UNIVERSIDADE DO ALGARVE

FACULDADE DE ECONOMIA

Assessing the Effectiveness of Noncommunicable Diseases Control and Prevention Using Data Envelopment Analysis: An International Comparison

ANA CRISTINA SOARES DO NASCIMENTO

Dissertação para a obtenção do Grau de Mestre em Gestão de Unidades de Saúde

Trabalho sob a orientação de:

Professora Doutora Carla Alexandra E. Filipe Amado

Professor Doutor Sérgio Pereira dos Santos

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“Declaração de autoria de trabalho”

Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos estão devidamente citados no texto e constam da listagem de referências incluída.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

BCC	Banker, Charnes and Cooper
BMI	Body Mass Index
CCR	Charnes, Cooper and Rhodes
COPD	Chronic Obstructive Pulmonary Disease
CRS	Constant Returns to Scale
CT	Computed Tomography
DALYs	Disability-Adjusted Life Years
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EMS	Efficiency Measurement System
GDP	Gross Domestic Product
MRI	Magnetic Resonance Imaging
NCDs	Noncommunicable Diseases
OECD	Organization for Economic Coordination and Development
OMS	Organização Mundial de Saúde
PPP	Purchasing Power Parity
PYLL	Potential Years of Life Lost
SFA	Stochastic Frontier Analysis
TCS	Tobacco Control Scale
USA	United States of America
VRS	Variable Returns to Scale
WHO	World Health Organization

RESUMO

As doenças não transmissíveis são por definição não infeciosas e não transmissíveis de pessoa para pessoa. Este grupo de doenças, em particular as doenças cardiovasculares, o cancro, a diabetes e as doenças respiratórias, lideram mundialmente o número de mortes. A mortalidade precoce é uma das consequências destas doenças que gera maior preocupação, assim como, a perda de qualidade de vida levando os indivíduos a viver um considerável número de anos com incapacidade para trabalhar segregando as famílias para situações de pobreza.

As doenças cardiovasculares representam a maior causa de morte, com 15.6 milhões de mortes em 2010, de entre as quais se destacam o enfarte agudo do miocárdio e os acidentes vasculares cerebrais. O cancro representa a segunda maior causa de mortalidade, responsável por 8 milhões de mortes em 2010, sendo expectável que venha a aumentar a sua incidência em todo o mundo, em particular nos países com menor nível de desenvolvimento. O cancro da traqueia, brônquios e pulmão são os mais frequentes, quase do dobro do cancro do estômago e fígado conjuntamente. Como terceira causa de morte surge a doença pulmonar obstrutiva crónica, a mais representativa do grupo das doenças crónicas respiratórias que são responsáveis por 3.8 milhões de mortes. Por último, a diabetes é responsável por 12.8 milhões de mortes, tendo também a particularidade de ser percursora de outras doenças, como por exemplo, os acidentes cerebrais vasculares ou a insuficiência renal.

Este grupo de doenças partilha um conjunto de fatores de risco bem identificados e que são similares em todos os países. Os quatro fatores de risco comportamentais que estão fortemente relacionados com as doenças não transmissíveis, anteriormente identificadas, são: tabagismo, dietas alimentares desadequadas, sedentarismo e consumo abusivo de álcool. Estes conduzem a quatro importantes alterações metabólicas: hipertensão arterial, obesidade, hiperglicemia e hiperlipidemia. No entanto, inerente ao desenvolvimento do país ou ao grupo socioeconómico a que o indivíduo pertence existe um conjunto de fatores mais amplos e menos passíveis de mudança a curto e médio

prazo que também condicionam o aparecimento das doenças não transmissíveis, tais como o rendimento, o acesso à educação ou a poluição atmosférica.

Por forma a prevenir ou controlar as doenças não transmissíveis, em particular estas doenças crónicas, a Organização Mundial de Saúde (OMS) propõe que sejam implementadas um conjunto de medidas específicas dirigidas aos fatores de risco comportamentais. A OMS identificou um grupo de medidas custo-efetivas para estes dois grupos de fatores de risco, como por exemplo, proibir fumar em locais públicos, adverter a população para o impacto negativo do tabagismo na saúde, aumentar os impostos sobre o tabaco, reduzir a quantidade de sal na comida, assim como, proporcionar à população rastreios do cancro do colo do útero e da mama para deteção e tratamento precoces do cancro.

Neste sentido, os decisores políticos dos diferentes países assumem um papel especialmente importante na gestão dos sistemas de saúde. A promoção de hábitos de vida saudáveis e as intervenções de rastreio pressupõem um melhor acesso aos serviços de saúde, em particular aos cuidados de saúde primários. A avaliação de desempenho dos sistemas de saúde tem sido um tema frequente entre os decisores políticos principalmente desde 2000, ano em que a OMS dedicou um relatório a este tema. A comparação do desempenho dos sistemas de saúde entre países tem sido levada a cado por diversos investigadores e reconhecida como importante por alguns autores. Os sistemas de saúde são extremamente complexos e a sua avaliação de desempenho tem um papel importante ao proporcionar informação relevante aos diferentes agentes que neles participam por forma a tomarem decisões informadas no sentido de atingirem os objetivos propostos.

Diversos estudos utilizando o *Data Envelopment Analysis* (DEA) para comparar a eficiência dos sistemas de saúde de diversos países foram desenvolvidos ao longo das últimas décadas, no entanto, menos estudos foram efetuados para avaliar a efetividade dos sistemas de saúde. Seja sobre eficiência ou efetividade grande parte dos estudos desenvolvidos avalia os sistemas de saúde como um todo. Neste sentido, esta dissertação introduz um contributo ao ter como principal objetivo explorar o potencial do DEA para avaliar a efetividade dos sistemas de saúde na prevenção e controlo das

doenças não transmissíveis. Para este efeito, foram recolhidos dados de 27 países da OCDE para o ano de 2009.

Os resultados obtidos apontam 11 países como efetivos na prevenção e controlo das doenças não comunicáveis. Os países considerados efetivos são: Finlândia, Grécia, Islândia, Israel, República da Coreia, Luxemburgo, México, Polónia, Eslovénia, Espanha e Suíça. De entre os quais, Israel e a Finlândia são os que mais vezes servem de referência para aprendizagem para os países não efetivos na prevenção e controlo das doenças não comunicáveis.

Os resultados do nosso estudo sugerem ainda que Israel e a Finlândia destacam-se particularmente na prevenção e controlo das doenças cardiovasculares e neoplasias, respetivamente. De facto, a OMS reconhece Israel como detentor de uma excelente rede de serviços de cuidados primários composta por equipas multidisciplinares próximas da comunidade proporcionando um melhor acesso a cuidados de saúde. A proximidade destas equipas multidisciplinares oferece, por um lado, maior oportunidade para promover hábitos de vida saudáveis junto da população, e por outro, controlar sistematicamente as pessoas que já se encontram em situação de doença. A Finlândia tem das taxas de incidência de cancro mais baixas da Organização para a Cooperação e Desenvolvimento Económico (OCDE), em particular a do cancro do pulmão. Por trás destes resultados está um forte investimento em programas de controlo do tabagismo e programas de rastreio de cancro (por exemplo, mamografias). Os programas de controlo do tabagismo têm sido baseados tanto em fortes campanhas publicitárias como em restrições de acesso e consumo legisladas desde meio da década de 90.

Os resultados obtidos indicam que há uma variação significativa na efetividade da prevenção e controlo das doenças não transmissíveis nos países analisados, sugerindo que a identificação das melhores práticas neste contexto poderá resultar na implementação de estratégias mais efetivas na prevenção e controlo destas doenças junto da população. Estes resultados também demonstram o potencial papel estratégico do DEA para um planeamento mais efetivo dos recursos existentes.

Palavras-chave: doenças não transmissíveis, DEA, sistema de saúde, efetividade.

ABSTRACT

Noncommunicable diseases (NCDs), with special relevance cardiovascular diseases, cancer, diabetes and respiratory diseases, are leading causes of death worldwide. For policymakers across countries, the prevention and control of these diseases is fundamental to ensure an effective management of healthcare systems. The main purpose of this dissertation is to explore the potential of using *Data Envelopment Analysis* (DEA) to assess the effectiveness of healthcare systems in preventing and controlling NCDs. To this purpose, data from 27 OECD counties has been used. Our results point out a remarkable variation in NCDs prevention and control across countries, suggesting that the identification of best practices in this context may contribute to the development of more effective strategies to prevent and control NCDs among the population. These results also demonstrate the potential strategic role of DEA for an effective planning of the available resources.

Keywords: NCDs, DEA, healthcare system, effectiveness.

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1. INTRODUCTION

Noncommunicable diseases (NCDs) are a group of medical conditions or diseases that are by definition non-infectious and non-transmissible from person to person (Kim and Oh, 2013). Although, NCDs include psychiatric, neurological, musculoskeletal, gastrointestinal and kidney diseases, the World Health Organization (WHO) (WHO, 2000a; WHO, 2008; WHO, 2011) considers four principal types of NCDs: cardiovascular diseases (including stroke and heart disease), diabetes, cancers and chronic respiratory diseases (including chronic obstructive pulmonary disease and asthma). These NCDs are the leading cause of mortality all over the world, causing more deaths than all other causes combined, and are no longer an issue of relevance to high income countries only, as recently they have hit with high incidence the low- and middle-income countries (WHO, 2011).

From a total of 57 millions of deaths all over the world in 2008, 36 million, or 63%, were due to NCDs (World Health Assembly, 2013). The premature mortality is one of the most important implications of NCDs, as the numbers reveal that about a quarter of the deaths occur before the age of 60, mainly in low and middle-income countries (Chand, 2012). Without preventable measures and actions on the field, according to the Global Status Report on NCDs 2010 (WHO, 2011) it is expectable that the number of deaths due to NCDs will rise to 52 million by 2030.

There are several risk factors identified for increasing the mortality due to NCDs. As the Global Status Report on NCDs 2010 refers, “A large percentage of NCDs are preventable through the reduction of their main behavioral risk factors: tobacco use, physical inactivity, harmful use of alcohol and unhealthy diet.” (WHO, 2011: 1). According to the same report, the behavioral risks, previously mentioned, are responsible for about 80% of coronary heart disease and cerebrovascular disease.

However, the risk factors are wider than those previously described and Chand (2012: 2) remembers that “the risk factors for NCDs are social, environmental, behavioral and biological”, with the behavioral risk factors influencing the biological ones such as blood glucose, lung function or brain chemistry. Also, “social and environmental factors such as urbanization, air pollution or consumption trends may influence behavior and biology" Chand (2012: 2). NCDs are caused by multiple risk factors, some are individual options and can be modified, others are more embracing and must be addressed by policymakers for wider changes.

NCDs have a very important impact on the global economy and on each country's economy in particular. Health expenditure is a very important part of the public budget and the WHO (2011: 36) refers that "national health-care budgets are increasingly allocated to treatment of cardiovascular diseases, cancer, diabetes, and chronic respiratory disease". However, NCDs have other important implications on the society[1]: an unhealthy population leads to a loss of productivity and to high levels of absenteeism. According to the World Economic Forum, by 2030 the cumulative loss in global economic output due to NCDs will be $47 trillion, representing 5% of the Gross Domestic Product (GDP) (Bloom et al., 2011).

The World Health Assembly (2013: 10) as a follow-up to the political declaration of the high-level meeting of the general assembly on the prevention and control of NCDs reinforces that:

> *"…for all countries, the cost of inaction far outweighs the cost of taking action on noncommunicable disease (…) the total cost of implementing a combination of very cost-effective population-wide and individual interventions, in terms of current health spending, amounts to 4% in the low-income countries, 2% in the lower middle-income countries and less than 1% in upper middle- income and high-income countries."*

Considering that the resources for healthcare systems are limited and the level of health expenditure is always a concern for all governments in all countries, having the right information to take the best decisions has a precious value to policymakers. Therefore, performance assessment in this field plays a crucial role as it helps "hold the various agents to account by enabling stakeholders to make informed decisions" (Smith

[1] The World Economic Forum includes mental health disorders as one of the most important NCDs. However given their global burden, their cost and the type of interventions needed to prevent and control these disorders, they should be analyzed separately. For that reason, in this study, as previously discussed, we will only focus on the four main categories of NCDs: cardiovascular diseases, diabetes, cancers and chronic respiratory diseases.

et al. 2009a:5). By offering timely information about the structure, processes and outcomes (Donabedian, 1980), performance assessment can contribute to improve health systems. A particularly valuable way to improve these systems consists in identifying and sharing the best practices, however, the identification of the best practices is complex since there are multiple factors contributing for health outcomes. Furthermore, the complexity increases at macro-level benchmarking, due to geographic, economical, cultural, social and political issues.

Data Envelopment Analysis (DEA) is a non-parametric linear programming technique developed by Charnes, Cooper and Rhodes (1978) to measure the relative efficiency of homogeneous Decision Making Units (DMUs). In the past two decades, the DEA technique has been extensively used in the health care field and different levels of DMUs have been considered. According to Ozcan (2008) the application of DEA not only allows the identification of top performers but also conduces to discovering alternative ways for health care performance improvement. As emphasized by Santos, Amado and Santos (2012) one of the interesting features of DEA is that it allows each unit to identify a benchmarking group; that is, a group of units that are following the same objectives and priorities, but performing better.

We can find many studies that have applied DEA at the micro-level (e.g. comparing hospitals or clinics in a particular country or region). However, there are considerably less studies using DEA at the macro-level (e.g. comparing healthcare systems of several countries). Examples of studies at the macro-level are those of: Hadad, Hadad and Simon-Tuval (2013); Santos et al. (2012); Afonso and Aubyn (2011); Hollingsworth (2008); Retzlaff-Roberts, Chang and Rubin (2004) and Puig-Junoy (1998). Whilst most of these studies take advantage of the rich database available for OECD countries, undertaking comparisons of health systems performance across these countries, Santos et al. (2012) compare the efficiency of mother to child HIV prevention in low-and middle-income countries. Despite the potential of DEA to evaluate the performance of health systems in controlling specific diseases, to the best of our knowledge, there is no published study using DEA to undertake an international comparison of the performance of countries in controlling and preventing NCDs.

The aim of this research is to contribute to this under-researched area by exploring the potential of using the DEA technique to assess the effectiveness of NCDs prevention and control in OECD countries. In particular, we aim to: a) identify the most effective countries in NCDs prevention and control; b) identify some of the most relevant reasons behind the levels of performance achieved by the most effective countries; and c) suggest improvement actions.

In order to achieve these objectives, the dissertation is organized as follows. Section 2 discusses the importance of the NCDs control and prevention, discusses their impact on healthcare systems and expenditure, and gives an overview of the DEA methodology discussing the extent to which its use has been documented for health systems performance assessment. Section 3 presents the DEA model developed to accomplish the purpose of this study and then discusses the empirical results obtained. Finally, Section 4 concludes the dissertation with some closing remarks and suggestions for future research.

2. LITERATURE REVIEW

2.1. The importance of comparing health systems performance in preventing and controlling NCDs

NCDs have a severe impact on individuals, communities and countries. This rapidly changing health and disease profile has serious implications for poverty reduction and economic development. The analysis of the Global Burden of Disease Study 2010 (Lozano et al., 2012) revealed that NCDs were responsible for almost 35 million deaths (or 65.5% of all deaths) and chronic NCDs have a special role in it. Cardiovascular diseases represent the most important causes of death, in which ischemic heart disease is the major cause followed by stroke. Cancer represents the second group of NCDs which causes more losses. The third leading cause of all deaths is chronic obstructive pulmonary disease (COPD), the most representative from the chronic respiratory diseases. Diabetes deaths worldwide almost doubled from 1990 to 2010, becoming one of the most important causes of death.

Premature mortality[2] is a very concerning issue because no one should be doomed to die prematurely. Nonetheless, premature mortality is not the only relevant issue in NCDs because these diseases also reduce people's quality of life, leading individuals to live a considerable amount of years with incapacity to work and pushing families to poverty. According to the Global Burden of Disease Study 2010 the distribution of DALYs[3] in 2010 reflect a predominance of NCDs globally, with 54% of all DALYs due to NCDs (Lozano et al., 2012). In order to give relevant background information to support the analysis, in what follows we will review some facts about each of the four main groups of NCDs (cardiovascular diseases, diabetes, cancers and chronic respiratory diseases).

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2 WHO (2011) defines 'premature death' as a death of a person with less than 70 years old.

3 The disability-adjusted life years (DALYs) are the sum of two components: years of life lost due to premature mortality (YLLs) and years lived with disability (YLDs). In other words, it is a measure of overall disease burden, expressed as the number of potential productive years lost due to premature ill-health, disability or early death (Murray et al., 2012).

Cardiovascular diseases keep leading the global causes of death with 15.6 million or 29.5% of all deaths (Lozano et al., 2012) and this number is expected to increase, achieving more than 23.6 million by 2030 (WHO, 2012). Cardiovascular diseases accounted for 11.8% of the total DALYs. Policymakers have to invest in the prevention and control of these diseases or $47 trillion will be lost in the next 25 years (Laslett et al., 2012).

Cancer is predicted to be an increasing cause of death (4 million per year) and disability in the next few decades. Overall, an estimated 12.7 million new cancer cases and 7.6 million cancer deaths occurred in 2008, with 56% of the new cancer cases and 63% of the cancer deaths occurring in the less developed regions of the world (Ferlay et al., 2010). More recent data shows that neoplasms caused in 2010 almost 8 million deaths, representing 15.1% of all causes of death and 23% of all NCDs deaths. Trachea, bronchus and lung cancer are the most frequent (1.5 million or 19.1% of neoplasm deaths) almost doubling the deaths when compared with the next two most common, stomach and liver cancer (Lozano et al., 2012). As expected, neoplasms have an important accounting on DALYs representing 7.6% of global DALYs (Murray et al., 2012).

High-income countries had more than twice the rate of all cancers combined when compared with the lower-income countries. Whilst a considerable increase in cancer incidence is expected worldwide in the next two decades, the low- and low-middle-income countries will have a higher increase (82% and 70%, respectively) when compared to the high-income countries (40%) (WHO, 2011).

The report “The Global Economic Cost of Cancer”, released at the 2010 World Cancer Congress in China, reveals that the total economic impact of premature death and disability from cancer worldwide was $895 billion in 2008 (1.5% of world’s GDP), in which lung cancer, trachea and bronchus represent the largest drain, nearly $180 billion on the global economy (John and Ross, 2010).

Chronic respiratory diseases represent, in turn, 3.8 million deaths, wherein COPD represents 76.7% of these diseases. Although the number of deaths from COPD has decreased from 1990 to 2010 (3.1 million to 2.9 million), it is relevant to emphasize that the massive increase in tobacco use since the 1970s might reverse this trend over the next decade or so (Lozano et al., 2012). Chronic respiratory diseases are responsible for 4.7% of global DALYs, with COPD making up two thirds of the total (Murray et al., 2012).

Lastly, diabetes is a common chronic disease that is rapidly rising in prevalence (Guariguata et al., 2013; Caspersen et al., 2012) representing 12.8 million deaths (Lozano et al., 2012) and 1.9% of all DALYs in 2010 (Murray et al., 2012). Diabetes is an important illness as having diabetes increases the risk of getting other diseases, for example, it increases twice the risk of having a stroke and it is responsible for several conditions that decrease the quality of life. Some of the diabetes complications are: renal failure, lower limb amputation, visual impairment and blindness. Furthermore, having diabetes increases the risk of getting tuberculosis (WHO, 2011). All these conditions and complications have an impact on global health expenditure. Dealing with diabetes represented a health care related expenditure of at least $376 billion in 2010 and will represent $490 billion in 2030. Globally, 12% of the total health care expenditure is expected to have been spent on diabetes in 2010. More than 90% of the global expenditure on diabetes is made in the world's economically richest countries and the USA are leading this group (spending more than half of the global expenditure on diabetes) (Zhang et al., 2010).

Behind these diseases a few main modifiable risk factors are identified and are similar in all countries (Ezzati et al., 2002). Four behavioral risk factors are strongly associated and causally linked to NCDs: tobacco use, unhealthy diet, physical inactivity and harmful consumption of alcohol. These individual behaviors lead to four metabolic/physiological changes: raised blood pressure, overweight/obesity, hyperglycemia and hyperlipidemia (WHO, 2011). The leading risk factor is raised blood pressure (13% of global deaths are attributable to this risk factor), followed by tobacco use (9%), raised blood glucose (6%), physical inactivity (6%), and overweight/obesity (5%) (WHO, 2009).

Tobacco use comes in both smokeless and smoking forms, however, smoking tobacco is the most commonly used form globally (WHO, 2011). Smoking is estimated to cause about 71% of all lung cancer deaths, 42% of chronic respiratory diseases and about 10% of cardiovascular diseases (Line, Ezzati and Murray, 2007). If prevention actions fail, by 2020 tobacco related deaths are expected to increase to 7.5 million, accounting for 10% of all deaths (Mathers and Loncar, 2006).

Insufficient physical activity is also a behavioral risk factor and is responsible for almost 3.2 million deaths, representing 4% of all DALYs (WHO, 2009). People who are physically inactive have a 20 to 30% increased risk of all causes of mortality compared to those who engage in at least 30 minutes of moderate intensity of physical activity on most days of the week (WHO, 2010). Physical activity decreases the risk of several cardiovascular diseases, like stroke and ischemic heart disease, but also cancer and diabetes. Men tend to be more active than women in all regions, but the high income countries lead physical inactivity levels in both sexes, where 41% of men and 48% of women are insufficiently physically active (WHO, 2011).

A balanced diet is composed by different aspects and therefore there are no estimates of unhealthy diet prevalence. However, there are some relevant aspects to take into consideration. In particular, the low fruit and vegetable consumption is estimated to cause 1.7 million deaths worldwide, representing 1.0% of all DALYs. The WHO recommends the intake of 400 grams of fruits and vegetables each day contributing to decrease the risk of cardiovascular diseases, diabetes mellitus (Bazzano, 2005) and cancer (Riboli and Norat, 2003). The amount of salt consumed is another concern because it plays an important role on blood pressure levels. The WHO recommends less than 5 grams per person per day, because reducing salt intake would have an important impact on decreasing the prevalence of cardiovascular diseases (WHO, 2007). Processed food, high in fats and sugars, represents a major risk in high-income countries, promoting overweight and obesity (WHO, 2011).

The fourth risk factor listed is the harmful use of alcohol, which represents a major risk for premature deaths and disabilities in the world, and is responsible for 2.7

million deaths and 3.9% global DALYs (Lim et al., 2012). Harmful use of alcohol contributes to more than 60 types of diseases and injuries and there is a direct relationship between high levels of consumption and cancers. Furthermore 50% of deaths due to liver cirrhosis are attributed to alcohol. However, it is important to emphasize that the relationship between heart and cerebrovascular diseases and alcohol consumption is complex, because, until a certain level, alcohol consumption can have a protective effect (WHO, 2009).

For the high- and middle-income countries, the most important risk factors are those associated with heart diseases and cancer. Tobacco is one of the leading risks for both conditions: accounting for 11% of the disease burden and for 18% of deaths in high-income countries. 70% of the deaths caused by tobacco use occurred, however, in low- and middle-income countries. The prevalence of smoking is also higher in Central and Eastern Europe, and in parts of East and Southeast Asia (WHO, 2011). In 2010, smoking accounted for 8.4% of the worldwide disease burden among men (the leading risk factor) and 3.7% among women (Lim et al., 2012). For high-income countries risk factors such as alcohol, overweight and blood pressure are the leading causes of healthy life style losses, each being responsible for 6-7% of the total losses. The highest proportions of deaths attributed to alcohol were in Eastern Europe and Latin America (WHO, 2009). In addition, the high-income countries have the highest prevalence of other risk factors: physical inactivity among women, total fat consumption and raised total cholesterol (WHO, 2011).

The behavioral risk factors discussed above have an important role in the metabolic/physiological risk factors. The changes on diet and the increase on physical inactivity have contributed to increase the rates of overweight and obesity among people worldwide (WHO, 2009). High body mass index (BMI) is an important cardiovascular disease risk factor, and its effects are partly mediated by high blood pressure, cholesterol and glucose (Danaei, 2013).

Excess of salt intake, alcohol, sedentary life style and obesity, all have a role to play towards increasing blood pressure, in such a way that these factors "…have been shown to be positively and progressively related to the risk for stroke and coronary heart disease" (WHO, 2011: 21). According to WHO (2009), these factors are responsible for 51% of strokes and 45% of ischaemic heart diseases. A more recent study reinforces their relevance for stroke, considering them as the most important mediators, accounting for two-thirds of the excess risk (Danaei, 2013). On the other hand, high intake of saturated fat, physical inactivity and genetics can increase cholesterol level, which is responsible, worldwide, for one third of ischaemic heart disease (WHO, 2009). The high blood glucose is also an important metabolic risk factor for cardiovascular diseases, causing all diabetes deaths, 22% of ischaemic heart disease and 16% of stroke deaths. Although genetics plays an important role in this risk factor, diet and physical activity are also relevant because adiposity increases the risk of diabetes (WHO, 2009; Danaei, 2013).

Blood pressure, considered as the most important mediator between BMI and cardiovascular disease, has decreased in high-income countries, such as Central Europe and parts of Latin America. Furthermore, serum cholesterol has decreased in western countries, but has increased in East and Southeast Asia (Danaei, 2013). High BMI has increased globally, presenting Australasia and Southern Latin America the highest values in this risk factor, with North Africa, Middle East and Oceania also ranking high in this risk factor (Lim et al., 2012).

In order to prevent and control NCDs the WHO proposed some main interventions, focused on the major behavioral risk factors, that even low- and middle-income countries should be able to implement with health gains. Each of these interventions was called 'best buy' because it "is an intervention that is not only highly cost-effective[4] but also cheap, feasible and culturally acceptable to implement" (WHO, 2011: 47). Some of these 'best buys' are: protect people from tobacco smoke and ban smoking from public places; warn about the dangers of tobacco use; enforce bans on tobacco and alcohol advertising, promotion and sponsorship; raise taxes on tobacco and alcohol; restrict access to retailed alcohol; reduce the salt content of food; replace

[4] An intervention is considered highly cost-effective if, on average, it provides an extra year of healthy life (equivalent to averting one DALY) for less than the average annual income per person (WHO, 2011).

saturated fat with unsaturated fat and promote public awareness about diet and physical activity, through counselling in primary care (WHO, 2011).

The control and prevention of NCDs also include measures to improve the access to essential health care services, because it is important to carry out interventions to help people with disease or at high risk of developing disease. Furthermore, it is also important to take screening interventions for an early detection and treatment of cancers. At this level, some ‘best buy’ interventions are: counselling and multidrug therapy for people with 10-year risk of fatal or nonfatal cardiovascular event, cervical cancer screening and treatment of pre-cancerous lesions to prevent cervical cancer (WHO, 2011). A wide adoption of these interventions is expected to reduce the NCDs deaths by 2% per year, saving tens of millions of lives by 2020 (Beaglehole et al., 2011).

However, all these modifiable and behavioral risk factors act with a background scenery, where socioeconomic factors, environmental and community conditions influence the risk of dying from NCDs. In this respect, people who have a low socioeconomic status or live in poor and marginalised communities have a higher risk of developing NCDs. Two of the socioeconomic factors identified as playing a background role in influencing health status are the level of income and the level of education (Di Cesare et al., 2013; WHO, 2009).

Therefore, poverty and the prevalence of NCDs are linked, people in vulnerable and socially disadvantaged conditions tend to get sicker and die sooner. Population in low- and middle-income countries are more exposed to common modifiable risk factors and an unhealthy behavior leads to a higher incidence of NCDs. Furthermore, these countries have limited access to effective and equitable healthcare services. At the household level, disability and premature death lead to a loss of household income, making families to get trapped in a vicious cycle where poverty and NCDs reinforce one another (WHO, 2011).

The numbers are clear and policymakers have a central role on NCDs combat by developing and implementing appropriate strategies and action plans. In September 2011, the United Nation High-Level Meeting on NCDs brought to discussion, at the highest level, priority actions and crucial interventions to combat the NCDs crisis, such as reducing risk factors and creating health-promoting environments. In addition, health systems should contribute to the combat of these diseases. As the WHO (2000b) defined, health systems have three main goals: first, to improve the health of the populations they serve; second, to respond to the reasonable expectations of those populations; and third, to provide financial protection against the costs of ill-health through fair contributions. Applying for these goals requires a two front response, one involves giving medical support to individuals with high risk or that already have the disease, and another comprehends public health interventions at population level and macroeconomic interventions (Strong et al., 2005).

The measurement of health system performance is a topic considered important by political international organizations because it "...seeks to monitor, evaluate and communicate the extent to which various aspects of the health system meet key objectives" (Smith et al., 2009a: 8). Health systems are very complex and have several stakeholders, including patients, various types of health-care providers, payers, purchaser organizations, regulators, government and the broader citizenry, each of them with different expectations and interests (Smith et al., 2009b). Performance measurement has an important role by enabling the different agents to have relevant information in order to make informed decisions and, through improved decision making, achieve their own goals.

Therefore, assessing the performance of a health system requires dealing with two issues: the first is how to measure the outcomes related with the health system's goals (good health, responsiveness and fair financial contribution) and the second is how to compare those attainments with what the system should be able to achieve using the same resources (WHO, 2000b).

International comparisons of health system performance are object of study from some of the most influent organizations, such as WHO and OECD. As emphasised by Veillard et al. (2009: 641) international benchmarking can be of great relevance for decision-making, considering that:

> *"The provision of comparative data presents vast methodological challenges but offers considerable potential for cross-country learning. Policymakers are looking for examples, benchmarks and solutions to address the pressures imposed by the epidemiological, economic, societal and technological demands on all European health-care systems."*

The World Health Report 2000 received much attention because it brought to discussion the importance of measuring the performance of health systems and outlined several initiatives to improve the perceived health situation in many countries. Notwithstanding criticisms to this study, it brought to discussion the importance of improving the data available so that more reliable cross-country studies could be done in order to improve the performance of health systems.

The limited resources available to prevent, treat and control the NCDs demands an efficient and effective health care delivery. In specific, efficiency is attained if the maximum benefits (outputs: goods or services) are obtained from the available resources (Smith, 2012), and effectiveness of care is attained if maximum desirable outcomes (health gains or equity) are obtained from a given level of outputs (Schinnar, 1993). One can also define effectiveness in terms of resources used. In this respect, effectiveness of resources is attained if the maximum desirable outcomes are obtained from a given level of resources (Street and Häkkinen, 2009). A comparative analysis across countries in order to identify the best practices can contribute to improvements in health care policy and practice. This research explores the use of the DEA technique to assess the effectiveness of NCDs control and prevention in the OECD countries.

2.2. The use of DEA for health systems performance assessment

Farrell (1957) was the first author to present an empirical method to calculate the relative efficiency of several DMUs. This method uses data regarding the level of resources used (inputs) and the level of goods produced or services provided (outputs) to measure the relative efficiency of a set of decision making units (benchmarking). Farrell (1957) also suggested that efficiency consisted in two different components: technical efficiency, which reflects the ability to obtain the maximum output for a given set of inputs and the allocative or price efficiency that reflects the ability for using the set of inputs in optimal proportions given their respective prices and technology production (Coelli, Rao and Battese, 1998).

Farrell's empirical work had been confined to single-output cases when Charnes et al. (1978) extended his work and defined a linear program in order to obtain efficiency values, for a production system characterized by multiple inputs and multiple outputs. They also introduced an innovation to Farrell’s measure of efficiency. They introduced slack measures to account for non-radial adjustments to the frontier. According to the production metaphor used by DEA, each homogeneous DMU is engaged in a transformation process, where by using some inputs (resources) it is tries to produce some outputs (goods and services). DEA uses observed inputs and outputs in order to construct the production frontier. The relative efficiency is defined as the ratio of the total weighted output to the total weighted input (the ratio ranges from zero to one). A DMU is considered relatively efficient if it achieves a score of one. The technique allows each unit to choose the optimal weight structure in order to maximize the ratio. In addition, DEA allows each unit to identify a benchmarking group, in other words, a group of units that are following the same objectives and priorities, but performing better. There are two main advantages in adopting this technique, first it can handle multiple inputs and multiple outputs, and second it does not require a precise knowledge of the form of the production function.

DEA allows two types of orientation, input-oriented or output-oriented models. According to Coelli et al. (1998) in the input-oriented model the question to be answered is: for a given set of outputs produced by a unit how much can the inputs be reduced maintaining the level of outputs? On the other hand, for the output-oriented models the question is: given a set of inputs, how much can the outputs be increased maintaining constant the level of inputs? To decide between these two orientations one must take into account the context under analysis and must identify which inputs and/or outputs are under the direct control of the DMUs. For example, if the DMUs have greater control over the inputs, then an input-oriented model should be used. It is also possible to use non-oriented models, which aim at a combination of input decrease and output augmentation.

The CCR model, also known as Constant Returns to Scale (CRS) model, measures the ratio of weighted outputs to weighted inputs subject to the condition that similar ratios for all DMUs under analysis are less or equal to unity. The mathematical formulation is:

$$\max h_0 = \sum_r u_r y_{r0} / \sum_i v_i x_{i0} \qquad (1)$$

subject to

$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \leq 1 \text{ for } j = 1, \dots, n \qquad (2)$$

$$u_r, v_i \geq 0 \qquad (3)$$

The y_{rj}, x_{ij} are the known outputs and inputs, respectively, of the j^th DMU and the u_r, v_i for all r and i, are the unknown weights to be determined by the solution of the problem. The constrain $\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \leq 1$ reflects the condition that the virtual output ratio and the virtual input ratio of every DMU must be less or equal to unity. The weights used for each DMU are those that maximize the DMU's efficiency score. However, this ratio of fractional programming above presented yields an infinite number of solutions, and it was necessary to transform it into a linear programming model for easier solution. The linearization can be done under two oriented model perspectives (input or output). The linear programming CCR model with output-orientation is represented by:

$$\min q = \sum_{j=1}^{n} v_j x_{jo} \tag{4}$$

subject to

$$\sum_{i=1}^{m} u_i y_{io} = 1 \tag{5}$$

$$\sum_{i=1}^{m} u_i y_{jk} / \sum_{j=1}^{n} v_j x_{jk} \leq 1 \quad \text{for k = 1, 2.....z} \tag{6}$$

$$u_i, v_j \geq 0 \tag{7}$$

The y_{jk}, x_{jk} represent the outputs and inputs for the industry, respectively, while y_{io} and x_{jo} represent the outputs and inputs for a given DMU. The output and input virtual weights are represented by $u_i y_{jk}$ and $v_j x_{jk}$, respectively, for the k^{th} DMU.

Later, Banker, Charnes and Cooper (BCC) (1984) suggested that only DMUs with similar economic scale should be compared. They proposed an extension to the CCR model so that variable returns to scale (VRS) are considered. The output-oriented BCC model is formulated as follows:

$$max \sum_{r=1}^{s} U_r^k Y_{rk} + L_k \tag{8}$$

subject to

$$\sum_{i=1}^{m} V_i^k X_{ik} = 1 \tag{9}$$

$$\sum_{r=1}^{s} U_r^k Y_{rj} / \sum_{i=1}^{m} V_i^k X_{ij} + L_k \leq 1 \; for \; j = 1, \ldots, n \qquad (10)$$

This model adds a constant variable, L_k, to the weight output ($\sum_{r=1}^{s} U_r^k Y_{rk}$) in order to permit variable (decreasing or increasing) returns to scale.

Since DEA was introduced in 1978, a great variety of DEA applications have been used to compare the performance of many different kinds of entities, activities and contexts (Liu et al., 2013). The electricity sector, banking, sports, marketing and agriculture are just some of these application fields.

The DEA technique has been widely used in the healthcare sector, considering that the comparative performance of a health system is of considerable interest for public management. Different levels of DMUs have been compared, although micro-level analysis is far more common than macro-level analysis. Hollingsworth (2008) reviewed 317 references on frontier efficiency [5] in the context of health services delivery, concluding that analysis at the micro-level are far more common than macro-level analysis, with the hospital as the most common unit of analysis. The efficiency measurement at a macro-level is undertaken in fewer studies to evaluate the performance of healthcare systems. Table 1A presented in Appendix 1 summarizes the characteristics of ten studies that have used DEA to compare health system performance across several countries. In this table we identify, for each of these studies, the type and number of units compared, the orientation chosen for the DEA model, the inputs and outputs chosen for analysis and the environmental variables included in the model. An analysis of the information presented in this table allows us to conclude that most of these studies have compared a sample of OECD countries, including the data available for several input, output and environmental variables. Examples of these macro-level studies are: Färe et al. (1997) who compared the productivity growth of a sample of countries; Puig-Junoy (1998) who measured the health production performance;

[5] There are two categories of methods for assessing efficiency: the parametric models, including classical regressions based in averages and stochastic frontier analysis (SFA) that uses econometric techniques and imposes a priori the functional form for the frontier and the distribution of efficiency and the non-parametric models like DEA that relies on linear programming to obtain a benchmark of optimal cost and production-factor combinations.

Hollingsworth and Wildman (2003) who re-estimated the efficiency of health production of WHO panel data using parametric and non-parametric approaches to provide additional information; Retzlaff-Roberts et al. (2004) who analyzed the technical efficiency in the production of aggregated health outcomes; Bhat (2005) who examined the effects of various health care financing, regulatory and organizational designs on the efficiency of healthcare delivery systems; Afonso and Aubyn (2011) who assessed health efficiency across countries with a two-step and booststrap analysis and Hadad et al. (2013) who estimated healthcare system's efficiency and analyzed the impact of health determinants on the efficiency score. We will now discuss in greater detail the DEA applications that are of greatest relevance to our study in order to provide a summary of the state of the art in this area.

Although several studies have assessed the performance of healthcare systems, the assessment of the effectiveness of these systems has been very rare. Some exceptions include the studies by Schinnar et al. (1990) who estimate the organizational determinants of efficiency and effectiveness in mental health partial care programs and by Schinnar (1993) who investigated the tradeoffs between efficiency and effectiveness in management of public services and proposed effectiveness as a ratio of outcomes to service activities. For the latter author effectiveness is the ratio of outputs achieved to services provided in the second stage service production model. Amado and Dyson (2009) explored, in turn, the use of DEA for formative evaluation in primary diabetes care among English practices, taking into account different criteria for evaluation including technical, allocative and cost efficiency, clinical and patient-focused effectiveness, and equity. It is important to mention, however, that although no explicit reference is made to the effectiveness concept, there are several other studies that also assess the performance of healthcare systems through the use of outcome measures, such as infant mortality rates and life expectancy (e.g. Hadad et al., 2013; Afonso and Aubyn, 2011; Reatzlaff-Roberts et al., 2004 and Puig-Junoy, 1998).

To the best of our knowledge, a pioneering work on cross-countries healthcare system performance assessment was the one developed by Färe et al. (1997), which analyzed productivity growth for a sample of OECD countries from 1974 to 1989. These authors used DEA to estimate Malmquist productivity indexes and to decompose productivity growth into efficiency change and technical change. This study was developed using two models, the first model used intermediate outputs (days and discharges) and focused on the hospital sector, the second model used health outcomes (life expectancy and infant mortality rate) and focused on the health system.

Later Puig-Junoy (1998) also used health outcome variables (male and female life expectancy at birth) as outputs in his study of health production performance in the OECD countries by using an input-oriented DEA analysis. This study estimated technical efficiency and decomposed it into its components of pure technical efficiency and scale efficiency. The author introduced some weight restrictions to make the results of the analysis meaningful. In particular, the restrictions imposed that on the side of the inputs the weight assigned to physicians must not be in any case lower than that of non-physician personnel, and that on the side of the outputs the weight assigned to male life expectancy must not be greater than four times the weight of the variable female life expectancy. The author also used tobacco and alcohol consumption variables as life style proxies and a non-discretionary variable (the proportion of individuals under 65) as a proxy for age. The results from the study suggested that problems of inefficiency in the American and other healthcare systems may spring from allocative efficiency rather than technical efficiency.

The World Health Report 2000 (WHO, 2000b) presented a study developed by Evans et al. (2000) which used a panel data fixed effects models to estimate the technical efficiency and create a ranking of 191 countries. Hollingsworth and Wildman (2003) later reanalyzed the data with DEA (Malmquist productivity index) and Stochastic Frontier Analysis (SFA), having concluded that the league table presented in the World Health Report 2000 hided valuable information regarding efficiency changes over time. Furthermore, these authors emphasized that efficiency assessment is far more than ranking countries on a league table and that SFA and DEA techniques provide other useful information. The authors also alerted to the importance of sample stratification by GDP or geographical region. Alexander, Busch and Stringer (2003) took this suggestion into consideration on their efficiency assessment analysis of the healthcare systems of 51 developing countries by dividing the sample into two groups according to the countries' GDP per capita. One group included the countries with a

GDP per capita less than $1500, and the other the countries with a GDP per capita between $1500 and $4500 per annum and three outputs (male disability adjusted life expectancy, female disability adjusted life expectancy and the infant mortality rate) were used in the first stage of the analysis. On the second stage of the analysis the authors used a regression model and found that health expenditure, literacy among women, access to health care services and essential drugs are positively related to greater efficiency of the healthcare systems.

To expand the previous international healthcare systems comparison Retzlaff-Roberts et al. (2004) applied the DEA technique to explore the relationship between medical and social environmental inputs and health status outcome. The study implemented a comprehensive model including inputs regarding the social environment: school expectancy, the gini coefficient[6] and tobacco use. The justification presented by the authors to use these variables were that education has a special role on determining health and is also associated with higher income, which allows the population to get better access to health care, housing and nutrition. In addition, they point out that unequal income distribution has an important effect on population health, representing a greater social environment challenge for improving population health. Finally, they argue that tobacco use is also an important variable to include in the analysis as it provides a measure for the lifestyle and behavioral choices of the population. Their study includes both input and output oriented DEA models allowing policymakers from each country to choose what suits them best, that is decreasing inputs or increasing health outcomes. The authors found that a country can be technically efficient or inefficient in its use of resources at any level of health outcome, for example, Mexico was found to be efficient in its use of health resources although needed urgent improvement in health outcomes. The authors also conclude that the USA can substantially reduce inputs while maintaining the current level of life expectancy.

Afonso and Aubyn (2011) have also contributed to this area of knowledge by regressing DEA scores on a set of explanatory variables, with a two-stage DEA/Tobit

[6] Gini coefficient is a measure of the degree of income inequality in a country. The values rage from 0 to 1, and the higher the value is the greater the degree of inequality in the actual distribution of income (Retzlaff-Roberts et al, 2004).

and bootstrap procedures. In particular, they found that health inefficiency in OECD countries is related to GDP per capita, education level, obesity and smoking habits. In their work, in addition to the variables life expectancy and infant mortality rate they also used a transformation of PYLL as an output variable, which had been previously used in Afonso and Aubyn (2006).

The influence of non-discretionary variables on population health, that is variables over which policymakers have no or limited control, has been an important concern to researchers aiming to assess the performance of healthcare systems. Hadad et al. (2013) have explored this issue by estimating healthcare systems' efficiency using two DEA models, one incorporating mostly inputs considered to be within the discretionary control of the healthcare system, and the other including mostly inputs beyond the short-term discretionary control of the healthcare system. Based on the results of their DEA models, they analyzed whether institutional arrangements, population behavior and socioeconomic or environmental determinants were associated with the healthcare systems efficiency. The results of this study showed that healthcare systems in nine countries with large and stable economies were defined as efficient by one model but were found to be inefficient by the other model. Therefore, the authors concluded that health system efficiency should aim to impact population behavior and welfare rather than only ensure adequate medical care.

Santos et al. (2012) also used some non-discretionary variables in their analysis aimed at exploring the use of DEA to assess the efficiency of mother-to-child HIV prevention in low- and middle-income countries. The results indicated that there are considerable variations across countries in the efficiency of preventive services, and also that DEA can have a potentially strategic role to assist an efficient and effective planning in this context.

From the discussion presented above we can conclude that whilst DEA has already been applied to assess the performance of healthcare systems, to the best of our knowledge, no studies have been documented on the use of DEA to compare countries effectiveness in preventing and controlling NCDs. An important departure of our study from others is that, while previous studies have used aggregated health outcomes, ours focuses exclusively on outcomes related with the NCDs. This is a relevant contribution given that identifying the countries with best practices in this context can lead to meaningful learning regarding the most effective structures and processes associated with NCDs prevention and control.

Policymakers all over the world are concerned about the NCDs long-term macroeconomic impacts. However, research on the global economic effects of NCDs is still at an early stage (Bloom et al., 2011). The WHO (2011) refers that one of the three major components of NCDs surveillance is assessing health system capacity and response. Considering that our study aims to contribute to this assessment, it is timely and practically relevant. Its relevance is also reinforced by views expressed by the European Commission, which has pointed out that increasing the return on health investments requires a solid assessment of the efficiency and effectiveness of spending (Social Investment Package, 2013).

Whilst efficiency and effectiveness assessments in the health care context have been and will continue to be relevant, Spinks and Hollingsworth (2009) have pointed out a number of outstanding questions that limit the interpretation of the results and consequently their policy implications. Firstly, DEA assumes that the inputs that produce the health outputs are known with certainty. This assumption is unrealistic considering that there is great uncertainty about the set of inputs responsible for health production. Secondly, the DEA also assumes that inputs and outputs are isotonic, in other words, if the inputs increase the efficiency scores decrease and if the outputs increase the efficiency scores also increase. Thirdly, although the authors consider the OECD data base as one of the best cross-country sources of comparative data, some limitations still remain, such as: missing data; not all variables are collected regularly and no variables still exist to capture variations on genetics epidemiological which may influence the health outcomes within and between country comparisons. Considering these limitations, it is very important to exercise great caution when interpreting the results of health system performance cross-country comparisons.

Our review of the literature allows us, therefore, to conclude that whilst cross-country comparisons of the performance of healthcare systems are not new, there are not many studies carrying out this type of analysis. Furthermore, the few studies that exist tend to focus on high-level global health outcomes. To the best of our knowledge no study has been published documenting the effectiveness of nations in preventing and controlling NCDs, which are a leading cause of death worldwide and are a priority of many governments.

3. EMPIRICAL ANALYSIS

3.1. The DEA model

The choice of appropriate input and output variables is a fundamental step in DEA analysis. The focus of this paper is to evaluate the effectiveness of OECD countries in preventing and controlling NCDs, with special relevance to the four main chronic diseases: cardiovascular, cancer, diabetes and respiratory disease. In this respect, the outputs of the model we propose below were chosen in accordance with this goal.

Having into account the main goal of this study and the methodological principles discussed in the previous section, we decided to use an output-oriented model with six discretionary inputs, one non discretionary input and four outputs. The output-oriented model is the most appropriate since in this context it is preferable to maximize the health gains with the available resources, rather than keeping the health gains constant and minimizing the resources, as assumed in the input-oriented model.

To undertake the performance assessment on health system effectiveness with the DEA method some inputs have been used in most of the studies previously presented and seem to be widely accepted by the scientific community. In this respect, hospital beds, number of physicians, other health professionals, MRI units and total health expenditure represent some of those widely accepted inputs. On the other side, life expectancy and infant mortality are between the most commonly used outputs to assess health system efficiency. Researchers are aware that socioeconomic factors influence health outcomes. However, considering that these factors are beyond the direct control of the decision makers, they should be included as non-discretionary variables, wherein tobacco and alcohol consumption, income and education represent the more commonly non-discretionary variables used in this context. In the comparison undertaken in this study we have attempted to take into account all the methodological issues previously discussed. Furthermore, effectiveness measurement is especially complex due to the time lag between the inputs and the outcomes achieved. Also during this time lag, as it was discussed on the previous chapter, the outcomes tend to be influenced by several variables that aren't controlled by health services. In this sense, and for the reasons previously discussed, the results from comparisons of effectiveness across different health systems, although very important, should be interpreted cautiously.

The choice of inputs for this study follows what has been widely used in healthcare systems performance assessment with the DEA method. The prevention and control of NCDs in each country depends on access to the healthcare system (WHO, 2011). The first three inputs in our model, "Practicing doctors per 100000 population", "Practicing nurses per 100000 population" and "Hospital beds per 100000 population" are considered medical inputs to represent the access to healthcare, in consistency with the inputs included in several studies (Puig-Junoy, 1998; Retzlaff-Roberts et al., 2004; Afonso and Aubyn, 2011; Hadad et al., 2013). Access to the healthcare system is a first step to prevention and control of NCDs. We have also included the input variable "Magnetic resonance imaging units per 100000 population" and "Computed Tomography scanners per 100000 population" acknowledging the investment in and relevance of healthcare technology. These variables have also been broadly used in several studies in this field (Retzlaff-Roberts et al., 2004; Bhat, 2005; Afonso and Aubyn, 2011).

The sixth input is "Total current health expenditure per 100000 population (Million US$, Purchasing Power Parity[7])" used as an input to provide a measure of a country's preference for providing healthcare, (Mackenbach, 1991; Retzlaff-Roberts et al., 2004; Schwellnus, 2009; Spinks and Hollingsworth, 2009; Hadad et al., 2013). As Di Cesare et al. (2013) point out, this variable captures the financial and physical access to healthcare. The inclusion of this input is important because total spending in healthcare (at all levels) influences NCDs screening, diagnosis and treatment.

The prevention of premature mortality is a major goal, shared by the different health care organizations and countries, and is extensively discussed on NCDs action

[7] Purchasing Power Parities (PPP) are used to provide a comparable measure in the use of OECD data (Or, 2000).

plans (WHO, 2008). To capture the objective of avoiding premature deaths we considered the Potencial Years of Life Lost (PYLL)[8] because it represents the number of lives lost before the age of 70 and that could be, theoretically, prevented. This is an acceptable variable as a health outcome indicator (Or, 2000) and has been used in some international studies with the DEA method (Afonso and Aubyn, 2011). However, unlike the studies that assess the health system as a whole, which use other outputs like life expectancy or infant survival rate, in our study we have only focused on PYLL from NCDs. As a result, we have only included PYLL of the four main groups of NCDs as outputs, according to what was previously presented in chapter 2. However, in a DEA model the outputs should be defined in such a way that ‘more is better’. In this respect, these variables were inverted in order to accomplish this principle. The output variables included are of the type 1/PYLL, so that, the smaller the number of years of life lost, the greater is the output value. The first output, “1/Diseases of the circulatory system years lost per 100 000 population, aged 0-69 years old”, includes the two main causes of premature death worldwide, ischaemic heart disease and stroke. The second output is “1/ Neoplasms years lost, per 100 000 population, aged 0-69 years old”. The third output is “1/ Diabetes Mellitus years lost per 100 000 population, aged 0-69 years old” and finally, the fourth output is “1/ Diseases of the respiratory system years lost per 100 000 population, aged 0-69 years old”.

The socioeconomic pattern is known to have a relevant role on the level of population health. The most important NCDs behavioral risk factors are strongly influenced by income and education levels of the population, as several studies in this field suggest (Di Cesare et al., 2013; Hiscock et al., 2012; Pampel and Denney, 2011; McLaren, 2007; Kanjilal et al., 2006 and Monteiro et al., 2004). Therefore to capture the influence of these factors in our analysis we use the variable “Average number of years of education received by people aged 25 and older” as a proxy to education level, and as a non-discretionary input (Spinks and Hollingsworth, 2009; Afonso and Aubyn, 2011; Santos et al., 2012). Di Cesare et al. (2013) reinforce the education role arguing

8 Potential Years of Life Lost (PYLL) is a summary measure of premature mortality which provides an explicit way of weighting deaths occurring at younger ages, which are, a priori, preventable. 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 (70 years old). The details are described at OECD Health Data 2013, Definitions, Sources and Methods: Potential years of life years lost by ICD categories available at: http://stats.oecd.org/index.aspx?queryid=30124.

that preventive actions, such as screening for breast, cervical, colorectal, and prostate cancers increase with education level and income level. The GDP per capita is also widely used as a proxy for the income level (Hadad et al., 2013; Schwellnus, 2009; Spinks and Hollingsworth, 2009). However, in this study we chose not to include this variable because, in our sample, there is a high correlation (98.5%) between the GDP per capita and the total health care expenditure per 100000 inhabitants. Table 3.1.1 presents all inputs and outputs used in our DEA model.

Table 3.1.1: DEA model to assess effectiveness of NCDs prevention and control

Inputs	Outputs
Discretionary:	
Input 1: Practicing doctors per 100000 population	
Input 2: Practicing nurses per 100000 population	**Output 1:** 1/Diseases of the circulatory system years lost per 100 000 population, aged 0-69 years old
Input 3: Hospital beds per 100000 population	
Input 4: Magnetic resonance imaging units per 100000 population	**Output 2:** 1/ Neoplasms years lost, per 100 000 population, aged 0-69 years old
Input 5: Computed Tomography scanners per 100000 population	
Input 6: Total current health expenditure per 100000 population (US$, PPP)	**Output 3:** 1/ Diabetes Mellitus years lost per 100 000 population, aged 0-69 years old
Non-discretionary:	**Output 4**: 1/ Diseases of the respiratory system years lost per 100 000 population, aged 0-69 years old
Input 7: Average number of years of education received by people ages 25 and older	

3.2. Data and effectiveness results

The data used in this study refers to the activity of 27 OECD countries regarding NCDs prevention and control. The data refers to the year of 2009. In a minority of countries we had to use data from 2010 for some of the variables, due to non-availability of data for 2009. We had to exclude 7 of the 34 OECD countries because of lack of available data. The data collected was extracted from trustworthy sources, mainly from the OECD database but also from the United Nations Development Programme.

Table 3.2.1 presents the summary statistics for the variables used. This table reveals some significant discrepancies among the 27 OECD countries compared. For example, whilst the average number of doctors per hundred thousand inhabitants is 321, this number almost doubles to 613 in Greece, whilst in Korea it is much lower with 192 practicing doctors per hundred thousand inhabitants. The differences in the number of practicing nurses are also expressive among the countries, while Denmark, Belgium and Switzerland have more than 1500 practicing nurses per hundred thousand inhabitants, Mexico has the lowest number (109). The health expenditure also has an expressive variation, while Luxemburg is leading with almost 598 million US dollars per hundred thousand inhabitants followed by Switzerland (516 million), Mexico is at the bottom with 92 million, followed by Poland with 255 million. This variation is related with the country's GDP, conditioning the resources available for health investment.

Considering that there are remarkable variations at the level of inputs, it is not surprising that we also find significant variations at the level of outputs. While Luxemburg and Slovenia are the countries with the lowest numbers of years of life lost due to diabetes and respiratory system diseases, respectively, Mexico has the highest PYLL in both groups. Finland and Israel have the lowest losses due to neoplasm and circulatory system diseases, respectively, and on the other side we find Hungary leading the PYLL on these two fields.

Table 3.2.1 – Data used in the DEA model

Country	Practising doctors per 100000 population	Practising nurses per 100000 population	Beds per 100000 population	MRI units per 100000 population	CT scanners per 100000 population	Total health expenditure per 100000 population US$ PPP	Average number of years of education	1/PYLL due to Circulatory system diseases	1/PYLL due to Neoplasm	1/PYLL due to Diabetes	1/PYLL due to Respiratory system diseases
	Input 1	*Input 2*	*Input 3*	*Input 4*	*Input 5*	*Input 6*	*Input 7*	*Output 1*	*Output 2*	*Output 3*	*Output 4*
Australia	310	1014	376	0,57	3,90	357296354	12	0,00253	0,00124	0,02242	0,00983
Austria	468	761	766	1,84	2,93	409813431	10,6	0,00225	0,00107	0,01905	0,01258
Belgium	292	1510	651	1,07	1,32	387440733	10,8	0,00205	0,00101	0,03247	0,00691
Czech Republic	356	806	711	0,57	1,41	197422387	12,5	0,00121	0,00087	0,02155	0,00500
Denmark	348	1544	349	1,54	2,37	422557663	11,3	0,00233	0,00102	0,01406	0,00741
Estonia	327	613	535	0,75	1,49	131479684	12	0,00072	0,00085	0,01305	0,00512
Finland	271	958	625	1,57	2,04	308567342	10,2	0,00153	0,00136	0,02174	0,01196
France	310	845	666	0,64	1,11	381577787	10,4	0,00267	0,00089	0,03279	0,01250
Germany	364	1103	824	1,03	1,77	403457534	12,2	0,00184	0,00105	0,02667	0,00898
Greece	613	331	485	2,17	3,38	293084576	10,1	0,00138	0,00108	0,05988	0,00633
Hungary	302	621	714	0,28	0,72	153299461	11,6	0,00069	0,00052	0,01258	0,00409
Iceland	365	1454	373	2,19	3,45	359609692	10,3	0,00241	0,00120	0,04808	0,01364
Ireland	274	1526	327	1,19	1,53	388366019	11,6	0,00194	0,00102	0,03236	0,00953
Israel	346	473	335	0,20	0,94	193095893	11,9	0,00350	0,00125	0,01357	0,01067
Italy	368	630	363	2,12	3,13	288179464	10	0,00255	0,00108	0,02717	0,01490
Korea	192	447	821	1,88	3,68	180128762	11,5	0,00265	0,00113	0,01379	0,01401
Luxembourg	270	1112	547	1,41	2,61	597653582	10	0,00256	0,00119	0,09709	0,00840
Mexico	205	247	167	0,19	0,43	91599590	8,4	0,00132	0,00128	0,00154	0,00225
Netherlands	292	836	466	1,09	1,13	451193499	11,5	0,00241	0,00097	0,02513	0,00933
New Zealand	257	970	240	0,97	1,46	298378504	12,4	0,00195	0,00106	0,01471	0,00657
Poland	217	525	665	0,37	1,24	126353124	9,9	0,00082	0,00075	0,01805	0,00495
Portugal	382	565	335	0,92	2,74	254874175	7,6	0,00244	0,00092	0,01946	0,00675
Slovak Republic	299	603	651	0,61	1,33	194183465	11,6	0,00081	0,00076	0,02315	0,00325
Slovenia	241	802	460	0,69	1,18	229978138	11,7	0,00196	0,00088	0,04255	0,02083
Spain	354	493	319	1,07	1,50	299194552	10,2	0,00246	0,00101	0,04525	0,00747
Switzerland	383	1520	510	1,78	3,28	515662013	10,9	0,00300	0,00129	0,04566	0,01742
United Kingdom	271	997	334	0,59	0,82	326112005	9,3	0,00182	0,00108	0,03831	0,00539
Mean	321	863	504	1,09	1,96	305205905	10,8	0,00199	0,00103	0,02897	0,00911
Standar-deviation	85	386	185	0,62	1,02	124478971	1,2	0,00073	0,00019	0,01911	0,00448
Maximum	613	1544	824	2,19	3,90	597653582	12,5	0,00350	0,00136	0,09709	0,02083
Minimum	192	247	167	0,19	0,43	91599590	7,6	0,00069	0,00052	0,00154	0,00225

In order to assess each country's effectiveness, we used the Efficiency Measurement System (EMS) Version 1.3 software (Scheel, 2000) and an output-oriented DEA model. We have used the formulation proposed by Banker, Charnes and Cooper (1984), also known as the BCC model, in consistency with the advice of Hollingsworth and Smith (2003). In this publication, Hollingsworth and Smith (2003) warn that when ratio measures are included in the DEA model, the CCR model (Charnes et al, 1978) is technically incorrect and the BCC formulation (Banker et al., 1984) should be adopted. According to Hollingsworth and Smith (2003), the BCC formulation assures that comparison of the DMUs is made by interpolation only, ruling out unfeasible extrapolations.

We included seven weight restrictions in the effectiveness model, in order to ensure meaningful results and to account for production trade-offs between inputs and outputs (Podinovski, 2004). The weight restrictions included were the following:

$$W1 \geq W2 \qquad \text{(Restriction 1)}$$

$$W2 \geq W4 \qquad \text{(Restriction 2)}$$

$$W2 \geq W5 \qquad \text{(Restriction 3)}$$

$$W2 \geq W3 \qquad \text{(Restriction 4)}$$

$$W6 \geq W5 \qquad \text{(Restriction 5)}$$

$$W6 \geq W3 \qquad \text{(Restriction 6)}$$

$$W6 \geq W7 \qquad \text{(Restriction 7)}$$

Our main concern was to ensure meaningful results. In this respect, the restrictions aim to establish meaningful production trade-offs between the inputs and were defined according to Podinovsky (2004) methodology. The first restriction states that the weight attributed to the number of doctors cannot be inferior to the weight attributed to the number of nurses. We are assuming that, if necessary, the work carried out by a nurse could also be carried out by a doctor, but the reverse is not plausible. The inclusion of this restriction is in line with the study by Amado and Santos (2009) regarding performance assessment and improvement in primary health care. In our work this restriction is also relevant, taking into account that important skills, like prescribing medication or complementary diagnostic examinations, are essential to accomplish an important part of the ‘best buys’ defined by WHO (2011) and are exclusive to doctor’s skills.

The second and third restrictions state that the weigh attributed to the number of nurses cannot be inferior to the weight given to the number of MRI units and CT scanners, respectively. These restrictions assure that the health care professionals have more relevance to the control and prevention of the NCDs than complementary diagnostic examinations since those have to be prescribed, carried out and assessed by a health care professional. It is also widely recognized that human resources are a central and fundamental piece of health systems (Narasimhan et al., 2004; Hongoro and McPake, 2004; Dussault and Dubois, 2003).

The fourth restriction goes along with the arguments presented above. It states that the weight given to the number of nurses cannot be lower than the weight attributed to the number of hospital beds. In our study the number of hospital beds is a proxy for the infrastructures available that determine access to healthcare. In this respect, we argue that the weight attributed to this proxy should not be superior to the weight attributed to the number of doctors and the number of nurses, which are fundamental to achieve good results in NCDs prevention and control.

The last three restrictions are related to the relevance of the health care expenditure. Those restrictions state that the weigh given by each country to the health care expenditure cannot be inferior to the weights attributed to the number of CT scanners, hospital beds and the level of education received, respectively. Health care expenditure influences health care delivery trough the access to hospital beds, medical staff and new technology (OECD, 2011). Total health care expenditure is related to health outcomes and several studies have revealed that countries that spent little on health care also have poorer health conditions (Poullier et al., 2002; Farag et al., 2013). In other words, a higher country's health care expenditure is significantly associated with large improvements in health outcomes (Nixon and Ulmann, 2006).

Having justified the variables used in our model, we will now present and discuss the results obtained for our sample of 27 OECD countries. Table 3.2.2 presents the effectiveness scores obtained as a result of our analysis.

Table 3.2.2 – Effectiveness scores obtained with DEA

Country	Score (%)
Australia	96.43
Austria	83.34
Belgium	80.14
Czech Republic	74.90
Denmark	79.24
Estonia	83.79
Finland	100.00
France	91.01
Germany	79.62
Greece	100.00
Hungary	55.82
Iceland	100.00
Ireland	81.47
Israel	100.00
Italy	95.16
Korea	100.00
Luxembourg	100.00
Mexico	100.00
Netherlands	80.19
New Zealand	84.52
Poland	100.00
Portugal	81.60
Slovak Republic	72.85
Slovenia	100.00
Spain	100.00
Switzerland	100.00
United Kingdom	87.05
Mean	89.15
Standard-deviation	11.64
Maximum	100.00
Minimum	55.82

Table 3.2.2 reveals that 11 countries out of the 27 are classified as effective in preventing and controlling NCDs. The effective countries are: Finland, Greece, Iceland, Israel, Korea, Luxemburg, Mexico, Poland, Slovenia, Spain and Switzerland. The average score is of 89.15% and there are 5 countries with effectiveness scores under 80%: Czech Republic, Denmark, Germany, Slovak Republic and Hungary.

For a better understanding of the results obtained it is important to identify the optimal weight structure chosen by each country. The virtual weight profile can provide some useful information about the strategy followed in each country to prevent and control NCDs.

Table 3.2.3 – Virtual weight attributed to the variables by the countries

	Practising doctors per 100000 population	Practising nurses per 100000 population	Beds per 100000 population	MRI units per 100000 population	CT scanners per 100000 population	Total health expenditure per 100000 population US$ PPP	Average number of years of education	1/PYLL due to Circulatory system diseases	1/PYLL due to Neoplasm	1/PYLL due to Diabetes	1/PYLL due to Respiratory system diseases
	Input 1	*Input 2*	*Input 3*	*Input 4*	*Input 5*	*Input 6*	*Input 7*	*Output 1*	*Output 2*	*Output 3*	*Output 4*
Australia	1	0	0	0	0	0	0	0.14904	0.83661	0.01435	0
Austria	0	0	0	0	0	0.78	0.22	0.04704	0.65245	0	0.30051
Belgium	1	0	0	0	0	0	0	0.17884	0.80444	0.01672	0
Czech Republic	0.14117	0	0	0	0	0.85883	0	0.01517	0.73048	0.20232	0.05202
Denmark	1	0	0	0	0	0	0	0.12819	0.87181	0	0
Estonia	0	0	0	0	0	1	0	0	0.45831	0.50784	0.03384
Finland	1	0	0	0	0	0	0	0	0.90725	0	0.09275
France	0.81842	0.10726	0	0.0075	0.0066	0.04642	0.0138	0.65097	0	0.10022	0.24881
Germany	0.00012	0.00006	0	0.00001	0.00001	0.9998	0	0.07029	0.86761	0.0621	0
Greece	0	0	0	0	0	0.72686	0.27314	0	0	1	0
Hungary	0	0	0	0	0	1	0	0.09886	0.26792	0.63322	0
Iceland	0	0	0	0	0	0.762	0.238	0.04071	0.60209	0.19881	0.15838
Ireland	1	0	0	0	0	0	0	0.16238	0.78095	0.02161	0.03506
Israel	0	0	0	0	0	1	0	1	0,00000	0	0
Italy	0	0	0	0	0	0.72548	0.27452	0.04607	0.60072	0.04316	0.31005
Korea	1	0	0	0	0	0	0	0.00051	0.00293	0.95883	0.03773
Luxembourg	1	0	0	0	0	0	0	0	0	1	0
Mexico	0.63699	0.13766	0.03066	0	0.01732	0.08869	0.08868	0.67679	0.16966	0.03136	0.12219
Netherlands	1	0	0	0	0	0	0	0.20223	0.7466	0.01681	0.03436
New Zealand	1	0	0	0	0	0	0	0.16637	0.82622	0.00741	0
Poland	0	0	0	0	0	1	0	0	0	1	0
Portugal	0	0	0	0	0	0.75462	0.24538	0.64466	0	0.35534	0
Slovak Republic	0.06698	0	0	0	0	0.93302	0	0	0.32308	0.67692	0
Slovenia	0.17903	0.10704	0.02026	0.00841	0.01124	0.67401	0	0	0	0.56703	0.43297
Spain	0.00633	0.00158	0.00034	0	0.00034	0.72273	0.26868	0.44624	0	0.55376	0
Switzerland	0.55435	0.23528	0.00703	0.01061	0.00263	0.16693	0.02318	0.27576	0.32773	0.07725	0.31926
United Kingdom	0	0	0	0	0	0.76279	0.23721	0.03131	0.74327	0.19256	0.03286

Table 3.2.3 reveals that the virtual weights given to the four outputs differ across the countries. While some countries gave all the weight to one output, such as Greece, Israel, Luxemburg and Poland, other countries distributed the weight between two or more outputs. It is also interesting to see that those countries which attributed total weight to a single output are among the group of effective countries. However, it is important to emphasize that there may exist alternative optimal solutions for the input and output weights of the countries classified as best performers (Cooper, Ruiz and Sirvent, 2007). In this respect, it is possible that the attribution of more balanced weight profiles to these effective countries would continue showing them as effective. The remaining effective countries distributed the weight unequally between outputs. It is interesting to see that 13 countries put more than 50% of the weight in PYLL due to neoplasm diseases, although none of them put all the weight on this variable. The second output most valued was PYLL due to diabetes, with Greece, Luxemburg and Poland giving it the total weight. PYLL due to respiratory diseases was the output least valued by the countries, where Slovenia attributed the highest value (43.3%).

The optimal input weight profiles are presented in Table 3.2.3. However, to discuss these weights it is important to recall that some weight restrictions were imposed to ensure meaningful results. Unlike what happened in terms of the choice of virtual output weights, some of the non-effective countries attributed the totality of the weight to a single input, such as Australia, Belgium, Denmark, Estonia, Hungary, Ireland, Netherlands and New Zealand. In consistency with what was imposed in the weight restrictions, the number of practicing doctors and the total health expenditure were the two inputs which received a full weight in the evaluation of these non-effective countries. Among the countries classified as effective, there were 5 that attributed the full weight to one of the referred inputs, these countries were: Finland, Israel, Korea, Luxemburg and Poland. Greece and Iceland have a similar input weight profile, distributing their weight between total health expenditure and average level of education. In contrast, the remaining effective countries, Mexico, Slovenia, Spain and Switzerland present a balanced weight profile, distributing the weight between at least six inputs. It is also worth noticing that the environmental variable was chosen by 10 countries, assuming a relative weight between 22% and 27% in the majority of these countries.

Another interesting piece of information provided by DEA relates with the identification of benchmarks for each of the ineffective countries. Benchmarks are units that are classified as effective when applying the optimal weight structure of the ineffective units under analysis. As we can see in Table 3.2.4, Israel and Finland are the countries that could serve as benchmark to the highest number of ineffective countries. In the particular case of Finland, this country could be used as a reference to Australia, Austria, Belgium, Denmark, Germany, Ireland, Italy, Netherlands, New Zealand and United Kingdom. DEA results also identify from which countries the nations with poor effectiveness scores can learn with. For example, the two countries with the lowest scores, Hungary and Slovak Republic, can learn from Greece, Mexico, Poland and Slovenia. Also the Netherlands and New Zealand share as benchmarks Finland, Israel, Korea and Luxemburg. The appropriateness in the benchmarks identified by the model can be evaluated through a detailed analysis of the structures and processes of health care provision in each country. In specific, observing their weight profiles, it is clear that Hungary and Slovak Republic, in one hand, and the Netherlands and New Zealand, in the other, have many commonalities in their NCDs prevention and control policies.

In addition to the information regarding the benchmarks from which the ineffective countries can learn, Table 3.2.4 provides useful information to define the targets to be achieved by these countries. This information is contained in the lambda values displayed in each of the rows of table 3.2.4. For example, the values of the lambdas associated with Hungary (0.087; 0.253; 0.455 and 0.204) represent the proportion of the outcome levels of Greece, Mexico, Poland and Slovenia required if Hungary wants to achieve effective levels of PYLL in each of the four groups of NCD conditions.

Table 3.2.4 – Peers and lambdas

	Finland	Greece	Iceland	Israel	Korea	Luxembourg	Mexico	Poland	Slovenia	Spain	Switzerland
Australia	0.40719			0.50666		0.06986					0.01628
Austria	0.23198			0.1268	0.06015						0.58107
Belgium	0.31705			0.34277	0.04868	0.2915					
Czech Republic		0.3161	0.05112	0.06607		0.01504	0.44966		0.10202		
Denmark	0.17887			0.39609							0.42505
Estonia		0.03385					0.4537	0.36528	0.14717		
Finland											
France				0.39016	0.11068	0.13419			0.15683		0.20814
Germany	0.48346			0.04097		0.01385					0.46171
Greece											
Hungary		0.08737					0.25307	0.45522	0.20434		
Iceland											
Ireland	0.3498			0.13331	0.1926	0.24981					0.07447
Israel											
Italy	0.05346			0.24158	0.22658				0.27435		0.20403
Korea											
Luxembourg											
Mexico											
Netherlands	0.03703			0.45315	0.25929	0.18209					0.06845
New Zealand	0.45126			0.19204	0.35595	0.00075					
Poland											
Portugal		0.10382		0.70757					0.18861		
Slovak Republic		0.1894					0.33393	0.01485	0.46182		
Slovenia											
Spain											
Switzerland											
United Kingdom	0.02581		0.0246	0.10192		0.41429	0.43338				
Number of times country i used as a peer	**10**	**5**	**2**	**13**	**7**	**9**	**5**	**3**	**7**	**0**	**8**

Whilst some countries serve as a benchmark to a large number of countries, such as for example, Finland and Israel, others are classified as effective but serve as a reference for very few countries, like Iceland and Poland. And more peculiar is the case of Spain that is considered effective but that does not serve as a benchmark for any country, which may be a result of its atypical weight structure. Since there are countries such as Israel and Finland which serve as a benchmark to 13 and 10 countries, respectively, it is very important to understand their strategies, structures and processes in this field, in order to provide guidance for other countries.

3.3. The practical and policy implications of the results

The information obtained from the results previously presented shows that there is potential for countries to improve their policies on NCDs prevention and control, learning from the experiences of other countries. Improvements in this area could save many lives and avoid premature deaths. The results can constitute a valuable information source to policymakers, programme planners, managers and health care professionals. The aim of this study is not to establish ranks between the countries but to identify best practices on NCDs prevention and control, in order to develop strategies and policies that have the potential to make healthcare systems more effective in handling this type of diseases.

As a result of our analysis two countries appear as important benchmarks to other nations, Israel and Finland. These two countries, according to our DEA analysis, constitute a benchmark for 10 countries in common: Australia, Austria, Belgium, Denmark, Germany, Ireland, Italy, Netherlands, New Zealand and United Kingdom. However, Israel is also a benchmark to Czech Republic, France and Portugal. Nevertheless, these two countries appear to follow different strategies to prevent and control NCDs. Whilst Israel was the only country to put the full weight on cardiovascular diseases, Finland has a weight profile that indicates that it has valuable experience to share on Neoplasm’s prevention and control. Hereafter, we will discuss some of the strategies developed and implemented by these two countries which can be an inspiring model to some of the non-effective countries, especially to those to which they serve as a reference.

Israel is between the OECD countries with the lowest ischaemic heart disease mortality rate and in 2009 presented the lowest stroke mortality rate along with a low admission rate for uncontrolled diabetes (OECD, 2011). The actions taken on the modifiable risk factors have contributed to these health gains, for example, a notable decline in tobacco consumption and an improvement on the level of control on hypertension, both known as important modifiable risk factors for stroke (WHO, 2012). Israel also has one of the lowest rates of alcohol consumption across European countries, although this may also be related to culture and religious options. As discussed in the literature review section, diet is another important life style factor on cardiovascular diseases and Israel has remarkable results on fruit and vegetables consumption, being far above the European average and far above the average for the countries participating in the EPA-cardio programme[9] (Lieshout, Wensing and Grol, 2008).

Israel achievements on cardiovascular diseases outcomes is particularly related to the high standard of primary care and all the policies that have been implemented in the last decades in this field (Lieshout et al., 2008; OECD, 2012). In addition, Israel is one of the OECD countries with the lowest level of health care expenditure. Whilst most countries have increased their health care expenditure, Israel has built a high quality primary care under tight budgetary circumstances (OECD, 2012). The results obtained with our DEA analysis corroborate these reports. The optimal weight profile of Israel shows that this country benefited from putting all its input weight on total health care expenditure and all its output weight on cardiovascular diseases.

[9] EPA-cardio programme concerns an international study of cardiovascular risk management in primary care in 10 European countries. Its aim is to provide insight into the current services delivered in primary care to prevent cardiovascular diseases, as well as to inform and support primary care practices, national health policies and decision makers in this domain.

In this particular field, the success of Israel is based on an effective primary health care service delivery, which takes advantage of the proximity to the population to implement prevention strategies and control measures. According to the OECD (2012) report a distinctive aspect on Israel primary care is the fact that the medical teams are set on community-based health clinics allowing the person to access a broad range of health expertise and support, such as regular monitoring of a patient’s health indicators, delivering follow-up support and tailoring preventive advice to the specific needs of the communities. They also provide care 24 hours a day through telephone lines, evening care centers, urgent care centers and home visit services. The patients suffering from chronic diseases are likely to find a healthcare professional (doctor or nurse) working to help them monitor their health condition, such as measurement of blood pressure and blood glucose for those suffering from diabetes, also known as a major risk factor for cardiovascular diseases (WHO, 2012). Team working seems to have an important role in these achievements. OECD publications reinforce that even in countries like the United Kingdom, Australia and New Zealand, with strong primary health care history, professionals are not working as a team, with a large proportion of doctors continuing to work isolated. According to the OECD report on Israel health care delivery (OECD, 2012), it is well established that health care teams are a distinctive asset allowing community health clinics to support patient with chronic diseases with strategies such as follow-up after a visit, routine health screening and proving advice on improving lifestyle. Other strength in Israel service delivery relies on an effective technology platform which reminds health care professionals about which patients have not received a regular check-up. This platform also allows the collection of an extensive range of data integrated with the Quality Indicators in Community Health Care programme. This platform provides basic patient demographics and thirty five measures across six key areas that include cardiovascular health, allowing the identification of some risk factors, the monitoring of quality of care delivery, the monitoring of drug utilization and the measurement of selected treatment outcomes.

The second example of success in preventing and controlling NCDs is offered by Finland and, according to its weight profile, it seems that this country has developed some effective interventions on cancer prevention and control. As discussed in the literature review section, it is well established that smoking is a major risk factor for cancer, in particular for lung cancer (Danaei et al., 2005). Furthermore it is known that lung cancer presents the highest mortality rate among men worldwide (Lozano et al., 2012). Finland has one of the lowest lung cancer mortality rates (Ferlay et al., 2013) and also one of the lowest global cancer mortality rates in 2009 across the OECD countries (OECD, 2011). Behind these good health outcomes may be the strong investment in tobacco control and an extensive screening programme. According to the Tobacco Control Scale (TCS) 2010 in Europe, Finland is the 5th ranked country in TCS score taking in consideration our sample of countries and the 6th higher investor among the 31 European countries, investing 0.28€ per person in 2009 for tobacco control. However, it has not always been like this, and forty years ago Finland was between the highest consumers of tobacco products when it decided to implement policies to decrease the number of daily smokers. As a result of these policies, after achieving a pick in the 70s, the rates of lung cancer in males in Finland have been decreasing since then. Finland was a pioneer to stipulate in law that it aims to end the use of tobacco products containing compounds that are toxic to humans and create addiction. The path taken by this country shows that a significant decrease in smoking prevalence and premature deaths can be achieved through tax increases, a high-intensity media campaign complemented with encouragement and treatment cessation programmes, stronger health warnings and enforcement of youth access laws (Levy et al., 2012).

Observing the Eurobarometer on tobacco (European Commission, 2010), implementing legislative actions and health promotions campaigns can change the population behavior. According to the data revealed in Eurobarometer on tobacco, the Finnish are the least permissive of smoking inside the house and have tight legislation in public indoor smoking and this is also one of the countries in favor of banishing the advertising of tobacco products in points of sales. Today, in Finland, smoking is considered to be primarily a public health, social and political issue. Since 1995 that smoking was restricted by law in such a way that no employee can be exposed to tobacco smoke against a person’s will. Furthermore, the age limit for selling tobacco products increased to 18 years old and indirect tobacco advertising and sponsoring was forbidden Cancer Society of Finland (2013).

Finland also has the highest breast screening rate (over 80% according to OECD, 2011). This country established some strong screening policies in order to deal with this major disease. Population-based mass screening is considered a crucial part for cancer control according to Finnish authorities. Besides breast cancer screening also cervical and colorectal cancer screening are widely carried out. Finnish Cancer Registry maintains a database on the screenings to evaluate their programmes including quality standards. These two major strategies are recognized by Hurtado, Swift and Corrigan (2001) who defend that high quality health care in the case of cancer include effective screening and early diagnosis programmes.

These two countries have in common a primary care sector broadly developed, that seems to be a major factor for the results achieved by each country. These results go in line with the findings suggested by Macinko, Starfield and Shi (2003) who suggested that countries with larger proportion of primary health care services potentially have more efficient and effective health systems.

The results obtained with our study illustrate the potential of the DEA methodology to measure, analyze and promote improvement in the context of NCDs prevention and control. Using this technique, policymakers and health care managers can identify which countries have been most successful in this area. Further to the identification of best practices, DEA results can prompt policymakers and managers to study these systems' structures and processes with the intention of adapting them to the contexts of the countries that need improvement.

Although our empirical analysis covers a single year and focuses exclusively on a limited number of countries, the results obtained provide useful information for policy making by identifying best performers and discussing some of the policies that have proved successful in some of these best performers. Further exploratory analysis of this type can contribute to the improvement of NCDs prevention and control.

4. CONCLUSION

NCDs are the leading global cause of deaths, wherein cardiovascular diseases, cancer, chronic respiratory diseases and diabetes are the main NCDs responsible for more than 65.5% of all deaths worldwide. A substantial amount of the NCDs are attributable to behavioral, dietary, environmental and metabolic risk factors. The fact that a great percentage of premature deaths can be prevented has attracted the attention of decision makers to the importance of implementing affordable interventions to prevent, control and treat these diseases. In this context the WHO presented the 'best buy' interventions that the healthcare systems should target at the individuals that are at risk of developing or that already have NCDs. This epidemic also has a high socioeconomic impact since premature deaths and disability have a negative impact on the productivity and consequently on the development of a nation. The burden of NCDs also causes impoverishment of the families, raises the health care systems costs and contributes to economic decline.

In the academic literature there have been important contributions exploring the use of DEA to assess the efficiency of healthcare systems across-countries. However, most of these studies focused on the healthcare system a whole, using health outcomes such as life expectancy and infant mortality. No distinction was made on these studies to particular diseases. In this dissertation, we have explored the potential of using DEA to complement the existing literature in the area. In particular, we have focused on the effectiveness rather than on the efficiency of the countries in implementing prevention and control policies targeted at a particular type of diseases – the NCDs. To this effect, we used data for 27 OECD countries for the year 2009.

Despite the exploratory nature of this research, there are some empirical findings that we consider relevant. In particular we identified 5 OECD countries with considerable potential for improvement in this area. These countries are Czech Republic, Denmark, Germany, Slovak Republic and Hungary. Additionally, our post evaluation analysis also identified some valuable insights that can assist these and other countries to implement more effective NCDs prevention and control policies. In order for a proper set of guidelines to be drawn to assist performance improvement in this context, it would be valuable, however, to carry out more extensive assessments.

Although the use of DEA has potential in this context, its formative implementation faces some challenges. As many other authors have referred, the lack of availability of data and the poor quality of some of the data available is perhaps the most relevant challenge. More reliable and available data would allow, not only the development of more informative models, but also the development of dynamic assessments. Furthermore, if data was available this type of analysis could be extended to other countries, including low- and middle-income countries.

Another issue that requires further research is related with the development of weight restrictions in order to ensure meaningful results. Although several studies have been carried out in the health care context, research on how to express weight restrictions that are valid and derive from the preferences of the stakeholders is still scarce.

In spite of these challenges, we believe that the DEA technique can provide very valuable information to assist nations improve their performances regarding the prevention and control of NCDs.

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APPENDIX 1

Studies of healthcare system performance assessment using DEA

APPENDIX 1 – Table 1A - Studies of healthcare system performance assessment using DEA

Study	DMUs	DEA orientation	Inputs	Outputs	Environmental variables
Fare et al. (1997)	19 OECD countries	Input and output-oriented	1.Number of physicians 2.Number of medical care beds	Model I: 1.Inpatient days 2.Number of discharges Model II: 1. Life expectancy of women at age 40 2.Infant survival rate	
Puig-Junoy, J. (1998)	21 OECD countries	Input-oriented	1.Number of physicians 2.Number of nonphysician personnel 3. Number of hospital beds	1.Male life expectancy at birth 2.Female life expectancy at birth.	1.Tobacco consumption 2.Alcohol consumption 3.Proportion of individuals under 65
Hollingsworth and Wildman (2003)	140 WHO countries	Output-oriented	1.Health expenditure per capita (US$, PPP) 2.Average years of schooling in the adult population	1.Disability adjusted life expectancy	
Alexander et al. (2003)	51 developing countries	Output-oriented	1.Health expenditure per capita (US$, PPP)	1.Male disability adjusted life expectancy 2.Female disability adjusted life expectancy 3.Infant mortality subtracted from 1000	Variables used in Tobit regression: 1.Health expenditure 2.Female literacy rate 3.Proportion of the population regarded as undernourished 5.Coverage of measles immunization rate 6.Number of doctors 7.Proportion of the population with access to essential drugs 8.Proportion of the adults living with AIDS
Retzlaff-Roberts, D.(2004)	27 OECD countries	Input and output-oriented	1.Number of inpatient beds 2.Number of MRI units 3.Number of Physicians 4.Health expenditure (US$, PPP)	1a.Infant survival rate 1b.Life expectancy at birth (the outputs were used separately)	1.School expectancy 2.Gini coefficient 3.Tobacco use
Bhat, V.N. (2005)	24 OECD countries	Input-oriented	1.Number of physicians 2.Number of nurses 3.Number of inpatient beds 4.Volume of pharmaceuticals consumptions (US$, PPP)	1.Population aged 0–19 years 2.Population aged 20–64 3.Population aged 65 or old	

Table 1A – *Continued*

Study	DMUs	DEA orientation	Inputs	Outputs	Environmental variables
Spinks, J. & Hollingsworth, B. (2009)	28 OECD/WHO countries	Output-oriented	1.School expectancy years 2.Total unemployment rate 3.GDP per capita 3.Total health expenditure (US$, PPP)	OECD dataset: 1.Life expectancy at birth WHO dataset:1. Disability adjusted life years	
Afonso and Aubyn (2006 and 2011)	24 OECD countries	Output-oriented	1.Number of acute care beds 2.Number of MRI units 3.Number of physicians 4.Number of nurses	1.Life expectancy 2.Infant Survival Rate 3.Potencial Years of Life *Not* Lost	Non-discretionary variables used in DEA bootstrapping and Tobit regression: 1.GDP per capita 2.Education level 3.Tobacco consumption 4.Obesity
Santos et al. (2012)	52 low- and middle-income countries	Output-oriented	1.Prevention of mother-to-child HIV transmission domestic spending from public and international financing sources (million US$	1.Reported number of pregnant women tested for HIV 2.Number of pregnant women living with HIV who received antiretrovirals for preventing mother-to-child transmission 3.Reported number of infants born to women living with HIV receiving antiretrovirals for preventing mother-to-child transmission 4.Reported number of infants born to women living with HIV receiving co-trimoxazole prophylaxis within 2 months of birth	1.People aged 15 years and older who can, with understanding,both read and write 2.People living in urban areas 3.Total health expenditure (million US$) 4.Political stability and absence of violence/terrorism
Hadad, S.et al. (2013)	31 OECD countries	Output-oriented	Inputs model I: 1a.Number of physicians 2a.Number of inpatient beds Inputs model II: 1b.GDP per capita (US$, PPP) 2b.Consumption of fruit and vegetables per capita Model I and II: 3.Health expenditure per capita (US$, PPP)	1.Life expectancy at birth 2.Infant survival rate	Variables used in the regression models: 1.Fat intake 2.Public expenditure 3.Unemployment 4.Gini index 5.Environmental performance index