et al.*, 2008).

The distinction between public and private spending in my analysis contributes to previous studies by exploring the distinction between sources of healthcare funding. I find that out-of-pocket expenditure has a positive impact on life expectancies and a negative impact on mortality rates. A possible explanation for this could be that those who are forced to spend more from their own pocket tend to live healthier lives to avoid higher costs in the future, as opposed to individuals who are covered through public programs who are

somewhat shielded from the “true” cost of their care. The answer is not to simply advocate for more healthcare to be funded through private sources. Instead, structures of healthcare systems must be investigated further since the current fractionated system that the United States operates under does not produce the greatest health outcomes.

Other countries’ more successful health systems can provide an example of effective healthcare systems. Most have created a financially stable source of public funding yet still encourage patients to pay a significant proportion out-of-pocket to yield better health outcomes. By placing a heavier financial burden on the individual or family, patients will have a greater incentive to stay healthy and avoid poor lifestyle habits.

Many countries, like Canada, Japan, and the United Kingdom, have variations of a single-payer healthcare system model, also known as nationalized healthcare. Each has their own structure for allocation of funding given to hospitals and healthcare providers. Nationalized healthcare may seem ideal; however, it does have its flaws. For instance, unfair medical treatment exists across the country, as resources may be preferentially used toward patients with higher profile health outcomes. In Canada, many patients and providers feel that hospital budgets are unrealistically low, resulting in outdated equipment, overcrowding, decreased capacity, and long queue wait times. State-of-the-art technology (i.e. coronary bypass surgery, computed tomography [CT scanners], and magnetic resonance imaging [MRI]) is only available at designated hospitals, and can be difficult for many people to access (Dewar, 1997).

On both the provider and hospital levels, the political process and policies are where the most choices about the allocation of healthcare resources are made. The goals of policy politics to maximize dispersion of healthcare inputs sometimes outweigh the results of

economic policy pushing to increase the effectiveness of every dollar spent on healthcare. One way to address the issue of inequality of medical resources available to the population is to achieve greater national uniformity of market regulation across health insurance markets, regardless of type of submarket (e.g., large group, small group, individual), geographic location, or type of health plan.

A prime example of a healthcare system that “achieves positive health outcomes with low expenditure” is found in Singapore. With a population of four million people, Singapore is efficient in both financing their health system, and obtaining high levels of community health outcomes. While the primary responsibility is placed on the individual to assume responsibility for their own health and health expenditure; it still has federally-funded programs to help those in need, such as Medifund, Medisave, Medishield and Eldershield (Tucci, 2010). Each of these programs are designed to help those who cannot afford treatment for catastrophic illnesses, hospitalization, day surgery, and certain outpatient expenses, particularly those with disabilities and/or the elderly. With the emphasis on the individual to make significant contribution towards their own health costs, the government is able to maintain a low level of public expenditure (Tucci, 2010). This has directly influenced individuals to maintain healthier lifestyles, resulting in higher life expectancies (currently up to 80.7 years at birth) (WHO, 2010).

In addition to changing regulation practices, all countries could move towards a health culture of “conservative medicine”, avoiding radical medical treatments and procedures whenever possible. This is not an easy feat, as many physicians in the US tend to overuse technology, due to perceived greater risk of lawsuits. The threat of malpractice daunts physicians, therefore they tend to practice “defensive medicine”, and perform more

laboratory tests or x-rays even if they are not necessary to direct treatment or the patient's probability to sue (Dewar, 1997). Many other countries do not suffer this problem, and have much less overutilization of technology and procedures, mainly due to their differences in culture and legal systems. Each country must find a balance between allocation of health resources within a population and healthcare spending (Becker, 2005).

C. Suggestions for Future Research

Future research could include additional control variables to specifically look at relationships between spending, technology, and health outcomes that were significant in this study. A limitation of this study was the availability of data for explanatory variables such as preventative medicine, nutritional factors, pollution, and education levels. Through further investigation, explanations can be hypothesized and tested for increases in private or public spending, and additional medical technologies if data is available.

Previous studies have focused on policy implication in relation to healthcare spending. Furthermore, taking into account the conclusions of this thesis, other implications such as the allocation of resources through policy regulation can be explored. Government structures could set up policies that will ensure equal access to quality care through the availability of pharmaceuticals and medical technologies. As mentioned by Or (2000), interesting results may arise from distinguishing between males and females for healthcare spending, lifestyles, and medical technology use. I have distinguished some health outcomes by gender (life expectancy at age 65 and PYLL); however, specifically looking at independent variables according to gender may distinguish discrepancies and biases towards males or females.

D. Focus on Preventative Medicine

Increased spending towards healthcare is not attributable to only a few items; many aspects are necessary to consider, such as governmental policies, allocation of resources, availability of care, equipment and medical personnel, and their relationship with healthcare spending. With this complex, multifaceted system of payers and patients, healthcare costs are rising drastically. Some suggest that one fundamental way to reduce individual health care costs is a focus on prevention. Arah *et al.* (2005) report these findings in an empirical analysis where preventative medicine was shown to have the largest impact on lowering mortality rates, in addition to lifestyle factors and public expenditures. In my analysis, tobacco and alcohol usage contribute to higher life expectancies and lower mortality rates as well, thus providing a similar conclusion. Lifestyle factors and preventative medicine have a large role in determining overall health outcomes for many countries.

Overutilization of procedures and technology is possibly due to increased numbers in diseases and ailments around the world. Decades ago, illnesses like malaria, polio, and other infectious diseases were more prevalent, especially in developing countries; however, their mortality rates have decreased and given way to less communicable diseases such as cancer, heart disease, and diabetes. Papageorgiou *et al.* (2007) suggests that mortality changes in developing countries came through the introduction of public programs and dissemination of knowledge, such as the role played by parasites and germs in the spread of disease. Sometimes, direct government intervention is not as important as the spread of information. Healthcare focus should narrow towards preventative medicine and education of people on healthy lifestyle habits. In the future, incidences of diseases and illnesses will likely decrease, and healthcare spending can be significantly smaller for future generations.

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