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Essays on Health Economics

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Abstract

Essays on Health Economics

This thesis provides a set of Health Economics Essays on the efficiency of health care provision and financing, with micro and macroeconomic perspectives. Chapter 1 investigates how hospitals react to a sudden change in their inputs, looking at the specific case of health professionals' strikes. Chapter 2 investigates pricing decisions of pharmaceutical firms following a change in the reference price system. Chapter 3 provides three macro applications on public health spending efficiency; on the relation between efficiency and HR skill-mix; and on the sustainability of the Portuguese NHS. Chapter 4 introduces a model to analyse public health spending sustainability.

Keywords: health professionals' strikes, reference price systems, public health spending efficiency, public health spending sustainability

To my grandparents

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Introduction

Health spending has been increasing in the last decades across developed economies. Although, different countries organize themselves differently in financing and providing health care to their populations, health spending tends to represent a significant share of their public expenditures. Thus, concerns exist regarding whether countries will be able to keep affording such health spending growth. Additionally, the quest for efficiency in health spending – particularly in public health spending – imply a proper understanding on how health care is produced, and on which policies contribute to better spending.

This dissertation provides four Health Economics applications related with public health efficiency and sustainability. The first two chapters offer two microeconomic empirical studies related with the role of labour input in the hospital production function, and with the impact of reimbursement schemes in the competitive dynamics of pharmaceutical firms, respectively. The last two chapters provide a macroeconomic perspective on public health spending, with an analysis on efficiency and a discussion on the sustainability challenges.

Chapter 1 provides an assessment on the impact of sudden changes of inputs in the hospital production function. Because health care is a labour intensive sector, health professionals play a key role in the hospital production function. In this chapter I analyse sudden changes to staffing levels on hospital activity and patient outcomes, by exploiting a set of strikes in the Portuguese NHS. I use a detailed patient-level dataset, comprising all NHS hospital admissions in mainland Portugal from 2012 to 2018. Additionally, I created a

strike dataset by combining and cross-checking multiple sources for hospital strikes (including reports from unions, media coverage and court rulings regarding strikes). The identifying strategy relies on comparing admissions exposed to strikes against admissions not exposed to strikes, after accounting for differences in the case-mix, hospitals, regions and, time. Patient selection, endogenous strikes or reverse causality are some of the concerns which I address throughout the chapter.

I detect a substantial decline on surgical admissions during strikes, even though no substantial evidence of patient selection is found. An overall decline on both inpatient and outpatient care admissions is also identified. Results suggest a modest increase in hospital mortality for patients admitted during physicians' strikes, and a slight reduction in mortality for patients already at the hospital when a strike takes place. Increases in readmission rates and length of stay are also found. Estimates reinforce the importance of health professionals' input on the hospital production function. Sudden and unplanned changes in the labour force have immediate and significant effects, suggesting that hospital structures are not very flexible nor very successful on avoiding declining outcomes following strikes.

Chapter 2 exploits the relation between pharmaceutical reimbursements and the competitive dynamics of pharmaceutical firms. In an effort to control public pharmaceutical expenditure, countries have been implementing reference pricing systems, which aim to increase competition among pharmaceutical firms, while reducing NHS co-payments. However, differentiated products and market power may shift the burden towards consumers. In this chapter, a policy change affecting prescribed drugs' reference prices is assessed. This policy aimed on increasing competition while inducing decreases in drug prices for a set of low competitive markets. A dataset for pharmacies monthly sales by product across regions was used, together with a pricing database. Results of a differences-in-differences analysis show that branded products (without patent protection) affected by the policy change increased their prices. Combined with lower reference

prices, this leads to an increase on the over-the-counter price paid by patients for both branded and generic drugs. Price changes were reflected on a decline on branded drugs consumption, with significant heterogeneity across regions and therapeutics.

Results suggest that reference pricing changes might have unexpected effects on prices, since pharmaceutical companies react strategically, transferring the burden to consumers. In this case, savings in NHS co-payments were mainly achieved through higher prices paid by patients – raising potential negative equity effects.

Chapter 3 presents a set of three macro-level applications regarding efficiency and sustainability of public health spending. The first application discusses the concept of public health spending efficiency. The health system has multiple goals which can be achieved with different types of health spending. An efficiency analysis is presented using both cost and production functions estimations. Results confirm that different health spending financing sources contribute differently to the numerous health system goals. Public health spending has a role on promoting access and providing financial protection to the population. Nonetheless, other forms of health spending also contribute to the general goals of the health system.

A second application expands such efficiency analysis and investigates how changes in health professionals' skill-mix can contribute to increase the overall efficiency of health spending. Such contribution might be relevant, considering that human resources represent a significant share of overall health spending. An aggregate production function is used, representing the broad features of health systems, to highlight the role of doctors and nurses. Estimates show that inefficiencies, in the sense of resources' waste, do not seem to be related with different nurses to doctor ratios.

Concerns regarding public health spending are related not only with efficiency considerations, but also with affordability issues. The last application on this chapter presents an analysis of the Portuguese NHS financial sustainability and a forecast for health spend-

ing growth. In this analysis, health spending financial sustainability is seen as a function of economic growth, and depends on the level of control of other public expenditures. Results show that under two alternative definitions – both related to fiscal space and compliance with sound public finances - public health spending growth is limited. Estimates suggest that annual public health spending growth should be kept below 3% to be considered as financially sustainable, in a context of modest economic growth.

Building on the previous application, chapter 4 discusses the issue of public health spending sustainability. I introduce a static model to highlight the main channels through which health affects the economy. In this model, health contributes directly both to the utility function (transforming life expectancy into an endogenous decision) and to the private good production function.

In this setting, sustainability concerns arise when health spending is financed by the government, which must respect a budget constraint. I relate the sustainability concept with fiscal space of public finances and with the crowding-out of other public expenditures.

The model suggests that increases on public health spending are not necessarily undesirable from a public finances' standpoint: the crowding-out of non-health public expenditures depends on the tax rate and coverage level of public health spending. Thus, economic growth is not a sufficient condition to achieve public health spending financial sustainability. Moreover, achieving financial sustainability by adjusting coverage levels might compromise ensuring the social sustainability of health systems. This chapter intends to be a contribution to the debate on whether current increases of health spending are sustainable over time.

Overall, I contribute to a better understanding on the channels affecting public health spending efficiency, and on the drivers determining its financial sustainability.

Chapter 1

The Impact of Hospital Strikes: Evidence from multiple strikes in the Portuguese National Health Service

Abstract

Hospital strikes in the Portuguese National Health Service (NHS) are becoming increasingly frequent. This paper analyses the effect of different health professionals' strikes (physicians, nurses, and diagnostic and therapeutic technicians - DTT) on patients' outcomes and hospital activity. Patient-level data, comprising all NHS hospital admissions in mainland Portugal from 2012 to 2018, is used together with a comprehensive strike dataset with almost 130 protests. Data suggests that hospital operations are partially disrupted during strikes, with sharp reductions in surgical admissions (up to 54%) and a decline on both inpatient and outpatient care admissions. The model controls for hospital characteristics, time and regional fixed effects, and case-mix changes. Results suggest a modest increase in hospital mortality for patients admitted during physicians' strikes, and a slight reduction in mortality for patients already at the hospital when a strike takes place. Increases in readmission rates and length of stay are also found. Results suggest that hospitals and legal minimum staffing levels defined during strikes are not flexible enough to accommodate sudden disruptions to staffing. Thus, quality of care during strikes should

be closely monitored, while minimum staffing levels should be reviewed.

1.1 Introduction

Hospital strikes are likely to disrupt and affect hospital operations. If such disruption is significant, one could hypothesize that patient care might also be compromised. In a context of rising healthcare costs, and increasing pressure from cost containment strategies, health workers' protests are probable to increase in developed health systems. A proper understanding on the impact of such protests is critical, as they are likely to affect the delivery of health services.

This paper provides an overall assessment of the impact of health workers' strikes on patients' outcomes and hospital activity. It uses patient-level data containing over 11 million hospital admissions and almost 130 different health workers' strikes in the Portuguese National Health Service (NHS) from 2012 to 2018. This study distinguishes between physicians, nurses, and diagnostic and therapeutic technicians (DTT) protests. The impact of strikes on health outcomes is estimated controlling for hospital heterogeneity, regional and time fixed-effects, as well as for changes in the case-mix.

A strike can be interpreted as a sudden, and sometimes unexpected, change in hospital staffing levels, which significantly affects the workload of non-striking health care workers. Such disruption of regular hospital operations might presumably affect patients. Typically, elective surgeries and doctor appointments are either cancelled or postponed. Also, several services in hospitals work at minimum capacity, with smaller teams. These changes can be expected to affect response times and service quality, which ultimately may have negative impacts on patients' outcomes.

Results suggest a decline on the number of admissions during strikes, with a sharp reduction on surgical activity. For instance, outpatient surgeries during physicians' strikes are

reduced by 54%. The paper finds that patients admitted during physicians' strikes have higher hospital mortality rates (5%). Patients already at the hospital when the strike takes place have lower mortality rates, even though they also display higher readmission rates. Estimates suggest that strikes severely disrupt hospital activities and that, in some cases, may result in a slight decline of health outcomes.

In the Portuguese NHS, health workers' strikes, particularly nurses' strikes, are becoming increasingly frequent. From a total of four strikes registered in 2011, health workers protests have increased to almost 50 in 2018. Such increase in protests is mostly explained by large dissatisfaction regarding careers and work conditions. This generalized dissatisfaction, and the inability of traditional unions to solve the problem, fuelled the creation of new, and arguably more radical, unions. These recent organizations have been driving most of the increase in strikes.

Strikes are typically very short, usually lasting for no more than one to three days. Still, these protests can paralyze some services such as elective surgery departments of major hospitals. Other departments such as Obstetrics and Gynaecology have also been severely disrupted during recent strikes. More recently, changes in strikes' financing schemes have also potentiated longer strikes - with greater impact. For instance, a crowd-funded five-week stoppage of 700 surgical nurses in the end of 2018 at five main NHS hospitals led to over ten thousand surgeries to be cancelled. A recent one-week strike in February 2019 resulted in almost two thousand surgeries cancelled.

Minimum staffing levels are established by a court before strikes to prevent strong negative impacts on patients. Nevertheless, some of these staffing levels allegedly failed to be ensured in some hospitals. This led the Portuguese Government, in February 2019, to enact a rarely used legal provision forcing nurses on strike to go back to work.

Media coverage on strikes is extensive, and public opinion tend to have extreme views regarding the strike itself. Nonetheless, literature on measuring and estimating strikes'

effects in the health sector is scarce. In this context, using a detailed dataset of strikes and NHS admissions, this paper analyses the impacts of such strikes on patients' outcomes, and hospital activity.

This paper focuses on assessing strikes' impacts on existing and newly admitted patients. It does not analyse the potentially long-term benefits from having the strike, neither the potentially long-run costs associated with cancelled or postponed procedures. The paper aims solely to quantify the impact of such protests on health outcomes, abstracting from the validity of the reasons that led to them.

The paper unfolds in the following way: the next section provides an overview of existing literature on healthcare strikes. Section 3 describes data sources and the empirical strategy. Section 4 studies how hospital admissions are affected by strikes. Section 5 investigates the impact of strikes on hospital discharges. Section 6 displays the impact of strikes on hospital mortality. Finally, the last section concludes.

1.2 Literature Review

In 1958, Bernard Karsh claimed that "the strike is among the most highly publicized and the least studied phenomena of our time" (Karsh, 1958). Although some research on healthcare strikes has been conducted since then, such longstanding claim remains still valid. This section discusses past research on hospital strikes. Particularly, given that much of the literature presents conflicting results, this section main goal is to highlight the key limitations of previous studies, which are addressed by this paper.

A strike in the healthcare sector can be thought as a severe disruption of hospital activity, increasing abruptly the workload for non-strike workers. Research shows that increasing workload on health workers have significant effects on hospital quality and patient outcomes. Aiken (2002) estimates that, after adjusting for patient and hospital character-

istics, an additional patient per nurse is associated with a 7% increase in mortality rates within 30 days of admission, and with a 23% increase in nurses' burnout. Such results are reinforced by Aiken et al. (2003), which suggests that higher nurse workloads are linked with increased mortality in surgical patients.

One may think that strikes are usually associated with provision of lower-quality care. However, regardless of strikes' impacts, health workers' unions may have positive effects on hospital outcomes. Register (1988) examines the effects of labour unions on the economic performance of hospitals. Results suggest that positive productivity effects occur in unionized hospitals. Similarly, Ash and Seago (2004) finds that, after controlling for patient and hospital characteristics, California hospitals with unionized nurses have lower heart attack mortality than non-unionized hospitals. Thus, even though some hospital administrators believe that recognizing a union might be a direct invitation to strikes (Metzger, Ferentino and Kruger, 1984), long-run benefits from unions in hospitals may arise.

Nevertheless, research is less clear regarding the effects of strikes on health systems. In the aftermath of the 1976 Los Angeles doctor slowdown, Wolfe (1979) predicted an increasing tendency to strike, given the emphasis on cost containing strategies in health systems. The author claims that "There is no extensive literature to measure the impact on health outcomes of strikes by either physicians, or by other health workers". However, despite this call for further research, concerns regarding measuring strikes' impacts on health outcomes are still present nowadays.

Such concerns with healthcare strikes are particularly relevant given the ethical and moral debate that surrounds the use of such negotiation tactics (Javed, 2016; Ketter, 1997; Neiman, 2011). Those concerns lead hospital administrators to carefully redesign hospital operations during strikes, in an effort to minimize disruptions and ensure proper healthcare for, at least, the most critical patients. Public health and medicine literature have studied the impact of some strikes on health outcomes. The review from Cunning-

ham et al. (2008) summarizes the impacts of five different strikes ranging from 1976 to 2003.

In January 1976 there was a one-month doctors' slowdown in Los Angeles hospitals. Several studies were conducted to measure the impact of the strike on health outcomes. James (1979) found that during the strike there was a 28% decrease in hospital admissions and a 42% decline in surgical procedures, compared to the same period in the previous year. However, the authors found that the population did not perceive any real difficulty in receiving medical care – which was consistent with the relatively stable trends on population mortality.

A similar study by Roemer and Schwartz (1979), found that the main impact of the strike was experienced on non-emergency surgery. Contradicting James (1979), the authors found that the decline in surgical activity was associated with a steady decline of mortality rates during the slowdown, rising abruptly to a peak in the first week that elective surgery was resumed. On a follow-up study, Roemer (1981) analysed actual death certificates to conclude that the sudden rise in mortality, following the 1976 doctor slowdown, was indeed due to postponed surgeries.

Nonetheless, despite such results, Slee and James (1980) argues that further research would be required to evaluate changes in patients and physicians' behaviour during strikes. Traveling to non-strike areas or changing criteria for recommending surgical care could be among the factors that would influence the results and were not accounted for on the original studies.

A second well-known doctors' strike happened in 1983 in Jerusalem. Hospitals were staffed only at 30% and all elective admissions were cancelled. However, despite the significant disruption on health services provision, Slater and Ever-Hadani (1983) finds no difference in deaths during strike and no-strike periods. Also, contradicting the results achieved by Roemer and Schwartz (1979), no sharp after-strike increase in mortality

was identified, despite the immediate resumption of elective surgery. However, Steinherz (1984) questions the validity of such estimates, as a substantial share of physicians that was theoretically enrolled in the strike ended up not participating – ensuring regular care and services.

Twenty years later, the Israeli strikes problematic was revisited after a doctor's protest in 2000. By comparing averages in funerals during the strike and off-strike, Siegel-Itzkovich (2000) finds an association between doctor strikes and a significant reduction of deaths. Again, a plausible explanation would be the temporary reduction in elective surgery.

Erceg, Kujundi and Babi (2003) analyses the impact of the 2003 physicians' strike in Croatia and fails to identify a significant change in population mortality rates during the strike. Similar results are achieved by Salazar et al. (2001), which analyses an emergency department strike of a Spanish hospital. Although no significant change in mortality is observed, fewer tests were ordered, and patients' length of stay was shortened.

Recent research by Ruiz, Bottle and Aylin (2013) analyses a 2012 doctor strike in England. Bhuiyan and Machowski (2012) examines the impact of a 20-day strike in a South-Africa Hospital. Results confirm that hospital operations are severely disrupted during strikes, given a decrease in elective admissions and surgery, and an increase in cancelled appointments. Contradicting previous research, Bhuiyan and Machowski (2012) finds that hospital mortality during the strike, when correlated with numbers of admissions, increases threefold.

Besides the impact of physicians' strikes there is also some research looking to the impact of nurses' strikes. However, strikes from other healthcare workers do not seem to be accounted for in the main literature. Belmin et al. (1992) finds no clear-cut increase in mortality following a nurses' strike in a French geriatric hospital. Different conclusions are reached by Stabler et al. (1984) when analysing a nurses' strike in a Canadian referral centre. Instead of comparing outcomes in different time periods, the authors compare

outcomes of a hospital subject to strike, with a nearby hospital that was not subject to it. They find that emergency admissions, severity of illness and mortality in the intensive care unit increase.

There is also literature relating health workers' strikes and infant care. A 1995 study by Mustard et al. (1995), describes the impact of a 31-day nurses' strike on the caesarean birth rate on Canada, by comparing the strike period with the pre-strike period. They find that the caesarean section rate in the strike interval was significantly lower than the pre-strike rate, and that the pooled incidence of adverse new-born outcomes was significantly higher during the strike period.

In a developing country, Friedman and Keats (2014) finds that babies born during strikes are less likely to have been born in health facilities, more likely to have been born at home, and more likely to have died within the first month. On a more recent paper, Friedman and Keats (2019) investigates child health outcomes for births that happened during a health worker strike in Kenya. They find a large immediate negative health impact that persists over time. Hirani, Sievertsen and Wüst (2019) uses health worker strikes in Denmark to identify the impact of nurse home visiting on infant and maternal health. They find an increase in GP appointments due to the lack of nurses' visits.

Most studies on strikes tend to conclude that mortality is reduced given a sharp reduction on elective surgery. However, they fail to acknowledge the potential increase in mortality for the remaining patients treated in strike days. This happens because some studies do not account for differences in hospital activity levels, nor for differences in patient composition. This problem might be particularly relevant when comparing strike periods with non-strike periods. It is possible that there are underlying differences between those periods, other than strikes.

Gruber and Kleiner (2012) overcomes some of these limitations. By controlling for changes in hospital characteristics and changes in patients' composition, they can sus-

tain provocative results, opposite to the vast majority of the literature. They analyse New York state nurses' strikes and use hospital-level data to find an increase of 18% in hospital mortality for patients admitted during strikes.

This paper builds on the empirical strategy followed by Gruber and Kleiner (2012) and expands it by using patient-level data with an extensive set of fixed effects. The paper innovates by introducing a large strike dataset, with over 100 different health strike records. Additionally, it looks not only into nurses' strikes, but it compares those with physicians' and DTTs' strikes. The pattern of strikes analysed is substantially different from previous studies, as most strikes are very short (1-2 days). Finally, instead of using hospital-level data, this paper exploits a comprehensive patient-level dataset. Such dataset contains all hospital admissions in the Portuguese NHS, which allows to carefully control for differences in hospital activities and across regions.

1.3 Data and empirical strategy

1.3.1 Admission data

This paper uses a dataset provided by ACSS (ACSS, 2019*a*), the Portuguese NHS central funding agency, comprising all NHS hospital admissions from 2012 to 2018. This excludes data on primary care units, private sector, emergency visits, and Portuguese autonomous regions (Azores and Madeira). Both inpatient and outpatient admissions are included, covering all public hospitals in mainland Portugal.

Portugal has a National Health Service based on universal access, and virtually-free of charge[1] at the user point. Citizens can also access healthcare from the private sector either through private health insurance, or by paying the full price directly to the provider. NHS

[1] Small co-payments are required to control for moral hazard, although almost 60% of the population is exempt from paying such charges.

agreements with the private sector might also occur for specific exams and procedures, or for patients with long waiting times. Still, in hospital care, private sector is small when compared to the NHS, and is focused mainly on large urban regions. In fact, in 2018 about three quarters of hospital spending was made on NHS hospitals (INE, 2019*a*). Thus, this dataset provides an accurate and detailed picture of hospital care at the National level.

The NHS operates in five Portuguese regions (North, Centre, Lisbon, Alentejo and Algarve), and employs over 130 thousand people, one third of which are nurses and one fourth doctors. In 2018, the NHS hospital care sector was a network of 90 hospital units structured in 46 hospital care centres. In a country with a population slightly above ten million, these hospitals were responsible, in 2018, for performing around 700 thousand surgeries, ensuring 12 million doctor appointments, managing 6 million emergency visits, as well as 800 thousand hospital admissions (ACSS, 2019*b*).

Our sample includes 11.5 million admissions episodes from 2012 to 2018, from which 57% refer to inpatient care and the remaining 43% to outpatient care. On average, each NHS hospital deals with almost 100 daily inpatient and outpatient care admissions. Length of stay is on average five days, with 80% of patients being discharged in less than one week. Over one third of admissions are urgent and referred by the emergency department. Also, roughly one third of patients are admitted to surgical services. Despite significant seasonality, particularly during Winter, average hospital mortality rate is below 3% (hospital admissions that resulted on the patient death while at the hospital). Urgent readmissions rate, within one month from previous discharge, is 5.3%. It is interesting to notice the existence of sharp asymmetries between North and South hospitals. Details on regional asymmetries (table 4.1), descriptive statistics (table 4.2) and variables distribution can be found in the appendix.

1.3.2 Strikes data

In addition to information on admissions, strikes' data was also collected. In Portugal, nurses have at least eight different unions, while doctors and DTTs have five each. Additionally, there are two major national unions' associations and 12 unions that represent public employees or workers from the health sector. Over 30 unions can organize a strike affecting the healthcare sector, representing close to 10% of the total number of unions' associations in Portugal (377 unions' associations registered in 2015 (MTSS, 2016)). Finally, five professional bodies regulate access to health-related professions.

Despite the large dispersion of unions, coverage rate for unionized workers in Portugal is low (8.3% in 2016 (MTSS, 2016)) and has been decreasing over time. The health sector is no exception, with union coverage of 9% (Portugal and Vilares, 2013). Despite such low representation, unions still have significant power on mobilizing workers and on launching strikes. Nonetheless, some strikes might not be the direct result of job dissatisfaction, but an opportunity to leverage health professionals' bargaining power. Thus, although strikes are not an exogenous phenomenon, they are also far from being an endogenous result from the institution struck – as national level politics and power struggles play an important role on the definition of such protests.

The multiple formats in which a strike can occur, as well as the multiple organizations that can call for such protests, make it difficult to register all information. An attempt was made by the Public Employment National Agency (DGAEP). Since 2011, unions are expected to submit their strikes' announcements to this entity. The announcement should contain the expected date for the protest, details on the motivation, and practical details on the strike. Courts should also establish mandatory staffing levels during strikes, to ensure appropriate responses for urgent and critical patients. Failure to comply with such minimum services can result in the cancellation of the strike, forcing employees back to work. Minimum services are usually similar to weekend or night shifts staffing levels -

without significant variation over time or across the country.

However, DGAEP data is subject to several concerns. Firstly, unions from outside the health sector can also call for strikes that affect healthcare (such as national strikes or public employees strikes). Secondly, the dataset comprises announcements of strikes which are cancelled given ongoing negotiations between the union and the employer. In such cases, even though the strike was scheduled, no health worker stoppage was verified. For the purpose of this paper, all strikes included must imply health professionals' absence from work. Finally, smaller strikes, usually at a local level, seem to be missing from the data.

After cleaning DGAEP records, cancelled strikes were excluded and additional strikes (not originally available in the platform) were added. A thorough investigation work was made, cross-checking strike records with information from media, hospital reports, courts and unions' statements. The final dataset contains a total of 127 strikes in the hospital care sector between 2012 and 2018. Over half of these strikes happened in 2016 and 2018. Table 4.3, available in the appendix, maps the evolution of hospital strikes across these years.

These 127 strikes had a total combined duration of 268 days. 56 strikes occurred at a national level and 71 were specific to a hospital, or a set of hospitals (table 1.1). More than two-thirds of strikes and strike-days were carried out by nurses. Protests in the healthcare sector are usually quite short, lasting on average for two days. Roughly 60% of strikes lasted only for one day, and more than 90% lasted for no more than three days. The largest strike happened in 2018 when surgical nurses were on strike for 40 days on specific hospitals. Typically, different health professionals' strikes do not occur simultaneously, except for public administration general strikes.

Table 1.1: Number of strikes and strike days in the NHS

	Physicians	Nurses	DTT	Total
		Number of strikes		
All strikes	13	87	27	127
National strikes	9	21	26	56
Local strikes	4	66	1	71
		Number of strike days		
All strikes	22	181	65	268
National strikes	16	40	64	120
Local strikes	6	141	1	148

Note: DTT stands for diagnostic and therapeutic technicians. National strikes are strikes affecting all hospital units simultaneously. Local strikes are strikes affecting only a subset of hospital units - typically a region or a single hospital.

1.3.3 Empirical strategy

This paper analyses health outcomes for admissions exposed to strikes relative to admissions not exposed to strikes. The paper's key analysis focus on inpatient care admissions, excluding extremely long hospital admissions[2]. An extensive set of controls is introduced to overcome most of the limitations identified in the literature. Namely, the model explicitly accounts for changes in the case-mix (addressing potential patient selection issues), as well as for differential trends across regions and over time. The paper main hypothesis is that patients exposed to strikes are likely to experience worse health outcomes, namely higher hospital mortality rates. The following model is estimated to test such hypothesis:

$$Y_{iht} = \alpha + \beta_P P_{iht} + \beta_N N_{iht} + \beta_D D_{iht} + \gamma X_{ith} + u_{iht}$$

The dependent variable, Y_{iht}, is a health variable representing a specific outcome. When looking at hospital mortality or readmission rates, this is a binary variable that takes the value one if admission i in hospital h at time t resulted in the patient death or readmission, respectively. Non-binary outcomes were also considered for robustness tests, such as length of stay, severity of illness, and risk of mortality indicators.

[2]Exclusion of long admissions (more than 30 days) is applied because long admissions are, by construction, more likely to be exposed to strikes, which would overestimate the strike impact. This issue is addressed in more detail in the next section.

Each model includes a variable to capture each type of health professionals' strike. P, N and D represent exposure to physicians', nurses' and DTT strikes, respectively. Each variable takes the value one if admission i was exposed to a particular health professional strike in hospital h at time t, and zero otherwise. β_P, β_N and β_D are the coefficients of interest, representing the impact of each type of strike on the outcome.

Three different specifications are considered. A broad specification defines exposure to strike if a strike occurs during the patient hospital stay. In the following models such approach is coded as ≪At anytime≫. A stricter specification defines exposure to strikes only for those patients admitted during a strike - a subset of the previous specification. In this case, the variable takes the value one if the admission day corresponds to one of the strike days. The following models code such approach as ≪On the admission day≫. A final specification focus on patients that were exposed to strikes after they were already admitted. This model is coded as ≪After the admission day≫.

Concerns regarding endogeneity and patient selection motivated the introduction of an extensive set of controls, captured by X_{iht}. The first set of controls comprises patient characteristics. Namely, models include a gender variable to control for potentially different outcomes depending on the patient's gender. A set of ten variables was introduced to represent each admission age group (in ten years intervals). An interaction variable between age and gender was also included to allow for different age effects depending on the patient's gender.

The second set of controls includes admission characteristics. Because urgent admissions are likely to be associated with lower health outcomes, a variable was included to control for whether each admission was urgent or not. Also, another variable was added to account for underlying differences between health outcomes of surgical versus medicine admissions. To further control for differences in the case-mix, the number of procedures and diagnoses per admission was also included. Additionally, fixed effects for the main diagnoses' categories were also introduced. These allow to control for different types of

patients admitted during strikes - accounting for potential patient selection. Failing to control for these effects, would result on overestimating the strike impact.

Hospital and regional fixed effects are also included to capture time-invariant effects specific to each hospital and region. Similarly, time fixed effects were also introduced at the year, month, week, and day of the week level. Finally, a full set of interactions of year with month and region fixed effects is introduced to account for any differential time trends by area.

A Linear Probability Model is employed to deal with the large volume of fixed effects and allow for an intuitive interpretation. Such identification strategy and estimation methods are close to Gruber and Kleiner (2012). However, rather than using hospital-level data, this paper uses a more detailed admission-level dataset. Identification hinges on the assumption that differences in outcomes of specific admissions, after controlling for differences in patient, hospitals and time, must be attributed to the existence of strikes. Nonetheless there are some concerns that can be raised regarding such approach. Such issues are addressed throughout the paper.

1.4 Hospital admission policy during strikes

1.4.1 Strikes and admission types

This section describes patients admitted during strikes - abstracting, for now, from the patients already at the hospital when the strike takes place. The goal is to understand if there are changes in the admissions' pattern during strike periods relative to non-strike periods. Each admission in the dataset was merged with strike information to determine patients' exposure.

Table 1.2 summarizes strike exposure indicators, considering the different specifications

discussed in the previous section. Over 9% of patients have been exposed to at least one strike day during their hospital stay, from which almost 4% were exposed on the day of their admission.

Table 1.2: Admissions exposure to strike from 2012 to 2018

	Number of admissions ('000)	Proportion of admissions (%)
Exposure to strike at anytime		
Any strike	1,077	9.36
Physicians strike	238	2.07
Nurses strike	554	4.82
DTTs strike	610	5.30
Exposure to strike on the admission day		
Any strike	444	3.86
Physicians strike	67	0.59
Nurses strike	171	1.48
DTTs strike	263	2.28
Exposure to strike after the admission day		
Any strike	656	5.70
Physicians strike	171	1.49
Nurses strike	383	3.33
DTTs strike	347	3.02

Note: DTT stands for diagnostic and therapeutic technicians. Adding Physicians, Nurses and DTTs strike exposure will not match exposure to "Any strike" since patients might have been exposed to more that one strike during their admission episode.

Variations in admissions during strikes relative to non-strike periods can reflect either a change in the hospital admission policy - signalling for instance stricter admission criteria - or changes in patient demand - suggesting that patients might be able to anticipate strikes. The possibility of patient selection during strikes needs to be addressed to prevent potential biased analysis. If, during a strike, hospitals refrain from admitting patients, one can hypothesize that patients admitted during a strike are different, possibly facing more severe conditions. Table 1.3 displays a comparison between inpatient and outpatient care admissions during and off strike periods. The upper panel reflects averages across all admissions for the whole period, while the bottom panel represents the average number of daily episodes per hospital.

Table 1.3: Inpatient and outpatient care admissions during and off strikes

	Inpatient care admissions				Outpatient care admissions			
	No strike	Physicians' strike	Nurses' strike	DTTs' strike	No strike	Physicians' strike	Nurses' strike	DTTs' strike
Averages across all admissions and all hospitals								
Age	53.5	53.3	53.8	54.1	59.8	61.2	61.1	61.1
	(27.1)	(27.4)	(27.2)	(27.1)	(18.5)	(16.3)	(17.1)	(17.9)
Females (%)	54.2	54.2	54.1	54.4	51.3	50.1	50.4	51.2
	(49.8)	(49.8)	(49.8)	(49.8)	(50.0)	(50.0)	(50.0)	(50.0)
Length of stay (days)	7.7	7.8	7.5	7.5	1.0	1.0	1.0	1.0
	(11.4)	(11.3)	(10.9)	(10.9)	(0.1)	(0.1)	(0.1)	(0.1)
Admissions longer than 30 days (%)	3.4	3.5	3.3	3.2	0.0	0.0	0.0	0.0
	(18.2)	(18.5)	(17.7)	(17.7)	(0.0)	(0.0)	(0.0)	(0.0)
Admissions longer than 15 days (%)	12.3	12.9	12.2	11.6	0.0	0.0	0.0	0.0
	(32.8)	(33.5)	(32.7)	(32.0)	(0.0)	(0.0)	(0.0)	(0.0)
Severity of illness (1-4)	1.5	1.5	1.5	1.5	1.4	1.5	1.5	1.4
	(0.8)	(0.8)	(0.8)	(0.8)	(0.5)	(0.5)	(0.5)	(0.5)
Risk of mortality (1-4)	1.6	1.6	1.6	1.6	1.2	1.2	1.2	1.2
	(0.8)	(0.8)	(0.8)	(0.8)	(0.4)	(0.4)	(0.4)	(0.4)
Urgent admissions (%)	61.1	64.5	64.1	60.0	0.0	0.0	0.0	0.0
	(48.7)	(47.9)	(48.0)	(49.0)	(0.0)	(0.0)	(0.0)	(0.0)
Surgical admissions (%)	32.3	25.9	23.9	29.8	39.4	20.1	25.6	40.6
	(46.7)	(43.8)	(42.7)	(45.8)	(48.9)	(40.1)	(43.6)	(49.1)
Births (%)	7.4	8.1	8.0	7.5	0.0	0.0	0.0	0.0
	(26.1)	(27.2)	(27.1)	(26.3)	(0.9)	(1.1)	(1.3)	(1.1)
Hospital transfers (%)	5.7	6.6	5.5	5.1	7.1	10.2	4.7	1.8
	(23.2)	(24.8)	(22.8)	(22.0)	(25.7)	(30.3)	(21.3)	(13.5)
Hospital mortality (%)	5.0	5.2	5.0	4.9	0.0	0.0	0.0	0.0
	(21.7)	(22.3)	(21.7)	(21.6)	(0.7)	(0.8)	(1.2)	(0.6)
Urgent readmission rate in 30 days (%)	8.3	8.7	7.9	6.5	1.5	1.3	1.7	1.4
	(27.6)	(28.1)	(27.0)	(24.6)	(12.1)	(11.5)	(12.9)	(11.9)
Urgent readmission rate in 15 days (%)	6.5	6.7	6.1	4.8	1.2	1.0	1.3	1.1
	(24.6)	(25.0)	(24.0)	(21.4)	(10.7)	(10.0)	(11.5)	(10.5)
Urgent readmission rate in 7 days (%)	4.9	5.1	4.6	3.4	0.8	0.6	0.9	0.7
	(21.6)	(22.0)	(20.9)	(18.1)	(8.7)	(7.5)	(9.4)	(8.5)
Observations	6,276,714	34,401	98,869	140,825	4,783,150	32,972	71,935	121,706
Daily average admissions per hospital								
Total admissions	56.4	50.7	46.5	49.2	53.6	52.0	38.0	46.7
	(52.6)	(45.5)	(49.2)	(47.2)	(56.2)	(60.5)	(39.4)	(43.7)
Urgent admissions	34.5	32.7	29.8	29.5	0.0	0.0	0.0	0.0
	(24.3)	(22.1)	(22.6)	(23.6)	(0.0)	(0.0)	(0.0)	(0.0)
Surgical admissions	18.2	13.1	11.1	14.7	21.2	10.5	9.7	19.0
	(18.1)	(12.4)	(11.9)	(14.6)	(20.2)	(12.3)	(12.8)	(19.1)
Births	4.2	4.1	3.7	3.7	0.0	0.0	0.0	0.0
	(4.0)	(3.7)	(4.0)	(4.0)	(0.1)	(0.1)	(0.1)	(0.1)
Hospital transfers	3.2	3.3	2.6	2.5	3.8	5.3	1.8	0.9
	(12.2)	(10.2)	(8.2)	(5.3)	(33.5)	(41.7)	(19.8)	(15.0)
Hospital deaths	2.8	2.6	2.3	2.4	0.0	0.0	0.0	0.0
	(2.5)	(2.2)	(2.3)	(2.4)	(0.1)	(0.1)	(0.1)	(0.1)
Urgent readmission in 30 days	4.7	4.4	3.7	3.2	0.8	0.7	0.7	0.7
	(4.4)	(4.1)	(3.9)	(3.6)	(1.9)	(1.1)	(1.6)	(1.6)
Urgent readmission in 15 days	3.7	3.4	2.9	2.4	0.6	0.5	0.5	0.5
	(3.6)	(3.4)	(3.3)	(2.8)	(1.8)	(0.9)	(1.5)	(1.4)
Urgent readmission in 7 days	2.8	2.6	2.1	1.7	0.4	0.3	0.3	0.3
	(3.0)	(2.9)	(2.7)	(2.2)	(1.7)	(0.6)	(1.4)	(1.3)
Observations	111,267	679	2,126	2,861	89,166	634	1,895	2,605

Note: Standard errors in parentheses. DTT stands for diagnostic and therapeutic technicians. Exposure to strike on the admission day. Transfers refer to transfer out of the hospital during the admission episode. Severity of illness (SOI) refers to the degree of loss of function or physiologic decompensation of an organ system. Risk of mortality (ROM) reflects the likelihood of dying. SOI and ROM are measured in a scale from 1 to 4 and are determined by an algorithm. The algorithm considers the principal and secondary diagnoses, age, presence of operating-room procedures, non-operating room procedures, and multiple operating-room procedures. Despite the influence of nearly all patient features, secondary diagnoses representing co-morbidities and complications are what typically drive SOI and ROM levels Souza et al. (2020). SOI and ROM data unavailable for 2012.

Inpatient care admissions (57% of total admissions) are usually longer and more complex episodes relative to outpatient care admissions. This is clear when looking to the average length of stay, but also to both severity of illness and risk of mortality indicators. On the other hand, outpatient care admissions are usually low-risk and planned - which explains why virtually no patient is admitted through the emergency department. Outpatient care admissions are characterized by the absence of hospital deaths, low readmission rates, lower mortality risk scores, and very short hospital stays (same-day discharges).

Daily total admissions fall during all types of strikes, both for inpatient and outpatient

care. This effect is particularly strong during nurses' strikes, where inpatient care admissions are reduced by 18%, while outpatient care admissions fall by almost 30%. Such result suggests that hospitals refrain from admitting patients during strikes. Also, surgical services seem to be significantly affected. For instance, daily admissions for outpatient care surgery decrease by 50% during physicians' strikes and by 54% during nurses' strikes. This is consistent with the hypothesis that, during strikes, elective surgery is typically cancelled or postponed. For inpatient care admissions, surgeries are also reduced during strikes by 28% and 39% for both physicians and nurses' strikes, respectively.

Hospital mortality rates for inpatient care admissions during physicians' strikes is 4% higher than in non-strike periods. However, given the decrease in admissions volume, the number of deaths during physicians' strikes is actually lower relative to non-strike periods. No significant effects are observed when looking into nurses or DTT's strikes.

Urgent readmission rates during physicians' strikes are also higher, while nurses' and DTT's strikes are typically associated with lower readmission rates. These results need to be carefully interpreted as no causal link is being claimed. Other factors might be driving these changes, such as the reduction in surgical services.

Interestingly, the proportion of births on inpatient care admission increases during strikes. As births are not easily rescheduled or anticipated, they still occur during strikes. For a lower volume of admissions, a similar number of births (4.2 daily births per hospital off-strike versus 4.1 during physicians strikes) results in a higher proportion of babies born.

By the same token, it can be noticed that during physicians and nurses' strikes, the proportion of urgent admissions, for inpatient care, increases. However, the daily number of urgent admissions decreases given the overall lower admissions level. Moreover, patients admitted during a strike do not seem significantly different from patients admitted in non-strike periods. Not only their age and gender are roughly the same, as severity and mortality risk indicators remain unchanged during strikes.

One can also compare the diagnostic categories of the admissions that occur during strikes and compare them with admissions that happen off-strike periods. Table 1.4 displays the top 10 main diagnostic categories for patients admitted during and off strike periods. The same table displays also more refined information, by listing the top 10 primary admission diagnoses.

Table 1.4: Frequent diagnoses during and off strikes

Exposure to strike on the admission day	No strike		Physicians' strike		Nurses' strike		DTTs' strike	
	Rank	%	Rank	%	Rank	%	Rank	%
Top 10 diagnostic category (2012-2018)								
Myeloproliferative DDs	1	24.39	1	36.28	1	29.92	1	24.99
DDs Kidney And Urinary Tract	2	8.46	2	8.68	2	10.21	2	8.45
DDs Eye	3	7.40	8	4.32	9	4.48	3	7.64
DDs Circulatory System	4	6.53	3	5.52	5	5.57	4	5.88
DDs Respiratory System	5	6.18	4	5.33	3	5.84	5	5.55
DDs Musculoskeletal System	6	5.83	6	4.44	6	4.89	6	5.51
DDs Digestive System	7	5.66	7	4.38	7	4.65	7	5.22
Pregnancy, Childbirth And Puerperium	8	4.77	5	4.83	4	5.58	8	4.80
DDs Ear, Nose, Mouth And Throat	9	4.41	10	3.57	10	3.96	9	4.49
DDs Skin, Subcutaneous Tissue and Breast	10	4.14	12	2.84	12	2.97	12	3.77
Top 10 diagnoses (DRGs) data (2013-2018)								
Chemotherapy	1	16.51	1	24.35	1	21.30	1	19.53
Eye procedures except on eye socket	2	7.55	3	4.70	4	4.17	2	7.20
Radiotherapy	3	5.31	2	6.35	2	7.11	3	4.12
Other kidney and urinary tract diagnoses	4	4.72	4	4.28	3	4.91	6	3.09
Normal newborn	5	3.44	5	3.54	5	3.84	4	3.24
Vaginal delivery	6	2.81	6	2.91	6	3.37	7	2.86
Pneumonia	7	2.24	10	1.90	8	1.94	9	1.85
Other ear, nose, mouth, throat and head diagnoses	8	1.42	8	2.05	9	1.89	10	1.57
Heart failure and shock	9	1.35	11	1.29	12	1.34	11	1.30
Other skin, breast and subcutaneous tissue disorders	10	1.32	16	1.05	16	0.96	12	1.16

Note: DDs stands for Diseases and Disorders. DTT stands for diagnostic and therapeutic technicians; No comparable DRG data available for 2012. Myeloproliferative disorders are an heterogeneous group of diseases characterized by cellular proliferation usually related to diseases of the bone marrow and blood. Percentages computed based on the total number of admissions recorded.

The top 10 major diagnostic categories for admissions exposed to strikes relative to admissions not exposed to strikes are virtually the same and its ranking remains very similar (table 1.4). There are two exceptions to this pattern. Firstly, during physicians and nurses' strikes, there is a reduction on the proportion of admissions with eye diseases and disorders. This is easily explained since over 96% of these admissions are outpatient surgical admissions which, as described above, decrease substantially during strikes. Secondly, during strikes, there is an increase on the proportion of pregnancy and childbirth admission. Again, this reinforces the previous result that the proportion of births increases during strikes.

Diagnoses related group (DRG) data shows no severe changes between non-strike and strike periods. Still, some changes can be identified. Chemotherapy and radiotherapy represent a higher proportion of admissions during strike periods. Conversely, surgical DRGs such as eye-related procedures, tend to fall during strikes.

Previous results suggest that patients admitted during strikes have similar characteristics to those admitted in other periods. Not only their individual characteristics are similar, but also their main diagnostic categories remain stable. The only difference identified is related with the overall reduction in surgical activity, steaming from the fact that surgeries are cancelled and postponed during strikes. Thus, no evidence is found that stricter admission criteria result in a significantly different pool of patients during strikes.

Moreover, even if that would not be the case, the statistical model used in the next sections to identify the impact of strikes has a set of variables specifically designed to capture potential case-mix changes. It includes a set of variables representing each of the main diagnostic categories, admission characteristics, information on the number of diagnostic and procedures by patient, as well as patient-specific information. These controls ensure that any change in mortality driven by case-mix changes is not attributed to the existence of a strike.

Since 2013, these controls have been used in a black-box algorithm to produce estimates on the expected risk of each admission. In particular, two indicators are estimated automatically following the recording of each admission: the Severity of Illness (SOI) and the Risk of Mortality (ROM) (Souza et al., 2020). An analysis of these indicators corroborates the previous conclusions. As described earlier by table 1.3, these indicators remain stable for patients admitted during a strike. Table 4.4, available in the appendix, pursues a stricter approach: it displays estimates on the impact of strikes on SOI and ROM indicators, with the full set of controls described in the empirical strategy section. No significant or persistent effects are found for any indicator (the exception being a small statistically significant positive impact of nurses' strike on ROM). These estimates reinforce the hy-

pothesis that strikes are not associated with the admission of more critically ill patients, or with the refusal of low-risk patients.

1.4.2 Anticipating strikes

Differences in admissions can reflect not only stricter hospital admission policies, but also changing behaviours from agents: patients could potentially anticipate strikes. This could induce changes in the case-mix, resulting in strikes' effects even before or after the actual strike takes place.

Consider the following example regarding the patient's decision to go to the emergency department. With an upcoming hospital strike, moderately ill patients may prefer to go earlier to the emergency department avoiding longer waiting times. This would lead to an increase in emergency department visits in the days prior to strikes. Conversely, during strikes, moderately ill patients might decide to postpone their visit to the emergency department, leading to an increase in visits in the days following strikes. A second example of such issue are visits to the emergency department in large metropolitan areas. During strikes, it is possible that some patients decide to go to private care facilities, avoiding public care facilities on strike. If this would be the case, then the private sector would be accommodating part of the strikes' impact, reducing the pressure on struck public hospitals. It would be interesting to analyse spill over effects from striking hospitals to non-striking hospitals using emergency department data. However, data used in this paper does not contain information on emergency department visits, nor private hospital records. Only admissions accepted through the emergency department are captured by data.

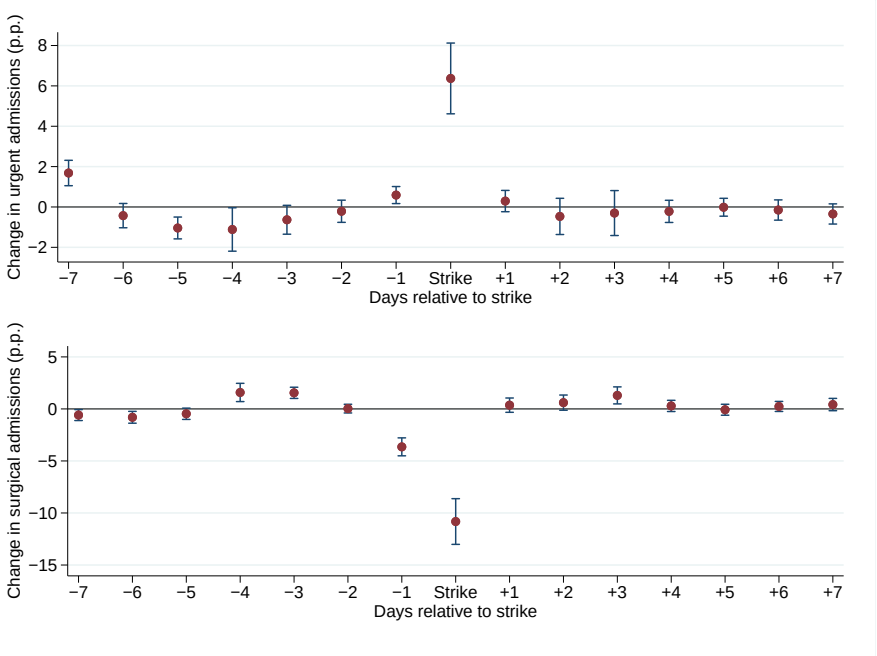
Patient anticipation is also limited by the institutional design of the Portuguese NHS: freedom of choice regarding hospital care is very low. A patient may decide to walk-in in any NHS emergency department. However, if the patient is transported by an ambulance,

its destination is decided by health authorities. These patients, usually the most complex cases, have no say on their preferred hospital. Additionally, for non-emergency care - such as doctor appointments, exams, or surgeries - the patient is assigned to her local area hospital. Even though some exceptions to this rule might occur, the patient is still not able to change her hospital in the event of an upcoming strike.

Nonetheless patients are not the only agents that can anticipate strikes. Hospitals can also adapt their operations given the threat of an upcoming strike. It may also be the case that strikes' effects persist following the end of strike – as restoring hospital operations might not be immediate. Figure 1.1 investigates the impact of physicians' strikes on the proportion of urgent (top panel) and surgical admissions (bottom panel), including controls for time differences, as well as permanent differences among hospitals and regions. Results support the suggestive evidence described previously. During physicians' strikes, the proportion of urgent admissions increases by more than 6 percentage points - even controlling for geographical and time factors. Results also suggest that anticipatory effects seem to be very small (only a small significant increase is observed in the day prior to the beginning of the strike). After the strike, hospital operations resume normal activity.

The bottom panel describes a severe decline on surgical activity during strikes. Controlling for time and locations, results suggest that the proportion of surgical admissions decline by more than 10 percentage points during strikes. Furthermore, such decline can already be identified in the day before the strike.

Figure 1.1: Change in urgent (top panel) and surgical (bottom panel) admissions for patients admitted during physicians' strikes



Note: Estimates for individual pooled data regressions on days around strikes. Includes controls for hospitals, regions, year, month, week, and day of the week. Standard errors clustered at the hospital level. 95% confidence level intervals displayed.

1.5 Hospital discharge policy during strikes

The previous section shows abrupt changes on urgent and surgical admissions. Still, no evidence of patient selection is found: patients admitted during strikes are not substantially different from patients admitted in other periods. This section explores the impact of strikes on discharges - namely their impact on patients' length of stay and readmission rates.

Length of stay can be affected through different channels. On one hand, if hospitals promote early discharges, this leads to shorter stays. On the other hand, if patients admitted during strikes face more serious conditions (although no evidence of such effect was found so far), length of stay could increase. Finally, if patients must wait longer for health

services provision during strikes, length of stay would also increase.

Table 1.5 describes the impact of hospital strikes on length of stay. Patients admitted during physicians' and nurses' strikes have longer admissions that patients not exposed to strikes. For these patients, the hypothesis of null impact of strikes on length of stay is rejected. Nonetheless the magnitude of such effect is very small (1% and 2% higher lengths of stay for physicians' and nurses' strikes, respectively). Modest changes in patients' length of stay are also identified when looking to patients discharged prior to the beginning of the strike, although the magnitude of such changes is also small.

Overall, estimates do not support the hypothesis that hospitals anticipate patients' discharges prior to the beginning of strikes. In fact, increases in the length of stay may contribute to prevent potential negative effects from strikes. Thus, increasing patients' length of stay can be a channel to prevent declining health outcomes during strikes.

Table 1.5: Impact of strikes on patients' length of stay

	Exposure to strike on the admission day	Discharged before the strike 1 day before
Physicians' strike	0.0102***	0.0267***
	(0.0032)	(0.0054)
Nurses' strike	0.0182***	0.0008
	(0.0041)	(0.0030)
DTTs' strike	-0.0035	-0.0183***
	(0.0030)	(0.0032)
Age x Female	0.0002**	0.0002***
	(0.0001)	(0.0001)
Female	-0.0097	-0.0097
	(0.0061)	(0.0061)
Surgical admission	0.2356***	0.2356***
	(0.0161)	(0.0161)
Urgent admission	0.3598***	0.3599***
	(0.0228)	(0.0228)
Number of diagnoses	0.0421***	0.0421***
	(0.0030)	(0.0030)
Number of procedures	0.0609***	0.0609***
	(0.0031)	(0.0031)
Observations	6,176,264	6,176,264

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the hospital level. Includes all inpatient care admissions from 2012 to 2018. Long admissions (more than 30 days) excluded. Female is equal to 1 if the admitted patient was a female, and equal to 0 otherwise. Surgical admission is equal to 1 if the admission was coded with a surgical DRG, and equal to 0 if the admission was a medicine DRG. Urgent admission is equal to 1 if the admission was coded as urgent, and equal to 0 otherwise. Each model includes the dummy variables for each of the 10 age groups, 26 diagnoses categories, 46 hospitals, 5 regions, year, month, week, weekday, and year-month-region.

A similar analysis can be conducted for readmission rates, as described by table 1.6. In this specification, the dependent variable takes the value one if the patient was readmitted in the days following her discharge. Such readmission is restricted on being urgent, which excludes all patients that return to the hospital for follow-up or regular care. The model compares readmission rates for patients exposed to strikes with patients not exposed to strikes - with the full set of controls described in section 3.

Table 1.6 describes the impact of strike exposure on 30- and 15-days urgent readmission rate. The table also displays the impact on readmission rates for patients that were not exposed to strikes but were rather discharged right before the beginning of the strike. This second section tests whether hospitals, as an anticipation to strikes, early-discharge

some patients - which could lead to future readmissions.

Estimates support the rejection of the hypothesis of no impact of strikes on readmission for patients already at the hospital during nurses' or DTTs' strikes. For instance, patients exposed to nurses' strikes after their admission have, on average, a 0.95 higher percentage point 30 days readmission rate - which translates to a 11% increase given the baseline readmission rate (8.3%). These results are compatible with the hypothesis of difficulties in the provision of care during strikes - even if length of stay increases. Again, hospitals do not exhibit persistent evidence of early discharges before strikes. Readmission rates for patients discharged before strikes have very small changes - both in terms of significance and magnitude. Looking at the 15-days urgent readmission rate does not change results substantially.

Table 1.6: Impact of strikes on patients' urgent readmission rates

	Exposure to strike			Discharged before the strike
	at anytime	on the admission day	after the admission day	1 day before
			30 Day readmission rate	
Physicians' strike	0.0024**	0.0020	0.0016	0.0034**
	(0.0010)	(0.0014)	(0.0011)	(0.0015)
Nurses' strike	0.0076***	-0.0010	0.0095***	-0.0006
	(0.0007)	(0.0011)	(0.0009)	(0.0009)
DTTs' strike	0.0095***	-0.0004	0.0110***	0.0002
	(0.0013)	(0.0011)	(0.0015)	(0.0013)
Age x Female	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Female	0.0035***	0.0035***	0.0035***	0.0036***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Surgical admission	-0.0112***	-0.0119***	-0.0121***	-0.0118***
	(0.0030)	(0.0030)	(0.0030)	(0.0031)
Urgent admission	0.0564***	0.0567***	0.0564***	0.0571***
	(0.0064)	(0.0064)	(0.0064)	(0.0065)
Number of diagnoses	0.0045***	0.0046***	0.0045***	0.0046***
	(0.0006)	(0.0006)	(0.0064)	(0.0006)
Number of procedures	-0.0018***	-0.0017***	-0.0018***	-0.0017***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
			15 Day readmission rate	
Physicians' strike	0.0008	0.0014	0.0001	0.0015
	(0.0010)	(0.0012)	(0.0010)	(0.0013)
Nurses' strike	0.0043***	-0.0007	0.0054***	-0.0008
	(0.0007)	(0.0010)	(0.0009)	(0.0007)
DTTs' strike	0.0069***	-0.0004	0.0081***	0.0008
	(0.0011)	(0.0011)	(0.0013)	(0.0012)
Age x Female	-0.0001***	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Female	0.0039***	0.0038***	0.0039***	0.0039***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Surgical admission	-0.0039	-0.0038	-0.0039	-0.0030
	(0.0028)	(0.0028)	(0.0028)	(0.0029)
Urgent admission	0.0463***	0.0465***	0.0463***	0.0468***
	(0.0064)	(0.0064)	(0.0064)	(0.0065)
Number of diagnoses	0.0030***	0.0030***	0.0030***	0.0030***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Number of procedures	-0.0015***	-0.0015***	-0.0015***	-0.0015***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Observations	6,176,264	6,176,264	6,176,264	6,176,264

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.

Notes: Standard errors in parentheses, clustered at the hospital level. Includes all inpatient care admissions from 2012 to 2018. Long admissions (more than 30 days) excluded. Female is equal to 1 if the admitted patient was a female, and equal to 0 otherwise. Surgical admission is equal to 1 if the admission was coded with a surgical DRG, and equal to 0 if the admission was a medicine DRG. Urgent admission is equal to 1 if the admission was coded as urgent, and equal to 0 otherwise. Each model includes the dummy variables for each of the 10 age groups, 26 diagnoses categories, 46 hospitals, 5 regions, year, month, week, weekday, and year-month-region.

1.6 Hospital mortality rates during strikes

1.6.1 Strikes and Hospital mortality

This section investigates changes in hospital mortality rates during strikes, which can be seen as a proxy for quality of care. Descriptive statistics suggest significant variability on mortality rates for patients exposed to strikes (table 1.7).

Table 1.7: Inpatient care mortality rates and strike exposure for inpatient care admissions

	All admissions			Admissions less than 30 days			Admissions less than 15 days		
Inpatient care admissions	Hospital mortality (%)	Observations	Change (%)	Hospital mortality (%)	Observations	Change (%)	Hospital mortality (%)	Observations	Change (%)
No strike	4.65	5,645,524		4.45	5,539,540		4.01	5,134,501	
	(21.05)			(20.62)			(19.62)		
Exposure to strike at anytime									
Physicians' strike	7.96	205,073	71	6.13	162,528	38	4.56	116,311	14
	(27.07)			(23.99)			(20.87)		
Nurses' strike	7.48	481,757	61	5.94	399,268	33	4.53	296,156	13
	(26.30)			(23.64)			(20.79)		
DTTs' strike	7.26	487,950	56	5.88	414,353	32	4.51	320,315	13
	(25.95)			(23.52)			(20.76)		
Exposure to strike on the admission day									
Physicians' strike	5.22	34,401	12	4.86	33,181	9	4.35	29,956	9
	(22.25)			(21.51)			(20.40)		
Nurses' strike	4.96	98,869	7	4.63	95,650	4	4.04	86,833	1
	(21.71)			(21.01)			(19.69)		
DTTs' strike	4.89	140,825	5	4.55	136,262	2	4.00	124,487	0
	(21.58)			(20.84)			(19.61)		
Exposed to strike after the admission day									
Physicians' strike	8.51	170,672	83	6.46	129,347	45	4.64	86,355	16
	(27.91)			(24.58)			(21.03)		
Nurses' strike	8.13	382,888	75	6.36	303,618	43	4.73	209,323	18
	(27.33)			(24.40)			(21.23)		
DTTs' strike	8.22	347,125	77	6.53	278,091	47	4.84	195,828	21
	(27.47)			(24.70)			(21.46)		

Notes: Standard errors in parentheses. Includes all inpatient care admissions from 2012 to 2018.

Inpatient care admissions not exposed to strikes have, on average, a hospital mortality rate of 4.65%. Regardless of the strike exposure measure chosen, mortality rates increase for patients exposed to any type of strike. The effect is particularly meaningful for patients already at the hospital when the strike takes place. For these patients, hospital mortality rate increases by at least 75%, depending on the type of strike. No causality on these results is being claimed, as there are other factors driving such estimates. Namely, sicker patients tend to have longer admissions and higher mortality rates. By construction, such patients are also more likely to have been exposed to a strike.

A way to circumvent the higher mortality associated with extremely long admissions is to eliminate these outliers. Table 1.7 computes mortality rates for admissions with less than 30 days and less than 15 days. For these subsets, there is still a noticeable increase in hospital mortality for patients exposed to strikes, although the magnitude is considerably lower than before.

As there are multiple competing factors that might account for part of the change in hospital mortality, a more formal approach is required. Table 1.8 displays estimations for the impact of strikes in hospital mortality, based on the model described in the third section. Inpatient care admissions from 2012 to 2018 are included in this model. To avoid the long admission bias on mortality, such admissions (more than 30 days) are excluded.

Three models are presented, one for each strike exposure indicator. For each model, the coefficient of the impact of each strike on hospital mortality is displayed. All models include standard errors clustered at the hospital level, as well as a full set of controls. The hypothesis underlying such models is that patients at the hospital (either existing patients or new ones) might be affected by low staffing levels during strikes. Such low staffing levels could result in lower quantity or lower quality of care provided. Ultimately, in extreme situations, such under provision of care could lead to the patient death.

Table 1.8: Impact of strikes on patients' hospital mortality

	Exposure to strike		
	at anytime	on the admission day	after the admission day
Physicians' strike	-0.0049***	0.0025**	-0.0060***
	(0.0010)	(0.0012)	(0.0011)
Nurses' strike	-0.0095***	0.0003	-0.0115***
	(0.0009)	(0.0007)	(0.0011)
DTTs' strike	-0.0090***	-0.0007	-0.0098***
	(0.0012)	(0.0007)	(0.0013)
Age x Female	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)
Female	0.0031***	0.0031***	0.0031
	(0.0007)	(0.0007)	(0.0007)
Surgical admission	-0.0194***	-0.0195***	-0.0193***
	(0.0027)	(0.0027)	(0.0027)
Urgent admission	0.0172***	0.0168***	0.0172***
	(0.0026)	(0.0026)	(0.0026)
Number of diagnoses	0.0074***	0.0074***	0.0074***
	(0.0006)	(0.0006)	(0.0006)
Number of procedures	0.0039***	0.0038***	0.0039***
	(0.0004)	(0.0004)	(0.0004)
Observations	6,176,264	6,176,264	6,176,264

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the hospital level. Includes all inpatient care admissions from 2012 to 2018. Long admissions (more than 30 days) excluded. Female is equal to 1 if the admitted patient was a female, and equal to 0 otherwise. Surgical admission is equal to 1 if the admission was coded with a surgical DRG, and equal to 0 if the admission was a medicine DRG. Urgent admission is equal to 1 if the admission was coded as urgent, and equal to 0 otherwise. Each model includes the dummy variables for each of the 10 age groups, 26 diagnoses categories, 46 hospitals, 5 regions, year, month, week, weekday and year-month-region.

Estimates suggest that the impact of strikes on hospital mortality is modest and asymmetric. Patients already at the hospital when the strike takes place have lower hospital mortality rates, compared to patients not exposed to strikes. This effect is common to all types of health professional' strikes - although its impact is small.

The effect differs when looking at patients admitted during physicians' strikes. These patients have higher hospital mortality rates, with an estimated impact of 0.25 percentage points. Hence, hospital mortality rate increases from its baseline (5.0%) to 5.3%. Such increase corresponds to a 5% increase on the probability of death. Despite being statistically significant, the overall effect is also relatively small.

Even though any health professional strike disrupts hospital teams, only physicians' strikes seem to have a negative impact on hospital mortality for newly admitted patients. This result might be related to the inadequacy of the current minimum staffing levels enforced by courts during strikes. By contrast, strikes do not negatively impact hospital mortality for patients already at the hospital. To some extent, estimates suggest that patients with an existing treatment plan (already at the hospital) are not negatively affected by strikes, at least in the short run. In fact, the model suggests that these patients' mortality rates are lower than patients not exposed to strikes. The absence of such plan, for patients admitted during physicians' strikes might contribute to explain the increase on hospital mortality.

The effects described above reflect, to some extent, changes in the quality of care experienced by these patients. These might be related with other factors such as length of stay and readmission rates - as described in the previous section.

1.6.2 Endogenous strikes?

Regardless of the controls introduced in the model, there is still a concern that might impact estimates: the possibility that strikes might be endogenous. If this is accurate, then reverse causality may arise, as worse health outcomes can motivate strikes. Therefore, results could be overestimating its impact since part of the increase in mortality could be causing the strike itself. Hence, it is particularly interesting to analyse how outcomes change, not only during the strike itself, but also on the periods immediately before and after it.

For local strikes, mortality rates were compared for hospitals subject to strikes with nearby hospitals not subject to strikes. No evidence of aggravating conditions for exposed hospitals prior the beginning of the strike was found. Take for instance Braga Hospital during a physicians' strike. Figure 4.7 (in appendix) displays mortality rates for patients admitted one month before and one month after the strike at Braga Hospital, as well as of nearby

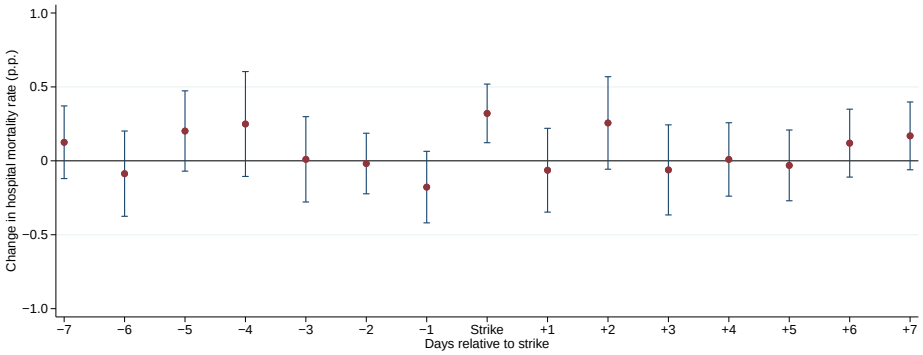
hospitals. Mortality trends before and after Braga's strike seem similar to the ones observed in nearby hospitals. The exception occurs during the strike itself. In fact, Braga Hospital has a 5.5% mortality rate for patients admitted during strikes, versus a 3.3% mortality rate on other periods. Nearby hospitals have, on average, a 4.3% mortality rate - which remains constant during the physicians' strike at Braga. Absolute number of deaths reinforces such results - mortality at Braga during strike increases almost five times more than in nearby hospitals.

Despite the usefulness of visual inspection, a more formal approach is pursued to analyse differences in hospital mortality for all hospitals around physicians' strikes periods. Figure 1.2 displays regression coefficients and respective 95% confidence intervals for the days around strikes. Regressions control for admissions and patients' characteristics, as well as for regions and time. Each point in the plot represents the change in hospital mortality for patients admitted to the hospital on a particular day. The plot displays the impact of strikes on hospital mortality in the week preceding the beginning of the strike, and in the week following its end were estimated.

No exogenous deterioration of quality was identified, although some fluctuations in mortality can be observed. In particular, no persistent increase in mortality rates is observed in the days before the strike. The only statistically significant change in hospital mortality occurs during the strike itself. This suggests that the hypothesis of no impact on hospital mortality during physicians' strikes is rejected.

As mentioned before, strikes are usually related with wage conditions and with relative unions' political capital. In the short run, both factors are not likely to affect hospital's outcomes significantly. Together with the aforementioned evidence, the assumption that strikes are exogenous to hospitals' outputs seems plausible.

Figure 1.2: Change in hospital mortality rate for patients admitted during physicians' strikes



Note: Estimates for individual pooled data regressions on days around strikes. Each model includes the following controls: age groups, gender, age x gender, surgical admissions, urgent admissions, hospital, region, year, month, week, and weekday. Standard errors clustered at the hospital level. 95% confidence level intervals displayed.

The impact from hospital strikes on health outcomes, namely on mortality, can be different depending on specific hospitals or diagnoses. Although heterogeneity is not the focus of this paper, some analysis is conducted in the appendix to disentangle such effects. Results suggest that the mortality increase for patients admitted during physicians' strikes is more significant for longer and severe admissions.

1.7 Conclusion

Hospitals are highly dependent on their workforce to deliver high-quality care to their patients. Hospitals may have some degree of flexibility to accommodate expected or small staffing level fluctuations. This happens in a daily basis given scheduled holidays, sick leaves, among other reasons. However, larger disruptions to staffing levels are harder to be accommodated by hospitals. In fact, sudden and unexpected disruptions to staffing levels are likely to disturb hospital operations. Depending on the magnitude of the event, patients and health outcomes might be impacted.

Strikes are amongst the most disruptive events which are likely to affect hospitals. They might be associated with worse health outcomes, such as surgical complications, urgent readmissions, or even higher mortality rates. Although healthcare strikes are controversial, little understanding exists regarding their true impact on patients' health outcomes.

This paper analyses the effect of different types of strikes on patient outcomes. Namely, it studies the effect of physicians, nurses and DTTs' strikes on mortality rates, readmission rates and length of stay. It expands current literature by comparing the impact of different health professionals on several outcomes, making use of a detailed patient-level dataset with an extensive set of controls, and by leveraging a robust strike dataset with almost 130 different records.

Information on strikes was carefully collected and merged with admission data for the Portuguese NHS between 2012 and 2018. A Linear Probability Model was used to analyse the impact of strike exposure on health outcomes, particularly on hospital mortality. An extensive set of controls and fixed effects was introduced to isolate the strike impact. These included variables to capture differences in patient characteristics, differences in hospitals' operations levels, as well as regional and time fixed effects.

Results suggest that hospital operations are severely disrupted with the existence of strikes. Such disruption is particularly clear during physicians' strikes, given a crowding-out on hospital admissions and an increase in urgent patients' proportion. Moreover, all types of strikes are followed by a sharp reduction on surgical admissions. For instance, during physicians' and nurses' strikes, surgical activity in outpatient services drops by 50% and 54%, respectively. To some extent, such results were expected and suggest that hospitals delay non-essential activity. As health professionals' teams are disrupted, more complex and team-based activities, such as surgeries, are particularly affected by strikes.

Overall, estimates suggest that exposure to physicians' strikes on admission increases mortality by 5%. Despite being statistically significant, such estimate is rather modest

considering the baseline mortality rate. Additionally, there is no evidence of significant estimates on hospital mortality for patients admitted during other types of strikes. The impact on hospital mortality is smaller than the one estimated by Gruber and Kleiner (2012) for a nurse strike in New York. Additionally, patients already at the hospital when the strike takes place have lower mortality rates. This may be related with institutional features and strike characteristics. In fact, strikes analysed in this paper are very short and frequent. To some extent, hospitals adapt and learn how to react and accommodate frequent strikes. Moreover, shorter strikes are likely to have smaller disruptions than longer protests.

Estimates do not support the hypothesis that hospitals anticipate patients' discharges prior to the beginning of strikes. When looking to length of stay, estimates suggest that patients exposed to strikes may have slightly longer stays. A possible interpretation for these results is that longer length of stay can be mitigating adverse effects from strikes. If this is true, then length of stay can be seen as a channel to compensate a temporary disruption on staffing levels.

Still, readmission rates estimates are higher for patients exposed to nurses or DTTs' strikes after their admission. Note that the impact of strikes can be reflected in factors other than mortality rates - namely lower quality of care. This quality of care will often not be captured by the type of administrative data this paper uses, and it should be investigated in further research.

All estimates derived are short-run results. This paper, given data constraints, does not analyse the long run effect of strikes on health outcomes. In the long-run, strikes could have two opposite effects. Firstly, postponed, or cancelled admissions/ procedures may lead to the future admission of sicker patients – with worse health outcomes. Secondly, strikes trigger the implementation of positive change in the organization. New policies implemented after the strike can lead to an improvement of overall quality.

Regardless of the long-term consequences, results show that in the short-run hospitals are negatively affected by the existence of strikes. In a context of cost-containment policies it is expected that tension between health professionals and management continues to increase. Nonetheless, the negative effects of such protests should be considered. On one hand, unions could consider alternative ways of protesting before starting a strike. On the other hand, hospital managers and governments should pursue active negotiations with unions to prevent strikes from happening. More importantly, results suggest that minimum staffing levels set during strikes - particularly for physicians - might not be enough to prevent a modest decline on health outcomes. The sudden change in staffing levels during strikes is too large to avoid negative impacts on health care provision, even if extending patients' length of stay.

Chapter 2

Pharmaceutical pricing dynamics in a reference price system: Evidence from changing drugs' co-payments [1]

Abstract

Reference price regimes for prescription drugs are usually implemented with the aim of curbing public expenditure with pharmaceuticals, induce drug substitution from branded to generics drugs and enhance competition. In these systems, patients co-pay the difference between the drug's pharmacy retail price and the reimbursement level. Relying on a detailed product-level panel dataset of prescription drugs sold in Portuguese retail pharmacies, from 2016 to 2019, we evaluate pharmaceutical firms pricing decisions for branded and generic drugs, as well as consumers' reaction to price changes. In particular, we exploit the variation induced by a policy change, which decreased reference prices for 36% of the equivalent-drug groups in our sample.

Results of a difference-in-differences analysis show that, despite the reference price decrease, affected firms increased their prices - particularly for off-patent branded products. Such reaction from firms results in an increase in the price paid by patients. Such price

[1] Co-authored by Carolina Santos, PhD candidate in Economics from Nova School of Business and Economics

effects resulted on a 16% decline on branded drugs consumption, with significant heterogeneity across regions and therapeutics.

Estimates suggest that NHS co-payments savings were mainly achieved through higher out-of-pocket payments paid by patients. Additionally, pharmaceutical firms' reaction to the reference price decrease was contrary to what was expected, suggesting underlying competitive dynamics which should be considered prior to policy changes.

2.1 Introduction

Rising health spending poses concerns to policy makers all over developed economies. Within health spending, particular concern exists with rising of pharmaceutical spending, often attributed to innovation and rising prices. Contrary to many markets, in the pharmaceutical market the relation between the pharmaceutical company and the customer is not direct. In fact, such relation is mediated and influenced by the physician, the pharmacy and by the insurance/ health system. The physician decides on which drugs the patient should consume, the pharmacy makes those drugs available to the patient, and the insurance firm, or the health system, establish a co-payment for that specific prescription. Additionally, the dynamics of pharmaceutical companies are also not standard. Some groups of medicines are subject to forceful competition (for instance, groups with many generic drugs available), while others are relatively protected from competition (for instance, due to patents or to the absence of similar generic drugs). Hence, the concern with public health spending together with the complexity of the pharmaceutical markets has led countries to implement sophisticated pricing reimbursement schemes.

This paper aims to analyse pharmaceutical firms' pricing decisions, in a reference pricing context. In such framework, patients co-pay the difference between the pharmaceutical firm's price and the reimbursement level made by the insurer/ NHS. Such reimbursement is determined based on a reference price, which in turn depends on the prices of equivalent drugs (from a clinical standpoint). These systems aim to foster competition among drugs and incentivize patients to choose the cheapest option. Ultimately, this system would result in lower pharmaceutical spending from the insurer/ NHS.

We evaluate the impact of reference prices on the firms' strategic pricing decision, in a setting of differentiated products (branded and generic). Using the Portuguese reference price system as an example, we exploit a policy change which decreased reference prices for a subset of products. In this context, such policy change affects the Portuguese NHS

expenditure, through a reduction in reimbursements.

If pharmaceutical firms' prices would remain constant, a lower reference price would imply a lower reimbursement made by the NHS. This would in turn increase the price paid by the patient - which could trigger consumption effects such as drugs substitution, or an overall decline in consumption. Thus, unless pharmaceutical companies bear some of its impact, any savings obtained by NHS would be reflected in higher out-of-pocket expenditure from patients.

Firm's decision on its prices depends on the competitive environment. There are some characteristics which might affect firms' optimal price setting. Firstly, these markets are characterized by some degree of consumer loyalty - which is likely to be reflected in relatively inelastic demands. Secondly, demand inducement might play a role since physicians and pharmacists - which work as agents for their patients - may advise them to adhere to specific drugs. Thirdly, consumers might not perceive generics and branded drugs as perfect substitutes and see them as differentiated products instead. Finally, price transparency and the fact the firms interact with each other on many markets, may influence the competitive environment, thus affecting pricing decisions.

Difference-in-differences analysis is used to study the firms' pricing decision and consumers' reaction. Drugs whose reference price was affected by the policy change are considered to be in the treatment group, while drugs whose reference price was not affected are assigned to the control group. The policy was not randomly implemented, as it targeted groups with lower competition. Such approach has some limitations arising from the fact that firms can react strategically to avoid being affected by the policy change. We discuss such concerns in detail and present additional robustness analysis.

Results suggest that, contrary to what was expected, firms do not adjust their prices downwards as a reaction to the new, lower, reference price. In fact, given an overall declining trend on drug prices, drugs affected by the policy are the ones with smaller declines -

particularly on branded drugs. Thus, the policy change is fully reflected on the consumer. We found negative and significant effects on consumption. Also, affected groups had an increase in the number of competitors in the equivalent drug group. Significant heterogeneous effects are found across regions and different therapeutics. These results suggest that NHS savings were also achieved at the expense of higher out-of-pocket expenditure - raising potential concerns regarding equity. Estimates suggest underlying competitive dynamics which need to be considered before implementing policy changes.

The paper unfolds in the following way: the next section provides an overview of existing literature on drug prices dynamics and patients' reactions. Section 3 outlines a brief stylized model to describe the main mechanisms on prices and consumption. Section 4 describes data sources, the empirical strategy and provides relevant background. Section 5 studies how changes in co-payments affected drugs' prices. Section 6 investigates the impact of the policy on drugs' consumption. Section 7 displays an extensive analysis on heterogeneous effects, particularly by looking to regional asymmetries across the country. Finally, the last section concludes.

2.2 Literature Review

Reference pricing in pharmaceutical markets is a system that groups drugs according to some equivalence criteria (chemical, pharmacological or therapeutic). Reference pricing is different from international price referencing. Under a reference pricing system, a third-party payer reimburses at most the reference price (RP) defined, which is the same for all drugs belonging to a given group. When the drug chosen by the patient exceeds the reimbursement, either the patient or the insurer pays the difference. Reference pricing was first implemented in Germany in 1989 and since then it has been put into effect in several other countries with the aim of curbing public expenditure with prescription drugs (López-Casasnovas and Puig-Junoy, 2000). Reference pricing intends to reduce the price of drugs under the umbrella of this mechanism by inducing patients to shift away from the consumption of highly-priced drugs to relatively cheaper ones (demand-side approach) as well as by encouraging producers to reduce prices in an attempt to secure their market shares (supply-side approach) (López-Casasnovas and Puig-Junoy, 2000). Across countries, reference pricing mechanisms differ widely in terms of equivalence level and criteria, the rule determining the reference price level and on the inclusion of patented drugs, which hampers the possibility of comparing the market outcomes of distinct reference pricing systems (Puig-Junoy, 2005).

The theoretical literature on reference pricing tends to evaluate this system relative to a pure coinsurance scenario (Brekke, Grasdal and Holmås, 2009; Brekke, Königbauer and Straume, 2007; Ferrándiz, 2001) or to a base scenario where the co-payment includes a fixed component and a variable one, determined by a coinsurance rate (Brekke, Holmas and Straume, 2011). These studies show that drugs with prices exceeding the RP suffer a decrease in their prices after the implementation of the reference pricing policy. If the reference pricing regime is compared to a scenario in which drug prices are directly regulated through price caps, and if these caps are not very strict, then reference pricing also

leads to lower generic prices (Brekke, Grasdal and Holmås, 2009; Brekke, Königbauer and Straume, 2007; Brekke, Holmas and Straume, 2011). Ferrándiz (2001) analysed how the introduction of reference pricing in a horizontally differentiated duopoly where producers compete à la Bertrand would affect equilibrium prices, relative to a setting in which patients paid a fixed share of drugs' prices. Ferrándiz (2001) concluded that if the RP is within a certain interval, then both the branded drug and generic drug prices are lower in the reference pricing scheme. The two producers, however, behave differently in face of an increase in the RP: the branded good producer has an incentive to increase its price as the RP increases, while the generic producer has an incentive to decrease its price as the reference price increases (Ferrándiz, 2001).

Whilst Ferrándiz (2001) and Brekke, Königbauer and Straume (2007) analysed situations where the RP is exogenously determined, Miraldo (2009), Brekke, Grasdal and Holmås (2009) and Brekke, Holmas and Straume (2011) addressed cases in which the RP is endogenous, in the sense that it is a function of the prices practiced by the firms in the market. Brekke, Holmas and Straume (2011) considered the case of a vertically differentiated duopoly and assumed that the endogenous RP corresponds to a weighted average of the generic and branded drug prices and concluded that, in such system, a decrease in the RP leads to a decrease in both prices. This contrasts with the finding that with exogenous RP a reduction in the RP brings about a reduction (increase) in the price of the branded (generic) drug (Brekke, Holmas and Straume, 2011). Miraldo (2009) analysed two endogenous RP rules - RP as a weighted average of practiced prices and RP as the minimum observed price – and concluded that total and out-of-pocket expenditures are higher under the minimum reference pricing policy.

Most of the literature defends that reference pricing induces competition in the market of prescription drugs by increasing demand elasticity and by fostering branded drug producers to price more aggressively. Brekke, Canta and Straume (2016), however, claim that reference pricing can be anti-competitive. Indeed, by resorting to a Salop-type model in

which the producer of a branded drug competes with various generic producers, Brekke, Canta and Straume (2016) showed that the decrease in the price of the branded drugs prompted by reference pricing curtails the expected profits of potential generic producers from entering the market. As a result, after accounting for the entry decision by generic producers, the effect of reference pricing on drug prices is ambiguous. There are empirical studies showing reference pricing deters generic entry in Spain (Moreno-Torres, Puig-Junoy and Borrell, 2009), while it fosters generic entry in Norway (Brekke, Canta and Straume, 2015). In a recent study, Granlund and Bergman (2018) evaluated the role of competition in the Swedish reference pricing system and found that an increase in the number of firms producing generics with equal strength, form and comparable package size decreases the price of generics and branded drugs.

The last review on reference pricing and its effects on pharmaceutical markets (Galizzi, Ghislandi and Miraldo, 2011) indicates that most empirical studies developed to that date relied on "before and after" evaluations, in which a treated group is followed in the period preceding as well as in the period ensuing the implementation of reference pricing. These studies preclude conclusions on the causal effect of reference pricing on market outcomes, as they are unable to isolate the effect of reference pricing from other policies as well as from social and economic factors influencing pharmaceutical expenditures. Galizzi, Ghislandi and Miraldo (2011) identified only seven empirical studies implementing a difference-in-differences methodology. A solid result from these studies is that reference pricing decreases the prices of prescription drugs. Indeed, from this pool of studies, only Puig-Junoy (2007) arrives at ambiguous results.

More recently, the empirical literature has focused on the evaluation of different designs of reference pricing systems. Kaiser et al. (2014) showed that a change from external RP (based on drug prices of a selected group of countries) to internal RP (grounded on domestic drug prices) in Denmark was responsible for sizable decreases in retail prices, reference prices and patient co-payments. Herr and Suppliet (2017) investigated the effect

of adopting tiered co-payments in the German reference pricing system. In the tiered co-payment regime, drugs priced below the co-payment exemption level are free from co-payments. According to Herr and Suppliet (2017), the new system brought about a decrease in generic prices and an increase in the prices of branded drugs.

Most empirical studies on reference pricing tend to focus on a restricted number of therapeutic, pharmacological, or chemical subgroups or on specific chemical substances, which hampers the external validity of the results. Pavcnik (2002) analysed the therapeutic groups of antidiabetics and antiulcerants for Germany. Grootendorst and Stewart (2006) studied the group of antihypertensive drugs for British Columbia, Canada. Ghislandi, Armeni and Jommi (2013), who evaluated the impact of RP in Italy, investigated four therapeutic subgroups acting on the cardiovascular system, as well as drugs for acid related disorders and psychoanaleptics, which comprise antidepressants. The chemical group of statins used to reduce high blood cholesterol was examined by Puig-Junoy (2007) for Spain, by Stargardt (2010) for Germany and by Kaiser et al. (2014) for Denmark. Brekke, Grasdal and Holmås (2009) and Brekke, Holmas and Straume (2011) examined, respectively, the 30 and 40 chemical substances with largest sales volume in Norway. More recently, empirical papers on reference pricing have started to encompass a greater number of prescription drugs (Brekke, Canta and Straume, 2015), and in some cases the entire market of prescription drugs under reference pricing was considered (Granlund and Bergman, 2018; Herr and Suppliet, 2017).

A topic which is seldomly addressed in empirical studies of reference pricing schemes is welfare analysis due to the lack of combined information on prices and quantities. Brekke, Holmas and Straume (2011) analysed the welfare consequences of introducing a reference pricing system in Norway, in replacement of price cap regulations. They concluded the policy was responsible for a 30% reduction in health expenditures and for a decrease of approximately 12% in the average co-payment. The welfare implications of reference pricing were closely evaluated by Kaiser et al. (2014). They estimate demand

for statins by a random coefficients logit model which accommodates both vertical and horizontal product differentiation. Kaiser et al. (2014) concluded that, if the perceived quality differences between branded-drugs and generics are real, the reference pricing scheme increased consumer surplus by 7.1%. Alternatively, if generics and brand-name drugs give the same utility to patients, consumer surplus increases by 35.8% after RP is implemented.

Surprisingly, the literature has overlooked how reference pricing might trigger asymmetric regional responses in terms of consumption of prescription drugs and the welfare impacts those different responses entail. Given the suggestive evidence that education decreases loyalty to branded-name drugs and that generics' acceptability differs across regions (Costa-Font, Rudisill and Tan, 2014), it is plausible to conjecture the response of consumers to an increase in co-payments will be heterogeneous within a country. Puig-Junoy (2007) evaluated the impact that reference pricing had in Andalusia and the rest of Spain. He analysed Andalusia separately from the rest of the country because this region introduced incentives for generic substitution that went beyond the reference pricing scheme put into effect nation-wide. In particular, the Andalusian reference pricing system required doctors to prescribe based on the name of the active ingredient instead of using the commercial name of the drug. In a similar vein, Ghislandi, Armeni and Jommi (2013) aimed at studying the effects of the Italian reference pricing system per region, as in certain regions medical doctors were given incentives to attain specific prescribing quotas or respect budget constraint. However, the absence of data disaggregated per region precluded them from conducting the analysis at that geographical level. What we propose is that even if a reference pricing system is implemented homogeneously in a country, the study of its impact in terms of consumption and patient expenditures should preferably be carried at the regional level, so as to measure welfare impacts at a finer level.

2.3 A stylized model for drug prices

We build a stylized model to help developing some intuition on the main effects and hypothesis. We are interested in analysing how firms set their prices in a market with differentiated products. Let us define two chemically identical drugs, which constitute our market. A patient who has been prescribed with such a drug, might decide to acquire in the pharmacy a branded drug (B) or a generic drug (G). Each product is produced by a different firm. Both firms compete in prices. We assume that both firms have constant marginal costs. Without loss of generality, these costs are assumed to be zero. Note that this approach assumes the existence of no multi-market contact nor multi-product firms.

Patients have a demand for both branded and generic drugs, but they consider the two products to be differentiated. In this market, patients do not pay the price set by the firm. Instead, the price paid by the patient will be the difference between the drug price and the reimbursement level. The reference price is the same for all drugs in the equivalent drug group and assumed to be equal to an exogenous reference price. The demand functions are therefore given by:

$$q_b = \alpha_b - \beta(p_b - w) + \gamma(p_g - w) \tag{2.1}$$

$$q_g = \alpha_g - \beta(p_g - w) + \gamma(p_b - w) \tag{2.2}$$

Where q_b and q_g are the quantity demanded of branded and generic drugs, respectively. Similarly, p_b and p_g, are the prices of branded and generic drugs, established by the firms. w is the reimbursement level, which is a direct function of the reference price. Thus, the price paid by the patient will be given by $p_i - w$. The parameter γ measures the level of substitution between both products, which is assumed to be positive. Note that the willingness to pay for both drugs is not the same, as we are assuming that $\alpha_b > \alpha_g$. Note that the reimbursement level is common for both the branded and generic drug. Thus,

higher reimbursement levels work as a change in the constants α_i, without affecting the trade-off of choosing a drug over a branded product. Since the reimbursement level is not a function of the price level (for instance, a fraction of the price), a unilateral price increase from one firm will result in an incentive for shifting towards the other firms' drug.

A firm in this market sets the price that maximizes profits, which are given by:

$$\max_{p_i} p_i q_i \Leftrightarrow \max_{p_i} p_i(\alpha_i - \beta(p_i - w) + \gamma(p_j - w)) \tag{2.3}$$

The best-response function for this firm's price is given by:

$$p_i = \frac{\alpha_i + \beta w + \gamma p_j - w\gamma}{2\beta} \tag{2.4}$$

In equilibrium, the price for the branded drugs will be given by:

$$p_b = \frac{2\beta\alpha_b + \gamma\alpha_g}{(2\beta - \gamma)(2\beta + \gamma)} + \frac{\beta w - \gamma w}{2\beta - \gamma} \tag{2.5}$$

The price for generic drugs will be given by:

$$p_g = \frac{2\beta\alpha_g + \gamma\alpha_b}{(2\beta - \gamma)(2\beta + \gamma)} + \frac{\beta w - \gamma w}{2\beta - \gamma} \tag{2.6}$$

The second term of both prices is identical and represents the effect of price and cross-price elasticities. However, the first term is symmetric for both prices and represents different willingness to pay for the different products. If the willingness to pay was equal ($\alpha_b = \alpha_g$), then prices would be the same for both drugs and equal to: $p_i = \frac{\alpha + \beta w - \gamma w}{2\beta - \gamma}$

Since the willingness to pay for branded drugs is larger than for generic drugs ($\alpha_b > \alpha_g$) and assuming that $2\beta > \gamma$, then the branded drug price will be higher than the generic

drug price. Despite different willingness to pay, both drug prices change with reference prices according to the following expression:

$$\frac{\partial p_i}{\partial w} = \frac{\beta - \gamma}{2\beta - \gamma} \tag{2.7}$$

The drug price will not be affected by reference price changes only when β equals γ. This is the case where there is no differentiation between generic and branded drugs, and the consumer considers them to be perfect substitutes. Such scenario is highly unlikely, since the literature is relatively consensual on determining that branded and generic drugs are not perfect substitutes, from the patient point of view (Shrank et al., 2009), as well as from the physician perspective (Hellerstein, 1998).

The previous equations shows that an exogenous change in the reference price will affect drug prices depending on price and cross-price elasticities. If β outweighs γ we would expect that a reduction in the reference price would lead to a reduction of both drug prices. Conversely, if the cross-price elasticity outweighs the own-price elasticity, then the reduction of the reference price could lead to an increase in drug prices. However, it has been shown that cross-price elasticities are smaller than own-price elasticities for many different drugs (for instance, for antiulcer drugs in the US (Arcidiacono et al., 2013) and oral anti-diabetics in Germany (Duso, Herr and Suppliet, 2014)). This condition should also be related with the stability of the oligopoly solution. Thus, according to this model and given normal price elasticities, one would expect that prices would decrease following a reduction of the reference price.

2.4 Data and empirical strategy

2.4.1 Background on the Portuguese Pharmaceutical Market

In 2018, Portugal pharmaceutical expenditure reached 15.4% of health spending (INE, 2019*a*), 48.3% of which is public spending made by the Portuguese NHS, followed by out-of-pocket payments on prescription drugs made by patients of 27.2%. The remaining 24.5% is relative to over-the-counter drugs spending (Infarmed, 2019*a*).

During the 2011 sovereign debt crisis, there was a decline on public pharmaceutical spending - mostly due to prices and margins reduction. However, since 2014, nominal public pharmaceutical expenditures have increased 16%, reaching a total of 2.461 million euros in 2018. This increase was driven by strong growth in hospital spending (26%), followed by a modest increase in ambulatory spending (7%). Nonetheless, ambulatory spending represents more than half of total public pharmaceutical spending (Infarmed, 2019*a*).

The Portuguese National Authority of Medicines and Health Products, Infarmed, regulates and supervises the sectors of medicines for human use and health products. When setting the prices for their drugs, pharmaceutical companies are not free to charge any price. Generally, the maximum price of non-generic drugs results from the comparison with average prices in comparable countries. Moreover, for generic drugs the maximum selling price must be at least 50% lower than the maximum selling price of the branded drug at the moment of patent expiration.

Additionally, regulation was also created to establish the NHS co-payment level for each drug, imposing specific out-of-pocket payments made by the patient. In Portugal, a reference price system for pharmaceutical drugs was established in 2003 to determine the NHS co-payments. This system intended to foster competition between firms, promoting the

usage of generic drugs and reducing NHS co-payments expenditure. In 2018, 63.8% of drugs sold were included in this reference price system – which is the scope of this paper. This system excludes drugs still protected by patents - which are subject to international prices based on reference countries.

All drugs in this system are grouped in equivalent-drug groups, according to their active substance and formulation. Different drugs in each equivalent-drug group are therapeutic substitutes for the patient. In 2019, a total of 8.453 different drugs were available in this system, grouped in 813 different equivalent-drug groups (each one including at least one generic drug).

With some exceptions, when prescribing a medicine for a patient, the physician prescribes an equivalent-drug group and not a particular drug. The medical prescription will then include the price that the patient will pay if she opts for the cheapest drug within that equivalent-drug group. The choice of the specific drug is then made by the patient when buying the drug at the pharmacy. The price paid by the patient will be the difference between the drug price and a certain co-payment made by the NHS.

The reference price system is used to establish such NHS co-payment on prescription drugs. Since drugs are grouped in equivalent-drug groups, and since patients are free to choose any drug within that group, the NHS co-payment does not depend on the specific price of the drug picked by the patient, but on a reference price, based on the equivalent-drug group.

Until October of 2017, this reference price was defined as the average of the five distinct cheapest drugs in the equivalent-drug group. The NHS co-payment rate would then be applied to this reference price, and not to the drug price established by the pharmaceutical company. Different equivalent-drug groups have different co-payment rates[2] (15%, 37%, 69% and 90%), taking into consideration factors such as characteristics of the average

[2]Co-payment rates are determined by the government and they do not depend on the firms' prices nor on the reference price.

patient, as well as incidence of certain diseases and public health targets.

Thus, the final price paid by the patient is given by the difference between the drug price established by the pharmaceutical company and the reimbursement level. Such reimbursement[3] is determined based on the reference price and the NHS co-payment rate (2.8):

$$Patient\ price = Drug\ price - Reference\ Price \times NHS\ Copayment\ rate \quad (2.8)$$

Pharmacies can implement ad-hoc discounts on the patient price. Special prices or co-payment rates can also be defined for specific population groups (for instance for poor elderly people). Nonetheless, the equation above describes the patient price for the general case.

This reference price system incentivizes consumers to buy the cheapest drug within the equivalent drug group since the co-payment from the NHS will be the same for all drugs included in the group. Ultimately, this should foster competition within each equivalent-drug group. However, in groups with few generics or with few drugs, such competition might not be as forceful as desired by policymakers.

With the goal of fostering competition in such groups, a policy change was implemented in October 2017. This policy change affected the way the reference price is computed. Instead of being equal to the average of the five lowest prices in the group, the reference price became equal to the minimum between the five lowest prices and the price of the most expensive generic in the equivalent-drug group. Such change affected mostly groups with few generics. The Regulatory Agency estimates that this change represented yearly savings of 12 million euros on NHS co-payments (Infarmed, 2019*b*). The new methodology for reference price calculation was applied to all drugs in the system. However, in practice, only drugs in low-competitive groups were affected by the change.

[3]The reimbursement level is capped to the Drug price. If the reference price times the co-payment are higher than the drug price (which can happen in the case of low-price generics), then the drug will be free-of-charge to the patient.

Although implemented in October 2017, such policy was not seen as a surprise by the industry. In fact, several official documents from Portuguese Institutions mentioned the intention of implementing changes in the reference price system. Some references were very explicit, while others were broader. In the end of 2016, the State Budget for 2017 included a measure to implement a pharmaceutical policy that fosters a rational use of drugs. The Health Ministry Budget for 2017, which accompanies the State Budget, is more explicit proposing the revision of prescription and NHS co-payment mechanisms. The same document also refers the objective of increasing the share of generic drugs. These objectives were also shared by Infarmed in March 2017, with the goal of contributing to the sustainability of the health system. In October 2016, the National Strategy for Drugs 2016-2020 was also approved. This strategy clearly established the goal of studying and revising the reference price system. Additionally, the same document refers the intention of changing the methodology of reference pricing particularly for drugs which have equivalent generic products.

2.4.2 Data and descriptive statistics

This paper combines two datasets with price and consumption information for prescription pharmaceutical drugs in Portugal. As mentioned above, the paper is focused only on prescription drugs included in the reference price system - which represented 63.8% of all drugs sold (between October 2017 and September 2018) (Infarmed, 2019*b*).

Monthly price data was manually collected from January 2016 to December 2019 from Infarmed price lists. Information on co-payment rates, reference prices, and pharmaceutical prices was collected for each drug, together with some additional information.

Consumption data was provided by hmR (a Health Market Research firm). This dataset is a projection for retail pharmacies sales in Portugal. Such projection is made based on real data collected for 90% of Portuguese pharmacies. Thus, this data represents pharmacies

sales in a very accurate way. Data includes the number of units sold for each product every month, from January 2016 to December 2019. Detail is provided for each Portuguese province (the country is divided in 18 different regions plus the two autonomous regions of Madeira and Azores).

In December 2019, our database included 6,879 different products available for sale (excluding outliers with abrupt prices changes). From these, 86% are generics. These products can then be grouped in 715 different equivalent products groups with 219 different active substances. Our database is at the product level. This represents the exact product bought by the patient - a drug with a specific active substance, dosage, package size, and brand. For instance, if we consider the active substance Paracetamol, our database will include all different brands (e.g: Paracetamol Generis, Ben-u-ron,...) as well as all the dosages and package size sold by each brand. Remember that generally, at the moment of the prescription, the physician prescribes an equivalent product group. The specific product within that group is a choice made by the patient at the pharmacy.

Until October 2017, the reference price was calculated as the average of the five different lowest prices in each equivalent-drug group. From October 2017 onwards, a policy change was implemented. The reference price is now computed as the minimum between the average of the five lowest prices and the most expensive generic in each equivalent drug group. In October 2017, 36% of the equivalent-drug groups were affected by the policy change (17% of all products). These groups had weak competitiveness dynamics, with a low number of products and generic drugs. Following the policy change, the average reference price for the affected groups became 14% lower than the average reference price without policy. Table 2.1 highlights the main characteristics of the affected groups in October 2017 relative to the non-affected groups, as well as key statistics for our database.

Table 2.1: Descriptive statistics (montlhy data)

					Average in October 2017	
	Average	Standard deviation	Maximum	Minimum	Affected drugs	Non-affected drugs
Number of products	6,879	211.71	7,231	6,545	1,177	5,642
Number of equivalent drug groups	715	31.99	783	673	248	433
Number of active substances	219	6.32	233	212	123	147
Monthly entries	49	51.64	157	0	13	101
Monthly exits	39	60.85	201	0	-	-
% generic drugs	85.72	0.17	86.02	85.30	65.17	90.07
Drug price (euros)	9.40	0.27	9.89	8.99	11.76	8.92
Reference price (euros)	7.63	0.16	7.96	7.43	10.24	6.87
Patient price (euros)	4.72	0.18	5.01	4.47	5.69	4.58
NHS Co-payment rate (%)	58.56	0.31	59.01	58.03	58.00	59.22
Consumption (millions of units)	9.47	0.42	10.36	8.59	1.87	7.08

Policy change occurred in October 2017. Affected drugs are drugs whose reference price in October 2017 changed following the policy change. Non-affected drugs are drugs whose reference price in October 2017 was not affected by the policy change.

Average reference prices have some variation over time (a plot with the reference price and the pharmaceutical price is provided in the appendix). Such variation can be explained by changes in drug prices included in the equivalent drug group and by the policy change introduced in October 2017. However, the entry or exit of products on a specific group will also change the respective reference price. Thus, some of the volatility on reference prices is explained by entries or exits - both in existing equivalent-drug groups but also with the creation of new equivalent drug-groups. To control for these effects, we have restricted our sample into a balanced panel. This subset of the original dataset includes only products available in the market in every month from January 2016 to December 2019. This panel includes 74% of all drugs. The remaining 26% are drugs that, at some point in time, entered or exited the market. We explore the entry and exit dynamics, as well as their relation with the policy change, ahead in the paper. For the balanced panel, the average reference price is relatively stable over time with one exception: October 2017. Figure 2.1 displays the average reference price for the drugs affected by the policy change in the balanced panel over time (the same plot is replicated for the unbalanced panel in the appendix). The dashed line represents the average reference price if the policy had not been introduced - assuming drug price behaviours and consumption patterns remained unchanged. For the balanced panel, in October 2017, the average reference price with the policy change was 14% lower than what it would be without the policy change.

Figure 2.1: Reference price for the affected drugs (balanced panel; 2016 - 2019; euros)

The decrease in the reference price for the affected group displayed in the previous figure has two effects on prices. On one hand, there is a strategic effect in the sense that firms may have incentives to change their drug prices. This strategic effect might also be different depending on the drug type. Branded drugs, which are on average more expensive than generic drugs, might have incentives to lower their prices. This happens because a lower reference price, for the same drug price, will result in a higher price paid by the patient. Thus, depending on the demand elasticity, firms might be willing to lower their prices to counteract sales losses. Generic drugs, which are on average cheaper, might have the opposite effect. Higher prices paid by the patients on their competitors creates the opportunity for some price increases given relatively inelastic demands. Such increases are likely to be small, not only because competitors' prices might move in the opposite direction, but also because pricing regulations prevents firms from increasing their prices significantly.

On the other hand, besides the substitution effect, there is a mechanic effect resulting

in changes in the patient price. In fact, a lower reference price and a change on the drug price will result in a change in the patient price. If generic drugs' prices increase following the policy change, and given the lower reference price, the price paid by the patient for generic drugs will increase. By the same token, with lower reference prices and if branded drugs lower their prices, the price paid by the patient will not increase as much (firms will bear some of the burden of the lower reference price, avoiding a full pass-through to the consumer).

The following figures display, for the balanced panel, the average drug prices (left panel) and the average price paid by the patient (right panel) both for the treatment and the control groups. A drug is allocated to the treatment group if its reference price was affected by the policy change. If its reference price is still equal to the average of the five cheapest drugs in the equivalent-drug group, then the drug is allocated to the control group. Ultimately, the decision to be allocated to each group depends also on the pricing decision made by the firm. Parallel trend assumption holds for each model at the usual 5% significance level - formal testing is provided in the appendix. The upper panel represents generic drugs, while the bottom panel includes branded drugs. Visual inspection suggests no strategic effect. In fact, drug prices both for the treatment and control groups exhibit a downward trend, but no sudden changes are observed around October 2017, when the policy was implemented. This downward trend can be explained by administrative price revisions. Consequently, we are able to identify a strong mechanic effect, since the average price paid by the patient for the treatment group increases substantially in October 2017.

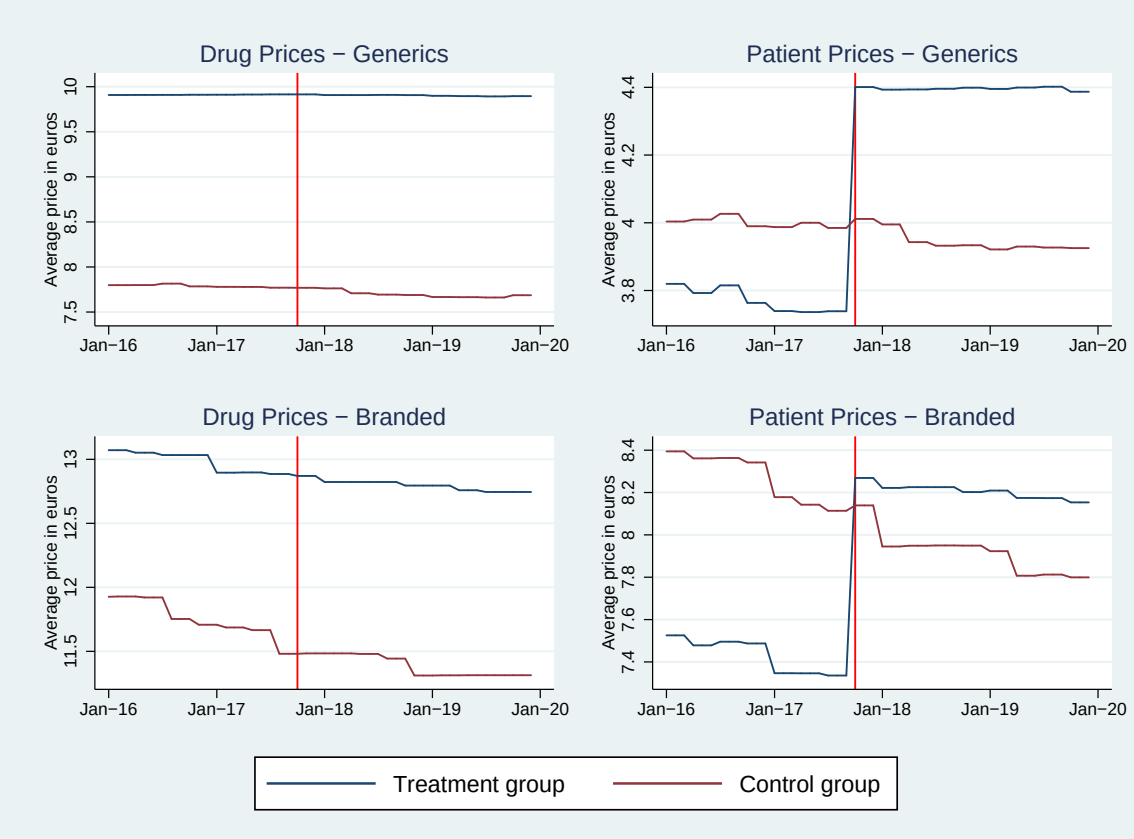


Figure 2.2: Drug and patient prices for the treatment and control groups (balanced panel; 2016 - 2019; euros)

So far, data suggests no sudden change on drug prices, which leads to a full pass-through to the consumers, reflected in higher prices paid by the patient. Demand theory suggests that such price increase might impact drug sales. Still, considering that such demand should be relatively inelastic, no huge effects are expected to be found. Figure 2.3 displays monthly sales for the drugs included in the treatment and control groups (branded drugs in the left panel and generic drugs in the right panel), for the balanced panel. High seasonality and volatility prevent the identification of a clear jump around the policy change.

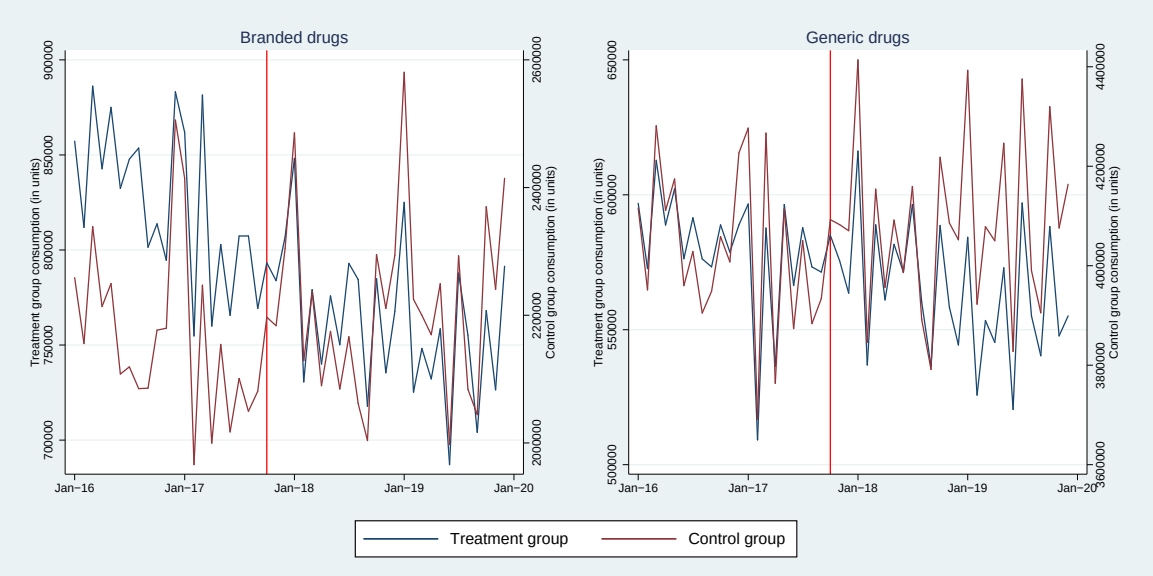


Figure 2.3: Drug sales for the treatment and control groups (balanced panel; 2016 - 2019; units)

Nonetheless, there are different underlying trends before and after the policy. In branded drugs, before policy (January 2016 to September 2017), there was an 8% and a 10% decline in sales for the control and treatment group, respectively. After the policy (October 2017 to December 2019), the treatment group sales remained virtually unchanged, while control group sales increased by 10%. Similar effects are found when looking to generic drugs. Treatment group sales decreased 4% before the policy, maintaining such trend after the policy (-5%). However, generic drugs sales in the control group declined 4% before the policy but increased 2% after it.

This suggests that consumers reacted to higher prices, through lower sales. Still, these analyses are purely descriptive since other factors might be in play. Namely, time trends and competition effects might explain part of the observed dynamics. Taking this into account, we employ a formal approach to test the causal impact of the policy change in the next section.

2.4.3 Empirical strategy

We apply a difference-in-differences model to compare treated products (whose reference price was affected by the policy change) with the control group (not affected by the policy change). The following model was estimated:

$$y_{igtr} = \beta_1 Policy_{it} + \sigma_{gt} + \gamma_t + \alpha_{ir} + \epsilon_{igtr} \tag{2.9}$$

In this specification, i represents the product (e.g. Paracetamol PharmaX 1000mg, Paracetamol PharmaY 1000mg, Ben-u-ron 1000mg,...), g denotes the equivalent drug group (e.g. Paracetamol 1000mg), t denotes the time period (month x year, from January 2016 to December 2019), and r represents the region (one of the 18 Portuguese provinces plus the two autonomous regions).

The dependent variable, y, is the pharmaceutical drug sales price (in euros per unit), the price paid by the patient (in euros per unit) or the quantity sold (in units). All models are estimated using both the dependent variable in levels as well as in logarithms. The natural logarithm accounts for the skewness in the distribution of drug sales and provides a more intuitive interpretation in terms of percentage.

The variable $Policy_{it}$ is an indicator equal to 1 for drugs affected by the policy from October 2017 onwards and 0 otherwise. Thus, β_1 measures the policy impact on drugs. Models are estimated separately for generics and branded drugs.

Standard errors are clustered at the equivalent drug level, to account for any serial correlation across the equivalent products - which can be viewed as substitutes.

Two models are estimated for each specification. The first model includes all drugs available in the database (unbalanced panel). This model includes drugs which are not present during the entire period. Despite having more information, such data is also noisier. The

second model controls for the existence of entries and exits in the pharmaceutical market over this period, including only drugs that are simultaneously available in all months from January 2016 to December 2019 (balanced panel). Each model is estimated twice, for generic and branded drugs.

A potential concern with this strategy is the fact that different equivalent drug groups can have very different competitive environments. In fact, groups with many generic drugs might have stronger price competition effects, than groups with less generic drugs. Additionally, it is likely to observe firms who interact multiple times with their rivals in different equivalent drug groups. Drug prices can be affected following such multimarket contact. Such effects will influence the pricing behaviour of each drug. To account for these effects, a competition variable is included (σ_{gt}), representing the total number of drugs and generic drugs in each equivalent drug group. Additionally, we also include a set of fixed effects to control for other factors that might affect the identification of the causal impact attributed to the policy change. γ_t is a vector of month-year fixed effects and α_{ir} is a vector of product-region fixed-effects.

The definition of a control and treatment group in this setting is not straightforward. In fact, the policy change implemented is relevant, in theory, for all drugs included in the reference price system. Thus, one could arguably think that all drugs could belong to the treatment group. However, even though the policy might potentially affect any drug, its specification targeted only some groups. The price distribution and the number of competitors within each group influence whether the group is affected by the policy change or not. This implies that the change is relevant for groups with low competition and few generics, in which the most expensive generic has a lower price than the average of the five lowest prices. In such setting, the five lowest prices might easily include branded drugs. On the other hand, larger groups with more competition and more generics are not likely to be affected by the policy change.

In fact, even if firms in larger groups change their prices, they will most likely remain

unaffected by the policy change. This happens because changes in one drug price have little influence - or even none - in the respective reference price. When looking at the pricing behaviour around the time of the policy change, no evidence is found of firms' self-selection out of the treatment group. There are no drugs that would be treated before the policy change (September 2017), that were not treated after the policy is implemented (October 2017).

This relates also to an additional concern regarding the possibility of reversal of treatment status. Because the new rule is valid from October 2017 onwards, price changes over time might induce reference price changes. Thus, it might be possible for a drug belonging to the control group to move latter on to the treatment group, and vice-versa. However, this issue is also rare and not significant, affecting less than 3% of all drugs included in the reference price system. As mentioned before, changes in a drug price have little effect on the reference price. Thus, it is difficult for drugs to move to or out of the treatment group. Overall, 97 drugs (1.91%) have moved from the treatment to the control group. Conversely, 47 drugs (0.93%) have moved from the control to the treatment group. The inclusion of these drugs does not significantly affect the sign, magnitude, or significance of our results. Nonetheless, these were excluded from the main models.

2.5 Reference prices and pricing behaviour

We have estimated difference-in-differences models for both the drug price - established by the pharmaceutical company - and the patient price - paid by the patient at the pharmacy's counter. The model was estimated both for the prices measured in euros, as well as for the natural logarithm of such prices. Results for the estimation using logarithms, described in the appendix (table 4.8 and 4.9), are similar both in terms of significance and sign. Table 2.2 displays our estimations of the policy impact on the drug price (which exhibits the strategic effect from firms described above). Table 4.7, available in the appendix, displays the estimations on the patient price. Results from the patient price analysis are straightforward in the sense that they reflect the mechanic effect resulting from changing drug and reference prices.

The model was estimated for branded drugs (left panel) and generic drugs (right panel), to assess different behaviours from these different products. For each case, three models were estimated. The first model includes only product fixed effects. The second model adds the competition variable to the set of controls. Results remain virtually unchanged from the first to the second model. Finally, the third model adds month-year fixed effects. The introduction of such variables affects estimations considerably, particularly for branded drug prices. This suggests important time dynamics that can only be accounted for if time fixed effects are included in the model.

The model was also estimated using two different datasets. The balanced panel (upper panel) - including only products present throughout the entire period (January 2016 to December 2019), and the unbalanced panel (lower panel) - also containing drugs which have exited or entered the market during this period. For the drug price and patient price estimations, no substantial differences are found when comparing both panels. Coefficients' signs and magnitude are identical, although unbalanced panel estimates are usually slightly larger than the ones from the balanced panel. Such differences suggest that

entries or exits can play an important role. We explore such issue ahead in the paper. For now, we will focus mainly on the balanced panel coefficients.

Table 2.2 displays the impact of the policy on drug prices. We focus our interpretation on the most complete models ((3) and (6)) from table 2.2, given the importance of controlling for time fixed effects. The $Policy$ coefficient on model 3 measures the policy impact on branded drugs' prices, while the same coefficient on model 6 captures the impact on generic drugs' prices. Results suggest that drugs affected by policy change increase their prices. Such effect is particularly stronger for branded drugs (0.18 euros increase for branded drugs relative to 0.09 for generic drugs).

Such increase in branded drug prices is somewhat surprising and suggests that competition is not increasing immediately following the policy change - as some prices increase rather than decrease. Also, the existence of generic drugs does not seem to contribute to a reduction on branded drug prices, suggesting some differentiation effect. Still, as described in the previous section, such increase is masked given the declining trend on average prices. Thus, these results suggest that in the affected groups such declining trend was less pronounced following the policy change.

Table 2.2: Impact on drug prices (in euros) for branded and generic drugs

	Branded Drugs			Generic Drugs		
Drug Price (in euros)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	-0.1653***	-0.1524***	0.1820**	0.0014	0.0096	0.0888***
	(0.0482)	(0.0479)	(0.0724)	(0.0056)	(0.0067)	(0.0224)
Competitors		-0.0959	-0.1685		0.0434	0.0248
		(0.1146)	(0.1112)		(0.0402)	(0.0385)
Generic competitors		0.3188**	0.3037**		-0.0178	-0.0264
		(0.1368)	(0.1282)		(0.0436)	(0.0432)
N	31,104	31,104	31,104	205,680	205,680	205,680
			Unbalanced Panel			
Policy	-0.2398***	-0.2321***	0.4028***	0.0210	0.0224	0.1665***
	(0.0669)	(0.0669)	(0.1205)	(0.0187)	(0.0191)	(0.0347)
Competitors		0.1002	-0.0789		0.0828**	0.0453
		(0.1042)	(0.0949)		(0.0357)	(0.0314)
Generic Competitors		-0.4015**	-0.2551		-0.1217**	-0.1139**
		(0.1747)	(0.1558)		(0.0474)	(0.0444)
N	43,942	43,942	43,942	275,256	275,256	275,256
Product FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

The increase in drug prices, together with the reduction in the reference price, should have a direct impact on the patient price. This mechanic effect is displayed in table 4.7 available in the appendix. As expected, both prices for branded and generic drugs increase on average for the affected products (1.20 euros and 0.69 euros, respectively). This implies a pass-through to the consumer above 100%.

Our estimates suggest that the reference price reduction for low-competitive drugs induced an increase in drug prices. Such effect was particularly strong for branded drugs. According to the stylized model described before, this would imply that the cross-price elasticity outweighs the own-price elasticity - which is surprising. These effects might be related with the fact that the policy change is targeting low-competition groups. In groups with few competitors, changes in reference prices may have different effects on demand than in low-price groups. For example, if patients prefer brand-name drugs, increasing prices in those groups is easier than in more competitive groups.

Coupled with an inelastic demand, firms have increased the price, increasing the burden on the consumer as well. Given the increase in the markup of branded drug prices relative to generic prices, this presented itself as an opportunity for generic drugs to increase their prices as well.

Figure 2.4 and 2.5 show that following the policy change, branded drugs affected by the policy change, approximate their prices to the maximum regulated prices. However, the same change is not observed when looking for branded drugs in control groups. Additionally, no major changes in pricing are observed with respect to generic drugs.

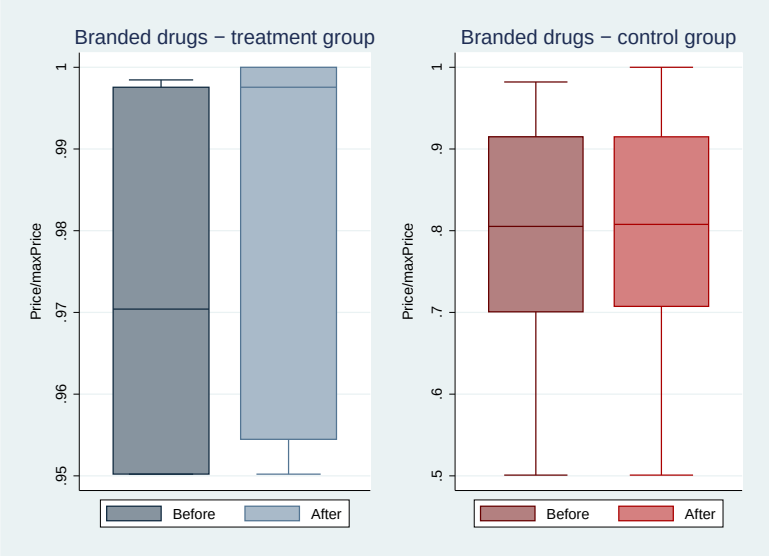


Figure 2.4: Price and Maximum Price for Branded Drugs before and after the Policy change

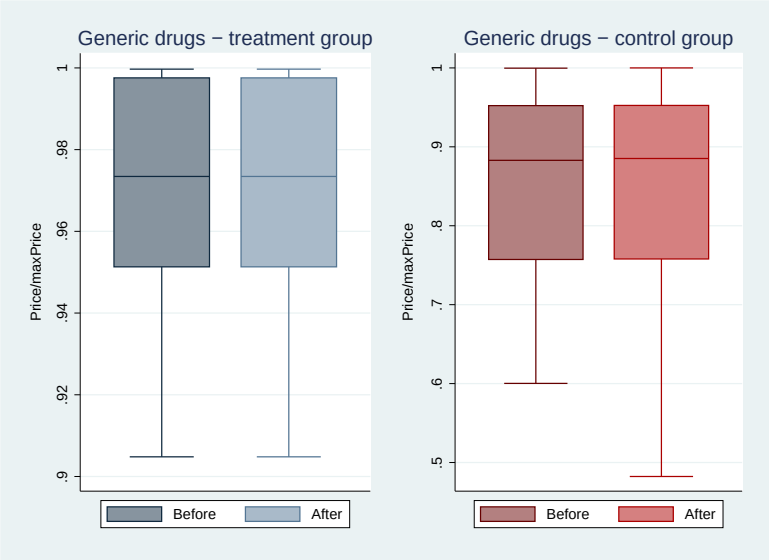


Figure 2.5: Price and Maximum Price for Generic Drugs before and after the Policy change

2.6 Reference prices and consumption behaviour

Given the availability of simultaneous price and consumption data, we have applied the same methodology to pharmaceutical sales. Table 2.3 displays estimations of the policy impact on log drug sales for branded drugs (left panel) and generic drugs (right panel). Estimation in levels provides similar results and is described in the appendix. The interpretation of the logarithm specification allows us to analyse these coefficients as elasticities and percentage changes - which is a particularly useful interpretation - and to account for right skewness of the dependent variable.

The model was estimated both for the balanced panel (upper panel) and for the unbalanced panel (lower panel). There are no significant changes in both estimations - similar significance and same sign. The model includes the same fixed effects as before with the addition of regional fixed effects. This is especially relevant since our unit of observation is drug sales at the region level. We will focus the analysis on the most complete models, containing the full set of controls: model 3 for branded drugs and model 6 for generic drugs.

Remember from the previous section that the price established by pharmaceutical companies increased for both branded and generic drugs, following the policy change. Together with the reference price decrease, an increase in the price paid by the patient was observed for all drugs affected by the policy.

When looking to sales data, the $Policy$ coefficient on model (3) measures the policy impact on branded drugs sales. Estimations suggest a 16% drop on sales for branded products affected by the policy change compared to the remaining products. The $Policy$ coefficient in model (6) measures the policy impact on generic drugs sales. The impact on generic drug sales is not significant - despite having a positive sign.

These results are consistent with the hypothesis that, given a price increase, some con-

sumers switched consumption from branded to generic drugs (substitution effect), and that some generic drug consumers stopped buying their medicines (income effect). We analyse such hypothesis ahead to try to disentangle these effects. We will also focus on the impact of chronic medicines consumption versus non-chronic medicines.

Table 2.3: Impact on log drug sales for branded and generic drugs

	Branded Drugs			Generic Drugs		
Drug sales (logs)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	-0.2878***	-0.2824***	-0.1662***	-0.0997***	-0.0918**	0.0583
	(0.0564)	(0.0565)	(0.0617)	(0.0372)	(0.0377)	(0.0421)
Competitors		0.0597	0.0277		0.0066	-0.0322
		(0.0481)	(0.0454)		(0.0379)	(0.0329)
Generic competitors		-0.0450	-0.0488		0.0473	0.0295
		(0.0526)	(0.0490)		(0.0449)	(0.0391)
N	572,208	572,208	572,208	3,484,944	3,484,944	3,484,944
			Unbalanced Panel			
Policy	-0.3357***	-0.3293***	-0.1735***	-0.0518	-0.0451	0.1094***
	(0.0474)	(0.0473)	(0.0534)	(0.0323)	(0.0323)	(0.0366)
Competitors		0.1004*	0.0478		0.0348	-0.0078
		(0.0579)	(0.0569)		(0.0312)	(0.0303)
Generic competitors		-0.1200*	-0.0780		0.0184	0.0236
		(0.0610)	(0.0593)		(0.0358)	(0.0340)
N	794,842	794,842	794,842	4,537,370	4,537,370	4,537,370
Product FE	x	x	x	x	x	x
Region FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

2.7 Further Analysis

2.7.1 Exits and entries following policy

Reference pricing schemes aim to reduce prices by incentivizing patients' choice towards cheaper drugs, and by fostering competition, namely through generic entry. We apply a difference-in-differences model to compare entries in equivalent drug groups whose reference price was affected by the policy change relative to entries in groups that were not affected by the policy change. Given that entries may be induced by previous conditions of the equivalent drug groups, we control for the total number of competitors, as well as for the number of generic competitors and average price, with a three-period lag. Table 2.4 displays the estimation results.

Results suggest that the policy change induced entries in the market, especially in equivalent drug groups that already had several competitors in the previous quarter. Hence, despite results of section 5 indicate that the policy was not effective in steering price competition, the policy change was at least able to foster entry. Interestingly, there is no sign of higher price competition following these entries. A plausible interpretation to this result arises from the fact that entry occurs mostly in groups with many competitors. Thus, price competition does not increase substantially given the overall pre-existing competition in these groups.

Table 2.4: Impact of the policy change on entries and exits

Dependent variable: Number of competitors in the equivalent drug group	
Policy	0.0878***
	(0.0259)
Competitors (t-3)	0.8238***
	(0.0882)
Generic competitors (t-3)	-0.0552
	(0.1072)
Average price (t-3)	-0.2427***
	(0.0413)
N	18,435

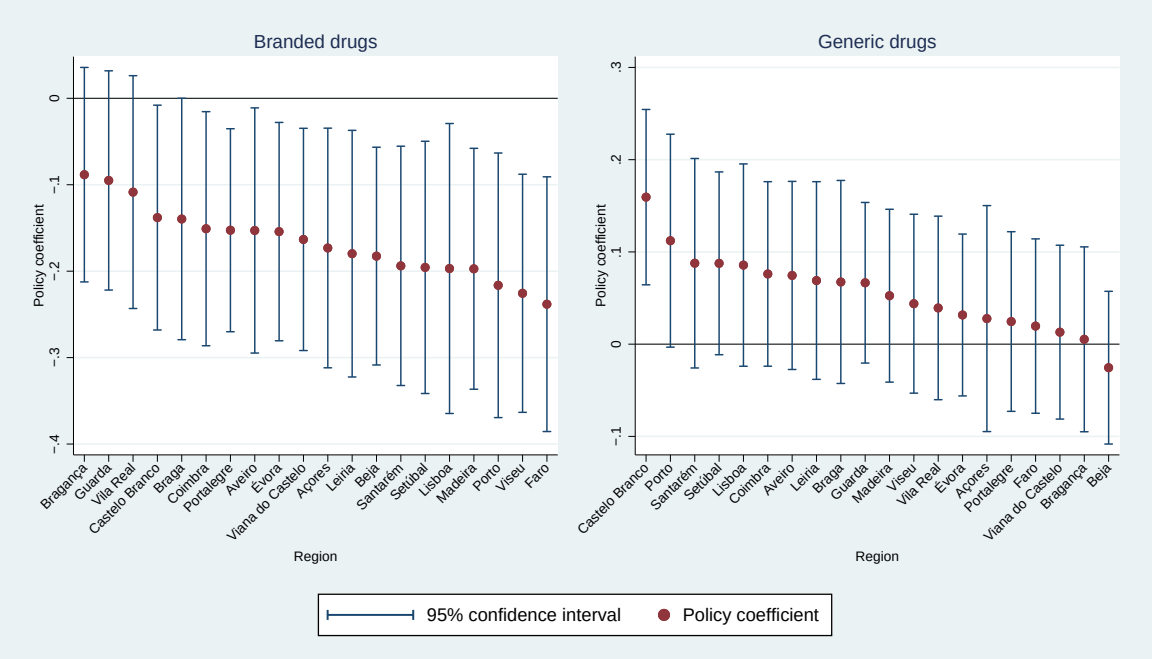
*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019. Competitors: number of competitors in the equivalent drug group in the previous quarter. Average price: average drug prices in the equivalent drug group in the previous quarter. Balanced panel. Regression at the equivalent drug group level. Includes fixed effects for the equivalent drug group and for the month-year.

2.7.2 Regional analysis on consumption

Previous effects found on consumption were at the national level. Despite being small, Portugal has significant regional asymmetries both in economic terms, as well as in access to health care and health outcomes. Thus, we analysed the effect of the policy on consumption of prescription drugs at the regional level, to disentangle potential heterogeneity. Figure 2.6 represents the impact of the policy change on consumption for branded drugs (left panel) and generic drugs (right panel). The plots represent the coefficient estimates, and respective 95% confidence intervals, for fixed effect regressions and for the natural logarithm of drug sales. These regressions are conducted for each region with the same controls included. Point estimates in a map are also available in the appendix, which facilitates data visualization.

As expected, there are asymmetric responses to the price change, suggesting different elasticities in different regions. The effect of generic drugs consumption is non-significant at the usual significance levels for all regions except for Castelo Branco (a rural region located in the centre-east Portugal). However, for branded drugs, the impact on consumption is negative and significant for most regions. The three regions with lower,

yet non-significant, decline in the consumption of branded drugs affected by the policy - Bragança, Guarda and Vila Real - are among the Portuguese NUTS III with lowest purchasing power per capita. In fact, the average purchasing power per capita in those regions does not reach 80% of the national average purchasing power per capita (INE, 2019*b*). Hence, this result is aligned with previous studies that identify, for other markets, that low-income patients tend to be sceptical towards generic medicines (Shrank et al., 2009). The largest negative impact is estimated at Faro (rural region located in the south), followed by Viseu (rural region in the centre of Portugal). Ad-hoc discounts from pharmacies might also contribute partially for these results, as some of those discounts might counteract the over-the-counter price increase.



Note: fixed effect model with all controls

Figure 2.6: Drug sales by region (balanced panel; 2016 - 2019)

2.7.3 Substitution effects

In section 6, we evaluated how consumption of both generics and branded drugs responded to the policy. However, it is not possible to rely on a simple comparison of the

coefficient of interest for those cases to conclude whether the decrease in consumption of branded drugs was offset by increased generic consumption. For that end, we evaluated whether consumption at the equivalent drug group level was affected by the policy.

Results suggest that the impact of the policy change on consumption evaluated at the equivalent drug group level is negative and strongly statistically significant. This, combined with results from section 6, shows that the increase in generic consumption was not enough to counter the decrease in the consumption of branded drugs. Hence, overall consumption decreases following the policy change. There are two possible interpretations for this. In one hand, this can represent an increase in unmet needs if some consumers are now unable to purchase drugs. On the other hand, this can represent a structural change in demand patterns - which can be positive. For instance, higher prices may act as a control for moral hazard, through the reduction of excess consumption.

Table 2.5: Impact of the policy change on overall equivalent drug sales

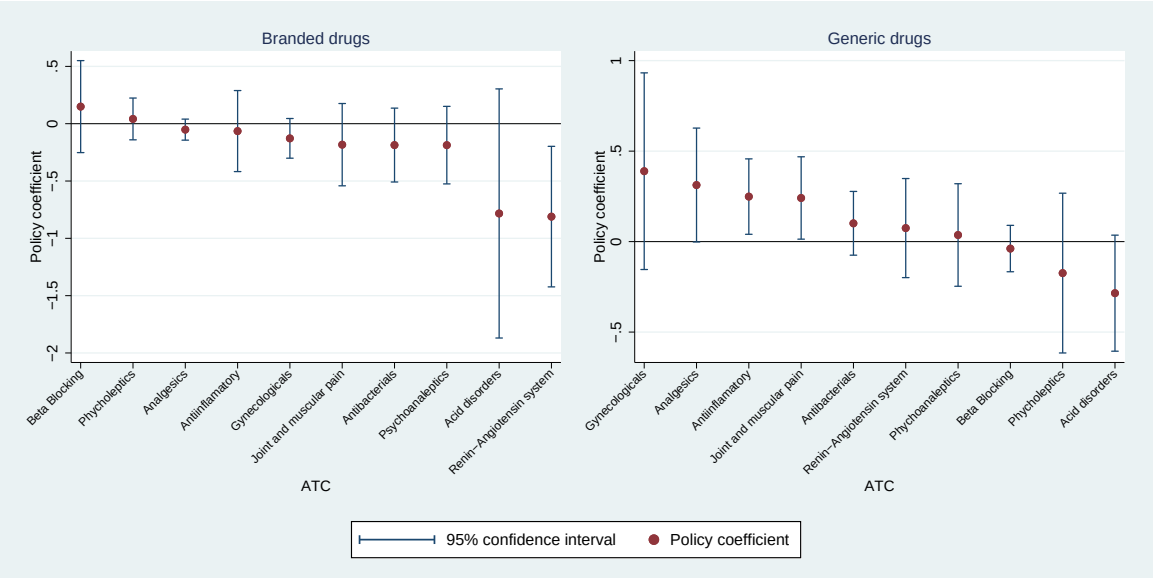
Dependent variable: Log drug sales	
Policy	-0.1726***
	(0.0646)
Competitors	0.2904**
	(0.1370)
Generic competitors	-0.2565*
	(0.1363)
N	32,924

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019. Balanced panel. Regression at the equivalent drug group level. Includes fixed effects for the equivalent drug group and for the month-year, as well as competition controls.

2.7.4 Heterogeneous impacts on different drug types

While results in section 6 indicate that consumption of branded drugs decreased, the response may be heterogeneous across therapeutic groups. Hence, we classified drugs according to the therapeutic subgroups of the Anatomical Therapeutic Chemical Classifi-

cation System (ATC2) and evaluated the impact of the policy on consumption of generics and branded drugs in each of those groups. Figure 2.7 presents the results of the 10 principle (in terms of volume of sales) therapeutic subgroups. Sales of these therapeutic subgroups represented 78% of prescription drug sales in December of 2019, considering the balanced panel.



Note: fixed effect model with all controls

Figure 2.7: Drug sales by therapeutic property (balanced panel; 2016 - 2019)

The consumption of generics increased for analgesics, anti-inflammatory and for topical products for joint and muscular pain. Regarding branded drugs, a sharp decrease in the consumption of agents acting on the renin-angiotensin system, such as hypertensives, is identified.

Table 2.6 displays the full-model estimation results with a distinction between chronic and acute drugs. Chronic drugs are those with a long treatment duration and acute drugs are those with short or medium treatment duration, according to clinical guidelines. The consumption of chronic branded drugs substantially decreased, which may essentially be driven by the substantial decrease in consumption of agents acting on the renin-angiotensin system, which are all chronic drugs. The consumption of acute and

chronic generic drugs did not increase in a statistically significant way, which again underpins the idea that overall consumption was reduced.

Table 2.6: Impact on chronic and acute drugs consumption

	Branded Drugs		Generic Drugs	
Log drugs sales (in euros)	Acute	Chronic	Acute	Chronic
	Balanced Panel			
Policy	-0.0786	-0.1791**	0.0389	0.0733
	(0.1240)	(0.0695)	(0.0689)	(0.0536)
Competitors	0.0767	-0.0393	-0.0888*	-0.0124
	(0.0665)	(0.0550)	(0.0516)	(0.0402)
Generic competitors	-0.0543	0.0189	0.0832	0.0122
	(0.0913)	(0.0587)	(0.0503)	(0.0475)
N	160,752	410,496	643,008	2,841,936
Product FE	x	x	x	x
Region FE	x	x	x	x
Competition controls	x	x	x	x
Month-year FE	x	x	x	x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019. Balanced panel.

2.7.5 Public health spending and out-of-pocket payments

The simultaneous availability of prices and quantities information allows us to compute changes in expenditure. This is particularly relevant since part of drugs' expenditure is paid by the NHS through co-payment mechanisms and the remaining share represents out-of-pocket payments made by the patients. Table 2.7 represents expenditure changes. In the 12 months before the policy change (October 2016 until September 2017), NHS co-payment expenditure amounted to 286.7 million euros, while out-of-pocket payments represented 400.7 million euros (column (4)).

If the policy had not been implemented – implying the reference price would correspond to the average of the five lowest unit prices of the equivalent drug group – and if the consumption pattern were the same as in the previous year (from October 2016 to September 2017), then NHS co-payment expenditure would amount to 307.8 million euros and out-of-pocket payments would increase to 407.8 million euros (column (3)).

Using pre-policy prices and current consumption, NHS co-payments would be 311.2 million euros and out-of-pocket expenditures would be 398.6 million euros (column (2)). This scenario, compared with the previous one, suggests that patients either switched to cheaper drugs and/or stopped consuming some drugs.

With current consumption and new prices, NHS co-payments amount to 297.4 million euros and out-of-pocket payments correspond to 411.1 million euros (column (1)). Hence, NHS saved between 10.4 million and 13.8 million euros, which corresponds, respectively, to 3.50% and 4.64% of NHS co-payments from October 2017 to September 2018. Regarding out-of-pocket payments, private expenditure increased between 3.3 million and 12.5 million euros, which correspond, respectively, to 0.81% and 3.04% of out-of-pocket payments from October 2017 to September 2018. These changes are not the correct counterfactual but should be seen as lower and upper bounds.

These results suggest that NHS co-payment savings were partially achieved at the expense of higher out-of-pocket payments. This happened because the policy limited the decrease in drug prices that would have occurred otherwise, which in turn increased the price paid by the patients.

Table 2.7: Out-of-pocket and public expenditure scenarios

Spending (million euros)	(1)	(2)	(3)	(4)
Out-of-pocket	411.1	398.6	407.8	400.7
Public expenditure	297.4	311.2	307.8	286.7
Total	708.5	709.8	715.6	687.4

Notes: Analysis 1 (10/2017-09/2018) Current consumption with current prices with policy; Analysis 2 (10/2017-09/2018) Current consumption with prices without policy; Analysis 3 (10/2017-09/2018) Old consumption with prices without policy; Analysis 4 (10/2016-09/2017) Old consumption with old prices

2.8 Conclusion

Rising health spending, and particularly rising pharmaceutical spending, poses concerns to policy makers all over developed economies. Reference price regimes for prescription drugs are usually implemented with the aim of curbing public expenditure with pharmaceuticals, induce drug substitution from branded drugs to generics and enhance competition. In these systems, patients co-pay the difference between the drug's pharmacy retail price and the reimbursement level. In Portugal, a policy change on the way the reference price is computed was introduced in 2017 with the goal of foster competition and further reduce NHS spending. Relying on a detailed product-level panel dataset of prescription drugs sold in Portuguese retail pharmacies, from 2016 to 2019, we evaluate the impact of this policy change on pricing strategies of pharmaceutical companies and on consumption.

In December 2019, our dataset included 6.879 different drugs distributed among 715 different equivalent drug groups. In October 2017, this change affected 36% of the equivalent drug groups included in the reference price system. The change in the reference price formula resulted, on average, on a 14% decrease in the reference price for the drugs affected by the policy change.

The reduction of the reference price, all else constant, represents a price increase for the patient. Thus, unless pharmaceutical companies bear some of its impact, all NHS savings would be reflected in higher out-of-pocket expenditure from the patients. Difference-in-differences models are employed to analyse the impact of such policy change.

Results show a strategic effect on the way pharmaceutical companies set their drug prices. We found evidence that firms do not adjust their prices downwards as a reaction to the new reference price. In fact, we observe that, following the policy change, branded drug affected by it, approximate their prices to the maximum regulated prices. The same effect

is not observed for branded drugs in control groups. According to our model, this would imply that the cross-price elasticity outweighs the own-price elasticity.

Such strategic effect might be related with the type of groups affected by the policy change. These groups have few firms, with low competition, and inelastic demand. Additionally, branded drugs do not typically affect reference prices. Thus, changes in these prices are taken as exogenous on the firm's profit maximizing strategy. Under such setting, and with a lower reference price, branded firms increase their prices, shifting the burden towards the consumer. The increase in branded drugs is also followed by a smaller increase in generic prices.

The combination of a lower reference price with higher drug prices resulted on a mechanic effect, translated into higher patient prices (both for branded and generic drugs) - a pass-through above 100%. These results contradict the hypothesis that lower reference prices would induce drug prices reduction to offset a significant change in patient prices.

When looking to consumption patterns, we found evidence of a 16% decline on branded drugs consumption. No significant effects were found on generic drugs consumption. Significant heterogeneity across regions and therapeutics was found. Results suggest that NHS co-payments savings were also achieved through higher out-of-pocket payments paid by patients, raising potential equity concerns. Further analysis is required on the determinants of pharmaceutical competition dynamics, particularly on low-competition drug groups. Customer loyalty (inelastic demands) and multi-market contact (both from firms and patients) might distort competitive dynamics in this market.

Chapter 3

Health Spending Efficiency and Sustainability: three applications

Health spending has been increasing over time across developed economies. Despite significant differences in terms of how health care is provided to the population, developed countries have a significant share of public spending in total health spending. Coupled with fragile public finances and adverse macroeconomic environments, the quest for efficiency in the health sector remains one of the key challenges governments currently face. Additionally, public health spending growth raises concerns on whether countries will be able to sustain such spending levels in the long-run.

This chapter provides three contributions, from a macro perspective, on these two issues: efficiency and sustainability. The next section provides an assessment on public health efficiency, highlighting its role in financing the provision of health care. Afterwards, such efficiency analysis is expanded by looking into how changes in health professionals' skill-mix can contribute to increase the overall efficiency of health spending. Finally, the last section presents a forecast for health spending in Portugal, and its implications regarding the NHS sustainability, in a context of public finances' constraints.

3.1 Public Health Spending Efficiency[1]

This section discusses the main challenges on measuring efficiency of public health spending. The first subsection describes the main characteristics of the health sector and highlights the rationale behind public intervention in health. The second subsection provides an overview of the relevant literature and discusses methodological challenges on measuring efficiency in the health sector. The subthird section illustrates these challenges by providing a critical analysis of public health spending efficiency. Finally, the last subsection concludes.

3.1.1 The public health sector: why is it special?

Access to high-quality care is a priority worldwide. The desire to protect citizens against adverse health shocks, has motivated multiple and ambitious programs across the world. The introduction of national social insurance or the provision of health care through a national health service are just some examples. In fact, the goal of achieving universal health coverage worldwide has become a major priority objective of the World Health Organization.

Despite the important role that private entities can play in funding or providing health care, attaining such ambitious objective implicitly recognizes a scope for government intervention. Public health spending is related with the need of providing adequate health coverage and access to the population, as well as of reducing unmet needs. This implicit role attributed to the public health sector was amplified following the Covid-19 pandemic, even in countries where the public health sector usually plays a smaller role. The need for public health investment, for national and supra-national coordination, as well as the

[1]Original research forthcoming in: Costa, E. and Barros, P.P., "Public Health Spending Efficiency", Venâncio, A., Afonso, A. and Jalles, J. T. (Ed.) *Handbook of Public Sector Efficiency*, Edward Elgar Publishing.

need to overcome market failures, create multiple grounds for government intervention in the health sector. Such intervention can take multiple forms, from regulation, financing, or direct provision of health care. Regardless of which option is chosen, public health spending is a crucial part of modern health systems.

The unequivocal importance of the health sector to modern societies, alongside with the rational for public intervention, led the public health sector to gain a major role among general government expenditure. In 2018, general government expenditure represented 41% of GDP, on average, for high-income OECD countries (OECD, 2019*a*). Health spending is one of the main areas of government intervention, representing 19% of public spending, surpassed only by social protection spending. The importance of the public health sector, measured by its proportion on public expenditure, has also increased over time. It is the sector with the second highest growth rate in government spending in the decade 2007-2017[2] (figure 3.1), representing an increasing share of GDP.

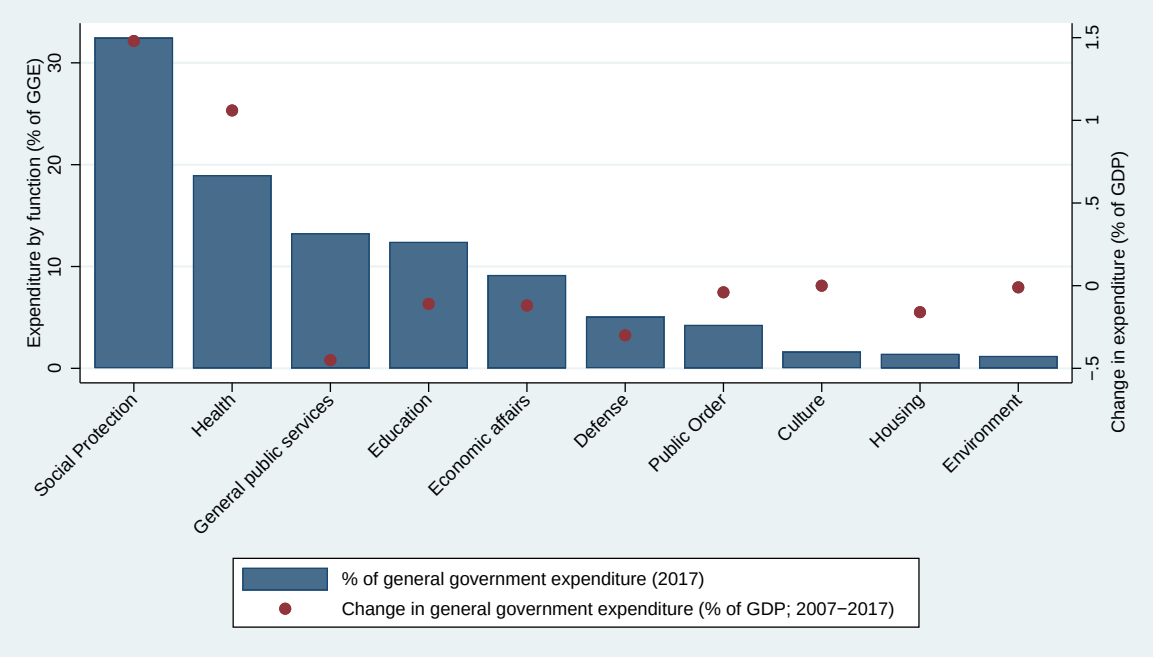


Figure 3.1: Expenditure by function (% of general government expenditure; left axis; 2017) and change in expenditures by function (% of GDP; right axis; 2007 - 2017)

[2]Selected OECD countries: Australia, Austria, Belgium, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States

Total health spending can be funded by compulsory health insurance, voluntary health insurance and out-of-pocket payments. Figure 3.2 displays the composition of health spending for a set of European countries[3] (Eurostat, 2020).

Compulsory health insurance is mandatory expenditure that aims on protecting individuals against negative health shocks. On average, it represents 76% of total health spending, and it can be either public (41%) or private (36%). Compulsory public insurance (which is the focus of this section and will be referred to as "public health spending") is determined by the government, who has the direct responsibility and a specific budget to manage the health program. On the other hand, compulsory private spending represents healthcare protection which is determined by law or by the government based on the payment of contributions by or on behalf of individuals (e.g.: social health insurance, mandatory health insurance,...).

Voluntary health insurance (5% of total health spending) represents spending made by individuals that buy additional health insurance, to achieve higher levels of protection, even if not mandated by the government.

Out-of-pocket payments (19% of total health spending) are direct healthcare payments done by individuals at the point of use. Still, such payment can result from the absence of insurance protection (for instance, if a patient goes to the hospital without insurance and must pay the full price), or from user charges determined by the insurance protection (for instance, co-payments mandated by the insurance firm). Thus, part of these payments is determined by insurance, while the remaining represents a direct decision of the individual to pay for immediate use of health care services or products. However, data in figure 3.2 does not allow to decompose those two effects.

[3]Countries included: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

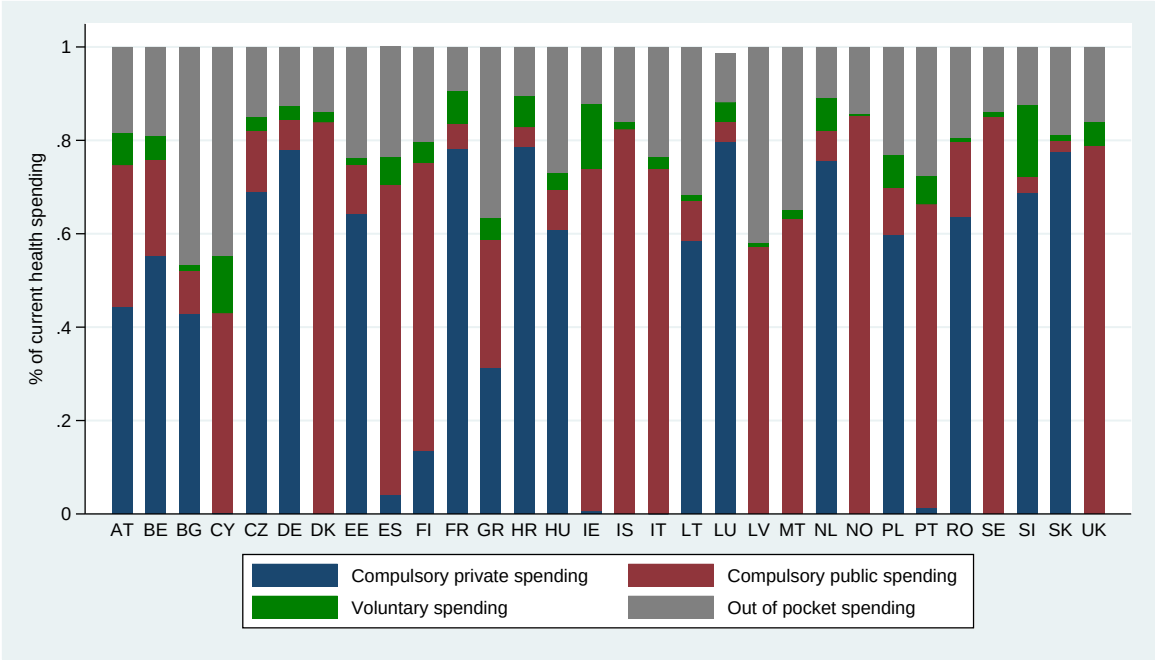


Figure 3.2: Decomposition of current health spending (%; adds up to 100%)

Health spending results from a price and a quantity effect. Higher health spending growth does not necessarily imply the provision of more or better health services. Instead, such growth might reflect cost increases on some of those services. By the same token, cost containment measures might achieve price reductions – which will be reflected in lower health spending, even if the level of health services remains unchanged. Also, health spending levels do not account for debt contracted by the health sector not paid in the current year. By not considering debts, the required spending level for the observed health outcomes would be greater than the one registered for that particular year. One should be careful when analysing health spending data given that the price and quantity effects might not be immediate or clearly displayed by the data.

The importance of public health spending in total health spending varies considerably across countries. The following figure represents such variables relative to the European average (Eurostat, 2020). The European average is used as a benchmark to aggregate countries, but it does not necessarily reflect an optimal allocation. Thus, convergence to the European average should not be seen as a goal or a desirable outcome. One can ob-

serve a positive relation between both variables. Countries with higher levels of health spending (relative to the European average), tend to have higher levels of public health expenditures. There are two exceptions for this behaviour. The upper left quadrant displays one of those: countries where public health spending lies above the European average, while total health spending is still lower than the average. This is the case of Portugal, Spain and Italy. The bottom right quadrant displays the second exception: the case where total health spending is above average, but public spending lies below it. Belgium, France, Luxembourg, the Netherlands and Germany are included in such group.

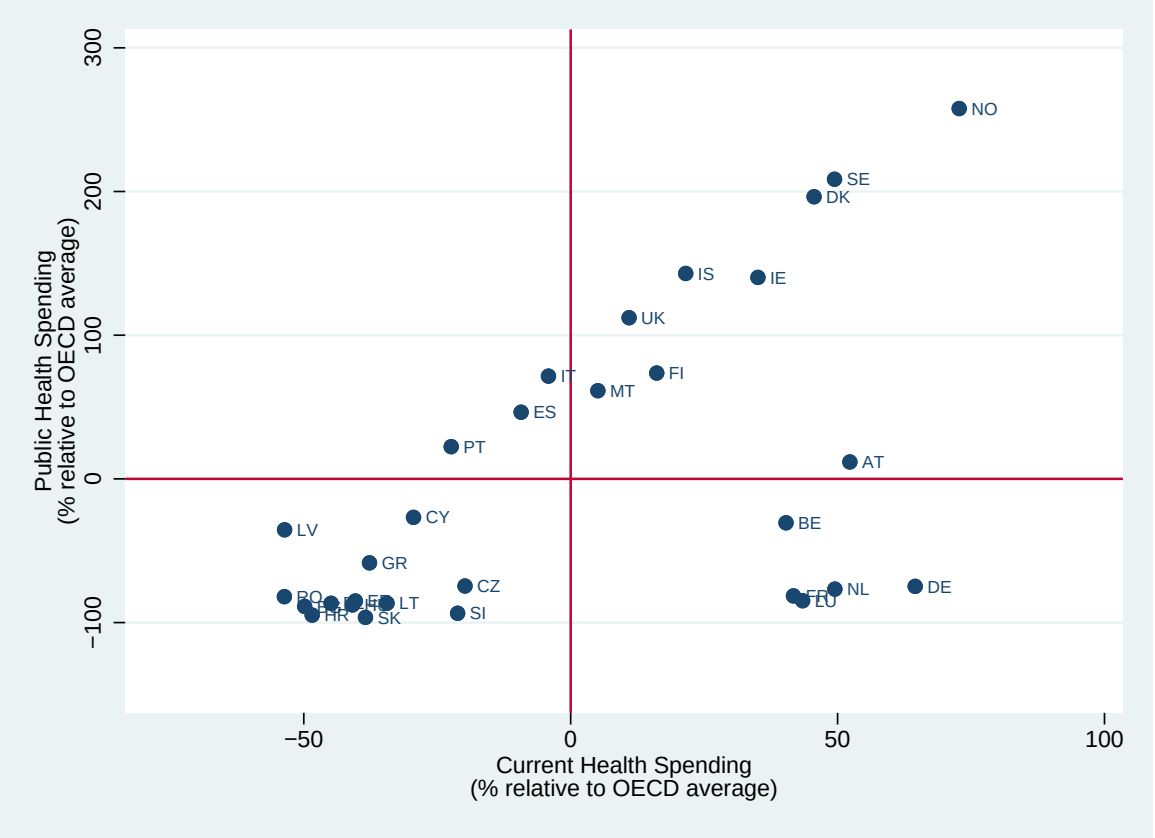


Figure 3.3: Current and public health spending relative to OECD average

The following figure displays growth rates for total and public health spending since 2010 and plots the current share of public health spending on total health spending. Except for Greece, total health spending has increased over this period. Moreover, public health spending and total health spending have a tandem behaviour. However, the share of public

health spending varies substantially across countries – reflecting different health systems organization. Among the 30 different countries, ten have a share of public health spending lower than 10%, while seven have a share higher than 70%.

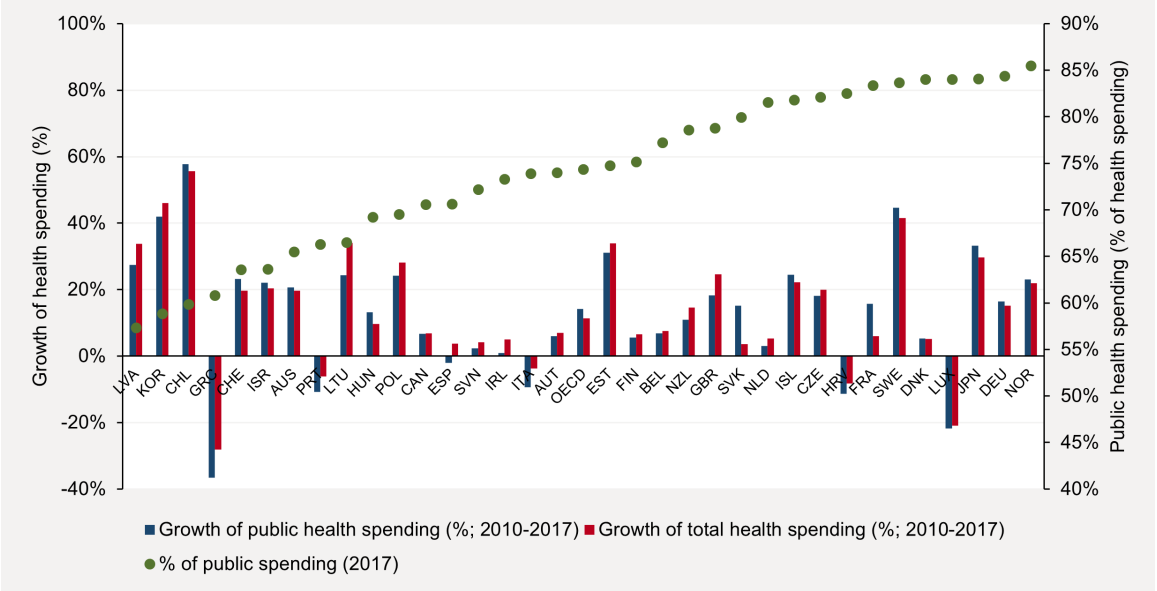


Figure 3.4: Growth of current and public health spending (2010-2018 or closest year; left axis) and share of public health spending on current health spending (2018 or closest year; right axis)

The growth on health spending reflects, among other factors, the roll-out of more expensive innovations, general economic growth (leading to higher aspirations and expectations for health care), as well as changes in demographic structures. On the opposite direction, this growth is also slowed by public policies for cost containment. However, in a context of low economic growth and fragile public finances, such growth imposes significant challenges to the fiscal sustainability of such spending. In fact, total public health expenditure to GDP ratio is projected to more than double between 2015 and 2060, to 13.9% in OECD countries. Even in a more optimistic scenario, where cost-containment measures are enforced, the ratio would still increase by more than half, to reach 9.5% (Oliveira Martins and de la Maisonneuve, 2015). Without significant room to increase revenues, governments need to balance the needs of different sectors. In that sense, public health spending competes with other sources of public spending - such as education or social security for

instance.

The health sector has typically restrictions to market competition as well as entry barriers. Firms in the health sector can also have different objective functions from traditional firms. Ethical behaviour, combined with regulation, may prevent purely profit-maximizing approaches. Additionally, the existence of public institutions or not-for-profit private institutions, can also change market interactions between all agents. This is also a sector subject to significant uncertainty: both on the demand side (uncertainty with respect to diseases incidence and severity), and on the supply side (uncertainty regarding the proper treatment and on its results). Such uncertainty, for a given patient in a certain moment of time, can result on abrupt changes on the health status and income. This is the cornerstone for protection schemes such as health insurance or public health care provision.

Unregulated private health insurance protects from uncertainty. However, such instrument is likely to exclude high-risk patients through very high premiums. Traditional health insurance, in the presence of asymmetric information, is also likely to face the typical problems of adverse selection, moral hazard and other market failures. The existence of public intervention helps counteracting some of these issues and, particularly, contributes to ensure protection for the entire population – preventing groups of patients from being excluded from the health system. Public intervention can take several forms, such as open enrolment rules, mandatory social health insurance, or the direct provision of health services.

Different countries have organized such protection in different ways. This introduces an additional characteristic of the health system: patients do not usually pay directly to providers. In fact, the health sector has typically a third-party, such as an insurance company or a public agency, which is responsible for collecting premiums or taxes from patients and making the payments for providers. Except for user-fees and co-payments, patient's payment occurs through such third-party agent. Such intermediary between con-

sumers and producers of health care, ensures protection and, at the same time, separates funding from provision. In fact, both funding and provision can be either private or public. Different health systems will have different combinations of such mechanism. No evidence supports superiority of a system in detriment of other, as different systems are the result of the evolution of countries social protection schemes.

3.1.2 Measuring public health sector efficiency

Public health spending has multiple objectives. Its main objective is to improve population health, which can be decomposed in terms of its quantity (longevity or life expectancy) and its quality (life quality indicators). This section will focus on both these objectives. Additionally, there are equity objectives of public health spending. In fact, such spending is used to promote access to health care, the protection of vulnerable populations (or specific population groups), as well as to ensure equity in the way the health system is financed. This section also accounts for the analysis of equity in health care access. However, the scope of equity in health system financing is not included here – as it is more related with tax system fairness and efficacy.

What is public health sector efficiency?

Health spending has increased over time and has resulted in improved health outcomes, such as longer and better lives. However, there is significant variability across countries, suggesting different degrees of efficiency of such spending. The following figure represents such relation. The upper right quadrant represents the relation between life expectancy at age 65 and total health spending, while the upper left quadrant displays the relationship with public health spending. By the same token, the bottom right quadrant represents the relationship between total health spending and healthy life expectancy at age 65. The bottom left quadrant displays the relation between that variable and public

health spending.

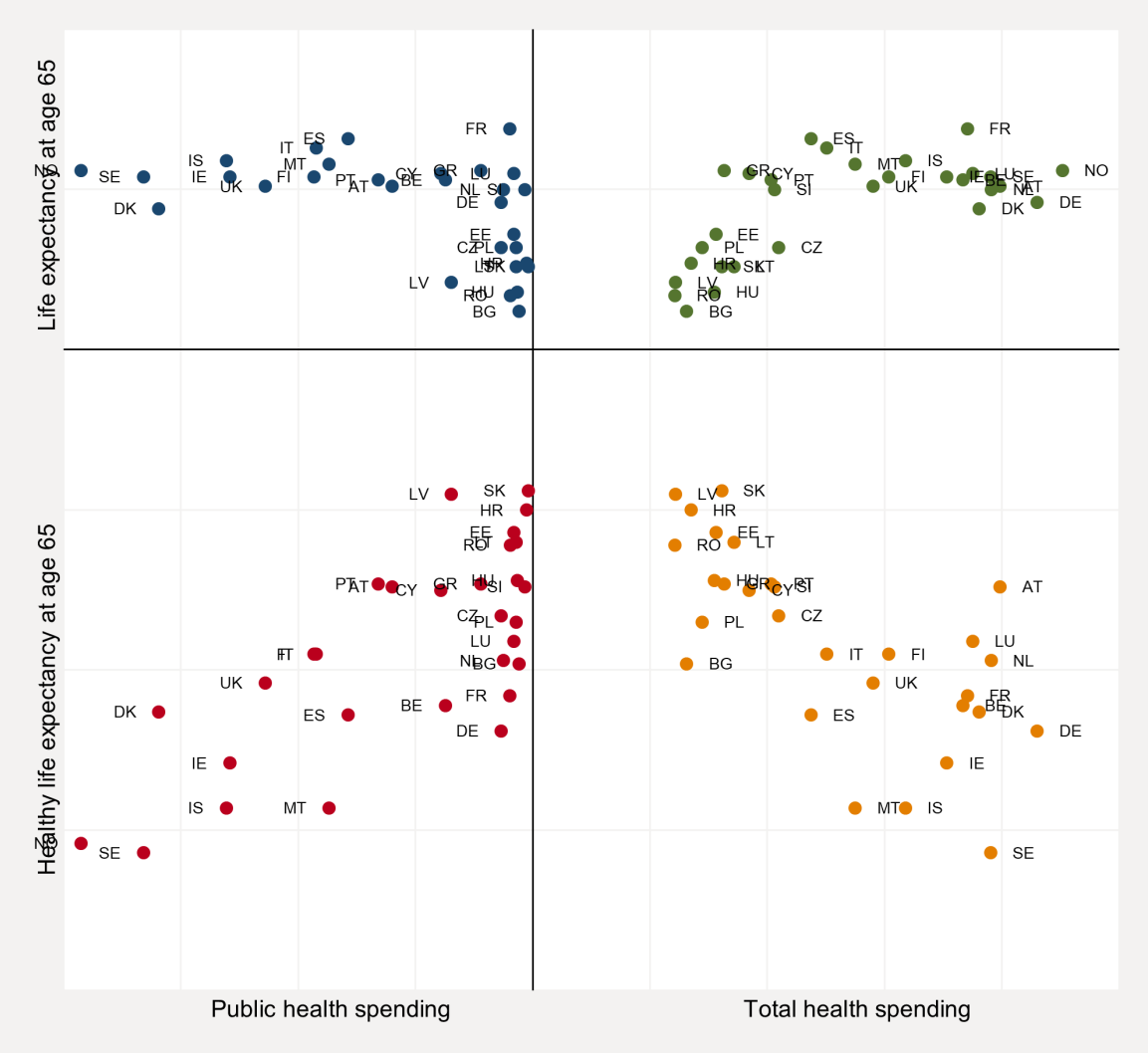


Figure 3.5: Relation between health expenditure and gains in life quality and quantity. Life expectancy at age 65 (top axis – 15 to 25 years) and Healthy life expectancy at age 65 (bottom axis – 0 to 20 years), Per capita public health spending (left axis – 0 to 4,000 euros) and Per capita total health spending (right axis – 0 to 5,000 euros). (2018; Purchasing Power Standard per inhabitant)

There is a positive relation between both total and public per capita health spending with life quantity and quality (captured by life expectancy at age 65 and healthy life expectancy at age 65 respectively). However, one can notice significant variability on per capita health spending levels.

If we focus on the upper right quadrant, we can find examples of those variations. Taking

Czech Republic as an example, one can find other countries with similar levels of per capita total health spending, but with higher life expectancies at age 65. For instance, despite having similar spending levels, Slovenia life expectancy at age 65 is higher by almost two years. Not only is Slovenia able to achieve higher life expectancies at age 65, but it is also able to achieve a healthy life expectancy at age 65 higher by roughly one year.

The same differences can be found when looking towards the relationship between health spending (public and total) with the years of potential life lost across countries. The next figure shows that countries with higher levels of public and total health spending achieve, on average, lower levels of years of potential life lost. However, one can notice again significant differences in outcomes across countries with similar levels of health spending. The existence of such differences raises concerns about whether different health systems have different efficiency levels. If such efficiency differential would be true, then one could implement measures that, for the same health spending level, would improve health outcomes.

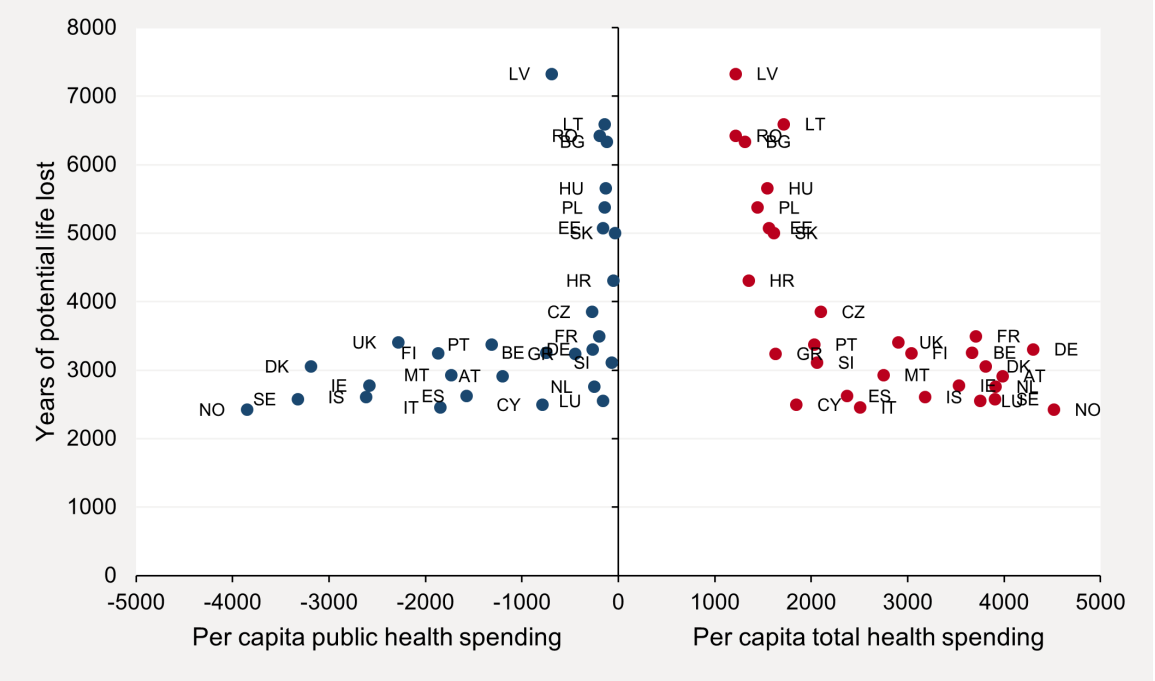


Figure 3.6: Relation between health expenditure and years of potential life lost (rate expressed per 100 000 age-standardised population under 70.). Per capita public health spending (left axis – 0 to 5,000 euros) and Per capita total health spending (right axis – 0 to 5,000 euros). (2017 or closest year; Purchasing Power Standard per inhabitant)

Economists define efficiency as the relation between inputs and outputs. A higher efficiency exists when the same level of inputs achieves higher outputs. Such definition is built upon the concept of production functions, where given a certain technology, inputs are combined and processed into an output. In the health sector, the efficiency discussion can be easily translated to value-for-money or bang-for-the-buck analysis, where spending (public, private or both) is seen as an input in the process of producing health. Inefficiencies in the health sector occur when resources are not being used efficiently. Examples of inefficiencies in the health sector setting can be thought as excessive hospital length of stay, over-prescribing, over-staffing, wastage of stock, among others.

Nonetheless, in economics, the concept of efficiency can mean different things. An important distinction needs to be made between technical and allocative efficiency. Technical efficiency implies that a certain unit, for instance a hospital, is producing at its maximum, with the set of inputs it has (doctors, nurses, beds,...). This implies that such hospital is

working on its production function, without any slack or waste of resources.

The concept of allocative efficiency is stricter, and it implies that money is not being spent on the wrong inputs. This allows for the possibility of selecting the optimal amount of inputs – instead of working with a fixed input level - such that a certain healthcare production level is achieved at the minimum possible cost. Therefore, from the set of technical efficient allocations (all production points lying on the production function), imposing an allocative efficiency requirement implies selecting the production function point compatible with the lowest cost. The following figure illustrates this idea.

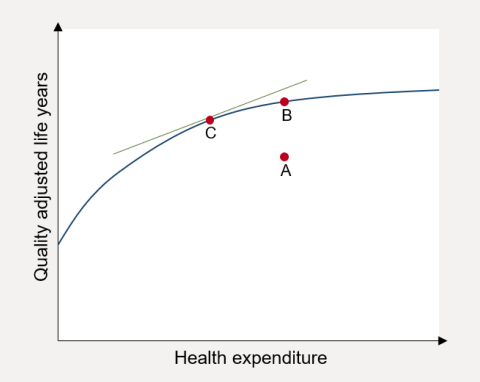


Figure 3.7: Illustration of technical and allocative efficient bundles

The horizontal axis represents health spending, which can be though as the key input used in the production of health. The vertical axis represents such health – measured in both quality and quantity of life terms, which can be interpreted as the quality adjusted life years (QALY). As seen in figure 3.5, countries with different levels of health spending can have different outcomes. The line in the plot represents the production possibility frontier, meaning that all points on and below the line can be attained by the health system. However, given a certain level of health spending, no point above the production possibility frontier can be achieved.

A healthcare system represented by point A is below the production possibility frontier. This means that the current spending level is not achieving the maximum possible output. Point A is therefore technically inefficient. If efficiency inducing measures were to be im-

plemented, the country health system could eventually evolve up to point B (the example of Czech Republic versus Slovenia mentioned above).

However, while point B is technically efficient, it is still allocatively inefficient. Cost-effectiveness thresholds ensure that only treatments that yield QALYs at a reasonable cost are adopted. If we assumed this to be the case, and we consider the green line in the plot to represent the "reasonable" threshold, then point B is allocatively inefficient. Although health spending is being used in an efficient way, we are spending an "unreasonable" amount of money for a given output. An alternative would be to move along the production possibility frontier towards point C. This point would be both technically and allocatively efficient. Point C would therefore be preferred to B since the reduction in health spending involved in getting from C to B would compensate for losses in QALYs. Note that this reasoning hinges on the assumption that we are able to define the "reasonable threshold" for the cost on an additional quality adjusted life year – which is one of the main challenges on cost-effectiveness analysis.

Hence, the concept of efficiency can be represented by a generic indicator such as the ratio of resources to output produced. Under this setting, any deviation from the production possibility frontier would represent inefficiency. However, despite the theoretical framework under which efficiency is analysed seems straightforward, practical difficulties on applying such concept to the health system and, particularly, to the public health sector remain.

One of the main challenges is the determination of the appropriate inputs that should be considered as noted by Cylus, Papanicolas and Smith (2016). Using different inputs will result on different estimates which may bias conclusions. Additionally, one needs to decide on the disaggregation level of inputs (Cylus, Papanicolas and Smith, 2017). At one extreme, a single measure of aggregate inputs might be used – such as the health spending example described above. This approach assumes that agents can freely choose their inputs, given such spending cap. However, for some analysis, such assumption is

unrealistic. For instance, in short run efficiency analysis for hospitals, it may be better to specify inputs at a more disaggregate level – such as physicians, nurses, beds, operating rooms, ...

A second challenge is the relation between inputs and outputs. In figure 3.5, we have seen that, for a similar public health spending level, Slovenia achieved higher life expectancies than Czech Republic. A crude efficiency analysis would then conclude that Czech Republic has an inefficient health system. However, there are factors other than health resources that can contribute for better health outputs. Education, income, or biological characteristics can affect health outcomes. Additionally, many other factors can explain health outcomes, such as health behaviours (smoking, alcohol consumption, drug use, obesity,...). Such multiplicity of factors prevents the development of robust measures of comparative efficiency, as noted by McDaid et al. (2012). Moreover, Cylus, Papanicolas and Smith (2017) argues that health care is tailor-made, with consequent variations in clinical needs, social circumstances, and personal preferences – affecting how inputs are consumed and outputs are produced.

A third challenge relates to the output choice. The relation between inputs, intermediate outputs and health outcomes is complex and multifaceted (Medeiros and Schwierz, 2015). As an example, hospital discharges are usually seen as outputs when in fact they are an intermediate output: health care activities do not necessarily have an immediate impact on improving health. Inputs and outputs differ in often inadequately measured dimensions such as on quantity and quality, or volume and value. Outputs tend to represent health outcomes, such as life expectancy, healthy life expectancy or mortality rates. Depending on the level at which the analysis is being made, outputs may also represent volume of production, such as number of surgeries or doctor appointments at a given hospital. In fact, research is usually constrained on examining efficiency based on outputs instead of on outcomes. Such measures are manifestly inadequate, as they fail to capture variations in the effectiveness and value of the health care provided. For micro-based analysis,

progress is being made in the use of common international metrics, which will allow more solid comparisons. Patient-reported outcome measures (PROMs) and EQ-5D or SF-36 questionnaires are just some examples.

Finally, as highlighted by McDaid et al. (2012), production function approaches typically do not account for other goals of the health system such as user satisfaction, equity, or financial protection. When analysing public health spending one should also consider equity and unmet needs as relevant outputs. This is a significant limitation of current research.

The concept of an aggregate production function is broad and flexible. Such framework can be used to the assessment of very detailed micro units (such as a physician's office or hospitals) or to macro units (such as the entire health system and cross-country comparisons). Even if all factors mentioned above are accounted for, an important question remains: do all countries or units have the same production function? If some institutional features of some units or health systems prevent them to produce as much health as other systems, should this be considered as inefficiency?

Efficiency analysis are often made using descriptive statistics, with benchmark and peer group analysis. However, econometric models can also be used to perform more robust analysis, controlling for some of the issues identified above. The most common methods are the Stochastic Frontier Analysis (Aigner, Lovell and Schmidt, 1977; Meeusen and van den Broeck, 1977), and Data Envelopment Analysis (Banker, Charnes and Cooper, 1984; Boussofiane, Dyson and Thanassoulis, 1991; Charnes, Cooper and Rhodes, 1978).

Stochastic frontier analysis, whose methods have been extensively developed, among others by Kumbhakar and Lovell (2000), allows to estimate the production frontier with an error term that has two components – a random error and a strictly nonnegative term, which captures inefficiency. Data envelopment analysis is a nonparametric method for the estimation of the production frontier using linear programming techniques – without

assuming a particular functional form for the frontier. Jacobs, Smith and Street (2006) provide a set of applications of both these methods in the health sector.

In the empirical literature, many efficiency analyses have been published with the goal of providing rankings for health systems. However, the problems highlighted above prevent fair comparisons to be made. Despite significant contributions, empirical studies still find significant challenges.

The WHO (2000) presents an extended efficiency analysis for over 190 national health systems, based on an empirical estimate of the production function. This production function includes indicators for: overall health level, distribution of health, overall level of responsiveness, distribution of responsiveness, and distribution of financial contribution. By including these five dimensions, the WHO report clearly recognizes goals for the health system other than health outcomes. According to these estimates, France was considered to have the most efficient health system - achieving 99.4% of its potential. Hollingsworth and Wildman (2003) used alternative parametric and non-parametric methods to re-estimate the WHO data. They found that different methods yield different results. Using the same dataset, Green (2004) suggests that there was considerable heterogeneity masqueraded as inefficiency.

Joumard, André and Nicq (2010) argue that efficiency is correlated with quality of care, even though the existing quality indicators still do not have wide coverage to make solid cross-country comparisons. Using DEA, they estimate that life expectancy at birth could be raised by more than two years, holding health care spending constant. OECD (2014) points to significant inefficiencies in the use of resources based on major geographical variation in medical practice across and within countries. Medeiros and Schwierz (2015) estimates EU health care systems efficiency using different models, with different combinations of outputs and inputs – including controls for environmental factors. Their results are aligned with previous empirical research, suggesting that EU life expectancy at birth could be increased by 1.8 years.

Health systems comparisons often ignores different public and private health spending combinations. However, such mix is far from being consensual. A common discussion is whether private spending achieves higher efficiency levels than public spending. On one hand, one can argue that private spending has stronger incentives for efficiency. On the other hand, such private spending does not account for market failures and can lead to a mismatch between profit maximizing and public health goals. Existing literature on efficiency between private and public provision of healthcare services shows inconclusive evidence: one cannot generalise which ownership model is best across countries or even within countries over time (Hsu, 2010). Still, the European Commission and Economic Policy Committee (2010), and the European Commission (2014) have suggested that inefficiencies in healthcare can be associated with non-optimal mix between private and public funding.

Hsu (2010) summarizes the main evidence regarding public and private health spending. Hollingsworth (2008) conducted a meta-analysis of 317 published works on efficiency measures and concludes that "public provision may be potentially more efficient than private". However, such conclusion largely depends on the specific country and health system under analysis. For instance, Lee, Yang and Choi (2009) determined that non-profit hospitals in the United States were more efficient than for-profit hospitals. In Taiwan, Chang, Cheng and Das (2004) found the private sector to be more efficient than the public sector. In Germany, evidence is mixed, with authors finding that private hospitals are less efficient than public hospitals (Helmig and Lapsley, 2001), while others conclude the inverse or no found difference (Staat, 2006). In Switzerland, hospitals' efficiency levels were not predisposed towards inefficiency by type of ownership (Steinnmann and Zweifel, 2003).

3.1.3 An efficiency analysis for the public health sector

This section illustrates some of the trade-offs mentioned above by conducting an efficiency analysis of public health spending for the same set of European countries. Variables were collected from the Health database from Eurostat and the World Health Organization (Eurostat, 2020; WHO, 2020), with a full description available in the appendix. Table 3.1 describes main descriptive statistics for the variables included in the analysis.

Table 3.1: Key variables descriptive statistics (average across countries for 2018 or closest year)

Variable	Units	Mean	Standard Deviation	Minimum	Maximum
Life Expectancy at 65	Years	19.48	1.56	16.20	21.90
Healthy life Expectancy at 65	Years	9.32	3.10	4.40	15.70
Unmet health care needs	% of population	25.26	9.55	9.40	41.80
Potential Years of life lost	per 100k pop (<70yr)	3,820	1,419	2,425	7,329
Catastrophic health spending	% of population	7.96	5.27	1.42	18.38
Public health spending	PPS per inhabitant	1,076.94	1,124.27	38.89	3,852.59
Other health spending	PPS per inhabitant	1,536.36	1,025.61	517.47	4,028.6
Government Balance	% of GDP	-0.25	1.65	-3.70	3.10
Risk of poverty	% of population	21.37	5.53	12.20	32.80
Low education levels	% of population	23.78	9.14	11.70	49.80
Obesity	% of population	16.31	3.23	9.10	25.20
Low fruit & vegetables intake	% of population	35.87	10.64	16.10	65.10
Daily smokers	% of population	19.64	4.94	9.80	28.20

We pursue two alternative analyses, that complement each other. On one hand we estimate a cost function using longitudinal data. On the other hand, we estimate production functions using information for 2018. These two approaches allow us to deal with the limited and incomplete data challenge.

The production function analysis, as described above, focuses on explaining the production of a specific output, with a given set of inputs. The cost function estimation is an approach that looks to the same problem with a different perspective: it estimates the contribution of output (which is a function of inputs), and input prices into an expenditure variable.

As discussed before, one needs to analyse the impact of health spending on different

outcomes. Five different outputs are considered in the 2018 cross-sectional analysis. However, due to data availability issues, only three outputs will be used for the panel estimation. The first outcome is life expectancy at age 65 to capture the goal of promoting longevity. Health spending has also the goal of promoting higher life quality. For that reason, the second output is healthy life expectancy at age 65. The third output is the potential years of life lost as an indicator of premature deaths. Finally, the last two outputs capture equity goals of health spending: unmet needs and catastrophic health expenditures.

Unmet needs represent the share of the population unable to access the health system due to waiting times, financial constraints, or distance/ transportation restrictions. Conversly, catastrophic health expenditures represent the share of the population who bears large health expenditures (greater than 10% of total household income). Catastrophic expenditures can be seen as a proxy for the value of health protection, as the role of health insurance (private or public) is to protect individuals from negative health shocks (and the respective financial burden). The goal of the health system should be to attain high levels of life expectancy and healthy life years, while minimizing potential years of life lost, unmet needs and catastrophic expenditures.

To estimate the cost function, we pursue a fixed-effects panel approach using data from 2008 to 2018 for a set of 28 countries. A stochastic frontier model estimation was used, with time-invariant inefficiency. The cost function estimated can be described by the following equation:

$$C = f(Q, W, X) \tag{3.1}$$

where C represents health expenditure, Q the relevant outputs considered, W a vector of inputs prices - which will be assumed constant or captured by the error term, and X is a vector of other control variables that can affect health expenditures - such as the share of out-of-pocket payments.

On this estimation, the dependent variable is health expenditure. We consider three different models. The first uses total health expenditure as a dependent variable. The second uses only public health expenditure (direct government financing schemes), while the third uses the remaining health expenditure.

As described by the previous equation, independent variables on the cost function are the relevant outputs, input prices, and other control variables. In this analysis we have included three out of the five outputs described above – due to data availability constraints. We assume that input prices have not changed significantly over time. Thus, these were not included in the estimation since their effect is captured by the fixed effect term. The same holds for the set of time-invariant characteristics that could affect the health system cost (such as the type of health system or population characteristics). Additionally, we introduce the share of out-of-pocket payments on lagged total health expenditure as a proxy for financial protection. Table 3.2 displays our main model estimates.

Table 3.2: Stochastic frontier estimates for cost functions (panel data analysis for 2008 - 2018 data)

	(1) Total health expenditure	(2) Public health expenditure	(3) Other health expenditure
Life expectancy at age 65	0.5582	-1.0536	0.1367
	(0.4502)	(1.2707)	(0.4774)
Healthy life expectancy at age 65	-0.0080	-0.1822	-0.0030
	(0.0512)	(0.1446)	(0.0548)
Potential Years of Life Lost	-0.7183***	-1.1052***	-0.6496***
	(0.1028)	(0.2909)	(0.1113)
Share of OOP on lagged total health expenditure	0.1354	0.3302	0.5949***
	(0.1183)	(0.3125)	(0.1100)

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses. Variables in logarithms. 28 countries included. Time-invariant inefficiency.

Results suggest that changes on longevity or life quality do not affect significantly health expenditure (neither public nor private). However, there is a significant impact from the potential years of life lost on all types of health spending. In fact, estimates suggest that lower levels of premature mortality are associated with higher levels of health spending. Such effect is particularly strong on public health expenditure, compared to other health

spending. These results reinforce the importance of health systems on reducing premature mortality.

A cross-sectional production function approach was also performed to complement the previous analysis. This approach uses 2018 data (or closest available year) for the same set of 28 countries. Full estimation results are available in the appendix.

This estimation was done by fitting a stochastic frontier model with a normal/half-normal distribution for each of the five different outcomes. On this production function approach the dependent variable is each outcome.

Independent variables represent inputs that contribute to the production of such output. In fact, this set of outcomes can be explained by multiple factors. We are particularly interested in analysing the role of health spending – which will be divided in four groups of health spending. We are considering health spending as monetary inputs into the production of each outcome considered.

Because different health systems are organized in different ways, interaction dummy variables were introduced to capture the role of public health spending in different health systems' organizations. We classify health systems into four different groups according to the OECD classification and Health Systems in Transition information (Bohm et al., 2012).

The government budget balance is also introduced as an indicator for fiscal space. Large government deficits might prevent significant increases on public health spending, while government surplus might allow them. Additionally, a set of control variables was included as they are likely to affect outcomes. If two countries have the same health system, but the population on one country has a high smoking prevalence, one should expect life expectancy to be lower in that country (Fuchs, 1974). Some controls have been dropped due to data availability and collinearity issues. The final model specification includes the proportion of people at risk of poverty, with low education levels, with obesity, without

daily fruit or vegetables consumption, and share of daily smokers in the population.

The inclusion and availability of additional variables is an advantage relative to the cost estimation. However, results should be taken with a grain of salt since this cross-sectional analysis has a very low number of observations. This prevents very precise estimates. Still, some conclusions can be derived.

Results suggest that public health spending is associated with improvements on longevity and life quality, while declining premature mortality. Countries with National Health Services are associated with significant and large reductions in catastrophic expenditures and unmet needs. This suggests that these systems (usually financed through public health spending) have an important impact in terms of promoting access and providing financial protection for negative health shocks.

It is interesting to notice the role of voluntary insurance in countries with a National Health Service. Results suggest that such voluntary financing scheme plays a role on improving longevity and reducing premature mortality. However, they reinforce unmet needs and catastrophic expenditures.

We also find that the inclusion of the government budget balance as an explanatory relevant is only relevant for countries with a National Health Service. For these countries, higher surplus (which may signal tighter control of public spending) are associated with higher levels of unmet needs and catastrophic expenditures.

Socio-economic factors also play a role on these outcomes. Higher levels of poverty in the population are associated with higher levels of potential years of life lost, catastrophic health expenditures, and unmet needs. Moreover, less educated individuals are associated with higher levels of potential years of life lost and unmet needs.

Health behaviours' variables are also usually aligned with common intuition. Low consumption of fruits and vegetables impacts life expectancy negatively, while increasing

potential years of life lost. Nonetheless, positive effects are found on unmet needs and catastrophic health expenditures. Populations with more obese individuals are also likely to have higher catastrophic expenditures, while lower levels of unmet needs.

Besides analysing the relation between inputs and outputs in the production functions, stochastic frontier models allow us to comment on the relative efficiency of different countries. The model predicts the distance from each country relative to the efficient benchmark (the production frontier). Our cross-sectional model has several limitations – mainly related with data availability and a small number of observations. Nonetheless, one can derive some conclusions relative to inefficiency.

Table 3.3 displays average inefficiency scores for all countries for each of the five different models estimated. Overall, estimates suggest relatively small inefficiencies. On average, countries are close to their production frontiers. However, models for unmet health care needs and catastrophic health spending display higher inefficiency scores, relative to the remaining models. Such pattern suggests inefficiencies in the way health systems deliver financial protection and ensure access to the populations. Thus, access and financial constraints seem to be more relevant than health outcomes to explain health systems inefficiency.

Table 3.3: Average Technical Inefficiency Estimates (Stochastic frontier for production functions: cross-sectional for 2018 data)

Model (Dependent variable)	Average Technical Inefficiency
Life Expectancy at 65	3%
Healthy life Expectancy at 65	5%
Unmet health care needs	10%
Potential Years of life lost	6%
Catastrophic health spending	12%

Different countries have different efficiency scores for each variable, with no systematic pattern displayed. However, we can identify countries which, on average, have higher inefficiency scores for these five outputs. According to this model, the top five countries

displaying higher inefficiencies are Latvia, Greece, Netherlands, Slovakia, and Slovenia. Similarly, it is possible to identify countries with low inefficiency scores. The top five countries with the most efficient health systems are Belgium, Bulgaria, Poland, Hungary, and Romania.

Interestingly, no particular health system is associated with higher or lower inefficiencies. In fact, both groups of countries (more and less efficient) have Eastern European countries and similar health systems. With few exceptions, all countries on both groups have health systems financed on a societal basis with private or societal provision. Thus, no specific pattern is associated with having higher or lower inefficiency scores. Results suggest that different health systems can be equally efficient on the production of health. Drivers for efficiency might be related to specific mechanisms within each health system, which are not easily identified or observed on these macro comparisons.

3.1.4 Conclusions

Health spending has increased over time in developed economies. In a context of low levels of economic growth and fragile public finances, there are concerns regarding the growth limit for public health spending. Therefore, the quest for efficiency in the health sector remains a major priority for governments. However, efficiency in the health sector, and particularly within public spending, is very hard to define. In fact, the health system has multiple goals. Additionally, different types of health spending contribute differently to attain each of those goals.

Research on health spending efficiency has been made, both with macro and microeconomic perspectives. Efficiency analysis is often conducted within a production function approach. Still, there are questions that remain unanswered: for instance, researchers struggle on determining which inputs and outputs to analyse. Different choices lead to completely different conclusions. Additionally, production functions' approaches typi-

cally do not account for other goals of the health system such as user satisfaction, equity, or financial protection.

In this chapter, we perform an efficiency analysis using both cost and production functions estimations. With our estimations, we highlight that health spending sources contribute differently to the numerous health system goals. Results suggest that public health spending has a role on promoting access and providing financial protection to the population. Nonetheless, other forms of health spending also contribute to the general goals of the health system.

When defining measures to improve efficiency of public health spending, governments should not ignore the contribution of such expenditure to attain some of the goals of the health system. This seems particularly relevant on National Health Service settings.

Further research is required to better understand the connection between the types of spending and the organization of health systems. Also, there are complement and substitution effects between the different sources of health spending which might be interesting to explore.

3.2 The Economic Impact of the Health Workforce in Health Systems[4]

3.2.1 HR in Healthcare

When a gunshot-wound patient enters the emergency room of a central hospital, a team of doctors, nurses, and other staff is immediately mobilized to stabilize the patient and restore her condition. The interaction between these different professionals is key to achieve good outcomes in the healthcare system. Additionally, the interaction between these human resources (HR) and non-human resources (such as technology, facilities, drugs...) is also essential for the success of such endeavour.

As each of these inputs is scarce and expensive, when designing the healthcare system, a policymaker needs to consider their economic impact. In other words, when deciding the reference skill-mix, one needs to select the optimal allocation of inputs and their quantity, such that a desired level of care is assured, at the minimum possible cost. Such decision must be made at the level of each organization, which can differ from the country average level.

In this section we provide an assessment of the efficiency of health systems, using an aggregate production function as a representation of the broad features and characteristics of health systems, to highlight the role of doctors and nurses. We find that inefficiencies, in the sense of resources' waste, do not seem to be a result of different human resources policies, here captured as different nurses to doctor ratios. However, different ratios lead to different costs. Thus, using a constant elasticity of substitution production function, we estimate the excess cost faced by health systems associated with non-optimal nurses

[4]Original research published in: Costa, E. and Barros, P.P. (2021), "Economic Impact of Human Resources in Health Systems", Fronteira, I., Dussault, G. and Buchan, J. (Ed.) *Rethinking Human Resources for health - On the edge of the Post-Modern Era*, Almedina, pp. 87-106.

to doctor ratios.

Despite significant investments in technology over the last decades, HR expenditure in healthcare does not seem to decrease in absolute terms. In fact, it may be the case that technology-driven savings are lower in healthcare when compared to other sectors. This effect, known as the Baumol disease (Baumol, 1993), suggests that productivity in healthcare increases at a slower pace than in other sectors. Hence, leading to health expenditure (and HR expenditure) growth (Atanda, Menclova and Reed, 2018).

It is difficult to obtain a very precise measure of HR spending in healthcare across countries given the lack of comparable data on the number of doctors and nurses, as well as on the respective wages, across countries. Based on available OECD data, we estimate that core HR expenditure, including only physicians and nurse's wages, amounts to at least one fourth of total healthcare expenditure. If we include all other health services staff, this share would increase significantly. Estimates point that high-income countries HR expenditure represents to 38% of total spending (Hernandez-Peña et al., 2013).

In 2015, more than 10% of the OCED labour force was employed in the health and social work sector. Nordic countries, such as Norway or Denmark, were at the top of this ranking, with around 20% of their labour force working in the health sector. The proportion of workers employed has increased by 42% since 2000 (OECD, 2017). Therefore, when discussing policies, particularly related to the supply side, that aim to slow down the growth in health spending, it is difficult to ignore policies that deal with HR.

Taking a closer look at healthcare HR in OECD countries, and focusing only on physicians and nurses, one notices that the increase in health spending is partially a result from the increase of the sector's workforce. On average, from 2000 to 2015, the number of doctors per 1000 population increased from 2.6 to 3.1, while that of nurses increased also from 7.0 to 8.5. These increases are common across most countries with the exception of Russia, where there was a small decline in the number of doctors, as well as the UK and Israel

with a reduction on the number of nurses.

Countries like Austria or Norway exhibit a very high proportion of doctors per 1000 population (5.1 and 4.7 respectively), while Switzerland and Norway, again, have more than 17 nurses per 1000 people. However, less developed countries like China, Turkey, South Africa or India have still less than 2 doctors and less than 3 nurses per 1000 population.

The significant increase in both professional categories, did not change the relative number of nurses per doctor substantially. In 2000, the 22 countries in our sample, had on average 2.7 nurses per doctor. This ratio evolved slowly over time, reaching 2.8 nurses per doctor in 2015. Japan, Finland, Denmark, or the US are the countries with more nurses per doctor (between 4.4 and 4.6), while Spain, China, Mexico or Turkey rank among the countries with less nurses per doctor (a ratio close to one).

The striking differences among the nurses to doctor ratio suggest that the role of doctors and nurses changes across countries. This raises immediate questions: what is the optimal combination between nurses and doctors? Is such optimal combination common to all countries?

Folland, Goodman and Stano (2013) note that health professionals often recognize only one correct way of treating a given illness, meaning a fixed ratio of nurses to doctors, which is seldom true. Such restrictive approach prevents policymakers from achieving cost-savings substitutions without impacting the quality of care provided. Instead, if there is some flexibility in the way human resources are combined on treating a given illness, namely in terms of who treats and how are teams composed, then cost-saving improvements might be possible without sacrificing outcomes or quality of care.

To understand if the healthcare sector has such flexibility, we need to consider questions as whether nurses can substitute some functions that are currently performed by physicians. This discussion has become popular given the shortage of physicians, strong economic constraints, as well as the need for high-quality care. Such concern is shared by most

developed economies, as well as by developing countries. In fact, health workers and health employment are the basis that led to the recent creation of the UN High level Commission on Health Employment and Economic Growth. Such commission has been tasked to promote health sector jobs as a channel to foster economic growth, particularly in low- and middle-income countries.

Typical proposals range from nurses managing chronic patients or following low-risk pregnancies, to providing follow-up care to multi-morbid patients. These grey areas are usually very controversial. On one side, doctors argue that patients will be harmed and overall quality reduced. On the other side, nurses claim that contemporaneous training has prepared them for those responsibilities. Nonetheless, regardless of the legal and political barriers, this substitution is already a reality (Maier, Aiken and Busse, 2017; Temido, Craveiro and Dussault, 2015). In fact, countries with a high gap between doctors' and nurses' wages, tend to have higher ratios of nurses to doctor.

Such substitution between nurses and doctors could have two important effects. On one hand, one may think that such shift could generate immediate cost savings for the system, since a nurse is usually cheaper than a doctor. On the other hand, such shift can reduce physicians' workload, which allows to improve health system's capacity.

The substitution idea is not self-contained by the doctor versus nurse example. In fact, one can think also on the substitution between nurses and auxiliary staff, doctors, and administrative staff, or even HR and technology. At each of these levels, a decision must be made to determine the input allocation compatible, not only with no waste of resources, but also with achieving the lowest possible cost. Nonetheless, this aggregate view does not substitute the analysis at the level of each organization.

The next section sheds some light on the impact on health outcomes of having different nurses to doctor ratio. Afterwards, we find the efficient allocation of nurses to doctor and map the cost associated to such inefficiencies. Finally, the last section summarizes the

key messages one should bear in mind when thinking about the economic impact of HR in healthcare.

3.2.2 Do HR policies impact health outcomes?

The increase in health care spending threatens health systems' financial sustainability, in the sense that health spending has typically outpaced economic growth in most OECD countries. Any attempt to control or mitigate this growth must also address HR spending.

From a hospital administrator perspective, both doctors and nurses, as well as the remaining staff, contribute to the same output (healthcare), although with different productivities and costs. Hiring a nurse is cheaper than hiring a doctor, but a nurse is not expected to provide the same range of services as a doctor. These two labour inputs are not perfect substitutes. However, there is some degree of substitution between them. There are some tasks that both doctors and nurses can perform reasonably well. Based on these, one can determine the efficient combination of doctors and nurses.

Before proceeding, it is important to define this concept of efficiency, which in turn leads to introduce the idea of a production function for healthcare. In this context, we consider that different staff, drugs, beds, technology, among other factors interact to produce healthcare services.

If each hospital produces the maximum possible amount of healthcare, with the set of inputs it has (doctors, nurses, beds,...), then it is technically efficient. In other words, this hospital is working on its production function, without any waste of resources. This happens if the hospital is unable to increase its production given the available inputs. Technical efficiency implies that teams are cooperating, machines are working properly and at full capacity, such that the hospital is operating at its maximum.

So far, we have assumed the hospital works with a given set of inputs. However, if the

hospital administrator has also room to choose the quantity of each input, then there might be room for improvement. This is the concept behind allocative efficiency: the hospital selects the optimal amount of inputs, such that a certain healthcare production level is achieved at the minimum cost. This definition is stricter than the technical efficiency, since it introduces the idea of optimizing input choices given input prices. For instance, a hospital administrator may decide to increase the proportion of nurses relative to the number of doctors, if the cost of hiring a nurse is significantly lower than the one of a doctor.

Therefore, from the set of technical efficient allocations (all production points that lie on the production function), imposing an allocative efficiency requirement implies selecting the production function point compatible with the lowest cost.

For the following analysis, we use data from 2000 to 2015 for 22 OECD countries, though we do not have all time periods available for all countries. We are considering North American countries, European countries, as well as Australia and New Zealand. For each country, data on life expectancy, nurses, doctors, hospital beds, transplants, wages, and other health-related controls was collected[5]. These controls included proportion of CAT scans in the population, alcohol consumption, air pollution, smoking habits, proportion of elderly in the population, as well as obesity prevalence.

Using stochastic frontier analysis, we estimate a production function for life expectancy. Such estimation gives also the respective efficiency score estimate for each country. The efficiency term captures wasteful allocations of inputs, which can signal effects such as lack of teamwork among staff, incorrect proportion of doctors and nurses, or poor management practices. This inefficiency is usually associated with lower health outcomes, as argued by McKay and Deily (2008). Details on the estimation methods can be found in appendix.

[5]Sources: http://www.oecd.org/els/health-systems/health-data.htm and http://www.transplant-observatory.org/

In the production function estimation, both inputs and outputs need to be specified. Measuring health output is not obvious. It is difficult to choose simultaneously a measure of population health status that captures healthcare related aspects, and that can be measured accurately (Folland, Goodman and Stano, 2013). Considering the goals of a health system, we use life expectancy as the output of the production function. If a country uses its inputs correctly, its population can achieve a longer life expectancy.

Estimations were performed using life expectancy at birth, at the age of 65, and at the age of 80 years old. Using these different measures allows to test the robustness of the estimation, as well as to understand how the impact of certain variables change depending on the indicator.

Usually, economists think about production as a function of an aggregate technology level, which transforms labour and capital inputs into an output. In this context, we consider as labour inputs the proportion of doctors and nurses in the population. As a proxy for capital, we use the proportion of hospital beds in the population, as it signals the investment made. Finally, technology level is proxied by the proportion of complex transplants (heart and lungs) in the population.

It is likely that life expectancy is affected, not only by the healthcare system, but also by the population lifestyle (Fuchs, 1974). To capture health behaviours, we include smoking habits, alcohol consumption and obesity. Finally, we also include demographics characteristics, namely the proportion of elderly individuals in the population, as well as for environmental factors, such as air pollution (Cropper et al., 1997). Other tests were performed, and some variables were dropped due to collinearity, time stability and data availability.

Table 3.4: Description of variables

Variable	Definition	Units
Doctors	Number of physicians	Per 1000 population
Nurses	Number of nurses	Per 1000 population
Beds	Number of beds	Per 1000 population
Transplants	Number of heart and lung transplants	Per million population
Air Pollution	Emissions of carbon dioxide	Tonnes per capita
Alcohol consumption	Consumption for individuals with more than 15 years	Litres per capita

Detailed results can be found in the appendix. Estimates suggest that, for countries with low levels of doctors and nurses, an increase in the number of doctors contributes to increase life expectancy. However, this impact declines with the number of doctors. Also, changes in the number of nurses seem to have a close to zero impact in life expectancy.

Considering life expectancy at birth, one can also observe that countries that perform more complex transplants, such as Spain or Switzerland, also achieve better health outcomes.

The same happens with the number of beds in most periods considered. An increase in the number of beds, capturing the investment and capacity of the health system, leads to a significant increase in life expectancy. The number of beds was analysed in each year, comparing with the baseline year 2000, to isolate the time trend. Throughout time, the number of beds has been decreasing to increase efficiency and reduce hospitalization durations. The interaction between the number of beds and each year allows to control for this effect, capturing only the contribution of beds in life expectancy. Also, it is interesting to notice that the reduction in the number of beds has a different impact in each year due to changes in technology. Everything else constant, to achieve the same output in both 2015 and 2005, it would be necessary to have three times more beds in 2005 than in 2015.

Finally, control variables also present significant results on some specifications. In fact, both air pollution and alcohol consumption, capturing environmental and lifestyle, seem to negatively impact life expectancy.

These estimates represent the set of allocations compatible with a technically efficient

use of inputs. However, not all countries are equally efficient in the production of life expectancy. Some countries, with the same inputs, achieve lower life expectancies, even after controlling for country specific characteristics such as air pollution or alcohol consumption.

Such deviations from the estimated frontier are partially due to inefficiencies at the country level, such as poor management practices, under-utilized equipment, lack of team cooperation, and others. Efficiency scores can be estimated for each of the 22 countries analysed, as shown below:

Table 3.5: Efficiency estimates

Dependent Variable	Minimum	Maximum	Average
Life Expectancy at Birth	91%	100%	98%
Life Expectancy at 65	80%	100%	95%
Life Expectancy at 80	74%	99%	92%

Efficiency estimates are time-invariant and country specific. Conditional on the dependent variable considered, efficiency ranges from 74%-91% up to 100%, depending on countries. Ranking countries according to their efficiency scores yields similar results, regardless of the variables considered.

Eastern European countries, such as Hungary, Czech Republic, Latvia, or Poland, are typically the countries with higher inefficiencies. Conversely, countries such as Luxembourg, Australia, Canada, or Italy are ranked consistently as countries with efficient allocations.

There are multiple factors that might explain the inefficiency pattern. However, a different nurse to doctor ratio does not seem to be a relevant one. Figure 3.8 represents the relationship between efficiency and nurses to doctor ratio. The figure does not suggest that countries with higher nurses to doctor ratio yield higher efficiency. In fact, this relation is not statistically significant at 5%.

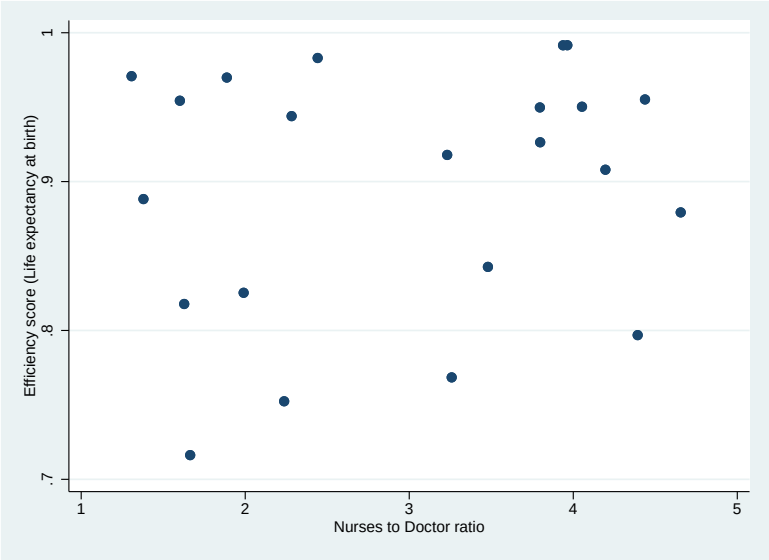


Figure 3.8: Relation between efficiency estimates and nurses to doctor ratio

This result suggests that, although not all countries are technically efficient in the production of life expectancy, different human resources policies (and specifically, different nurses to doctor ratio) do not seem to be driving such inefficiencies.

3.2.3 Do HR policies impact health costs?

Different nurses to doctor ratios do not seem to impact the efficient production of life expectancy. However, this does not mean that any nurses to doctor ratio is optimal. Given that nurses and doctors receive different wages, with doctors receiving usually higher wages than nurses, a lower proportion of nurses to doctor may signal higher costs faced by the health system.

The degree to which costs are affected by different nurses and doctor ratios, depends on the substitutability between these two inputs. The idea of substitution between health inputs has been around for a long time. Multiple studies have already identified this substitution effect between doctors and other staff. Brown (1988) shows that office-based physicians underutilize their aides, whereas Martínez-González et al. (2015) and

Laurant et al. (2005) found that specially trained nurses can provide primary care management of chronic diseases yielding some improvements in outcomes. Jensen and Morrisey (1986*a*,*b*) explore substitution effects in teaching hospitals and Okunade and Murthy (2008) investigate the substitution or complement effects on mental health professionals. Research shows that one physician extender, for instance nurses or physicians aides, could substitute 25% to 50% of a doctor's services (Brown, 1988; Deb and Holmes, 1998; Liang and Ogur, 1987; Okunade and Suraratdecha, 1998).

As discussed before, this depends on the organization of the health system, HR training and the legal framework in each country. This task shifting discussion is very much present in the public debate and involved in controversy. Policymakers usually argue in favour of broadening nurses' responsibilities to areas traditionally covered by physicians. Some examples of these discussions are the low-risk pregnancies' monitoring, chronic patients' management, or even standard medicines prescriptions (Temido, Craveiro and Dussault, 2015).

Regardless of the actual spectrum of action for nurses, some substitution is already in place. Following the usual cost minimization problem, which is derived in the appendix, under a Constant elasticity of substitution production function, an increase in the relative wage of doctors implies a reduction on the proportion of doctors (relative to nurses). Conversely, if the relative wage of doctors decreases, the nurses to doctor ratio should also decrease.

This can be observed using the same dataset as before, despite less data for wages is available. For instance, Canada, Germany, and Luxembourg exhibit large gaps between the wage paid to doctor and nurses, leading to high nurses to doctor ratios. Conversely, countries such Spain or Poland, where the wage difference is not as significant, tend to have lower nurses to doctor ratios.

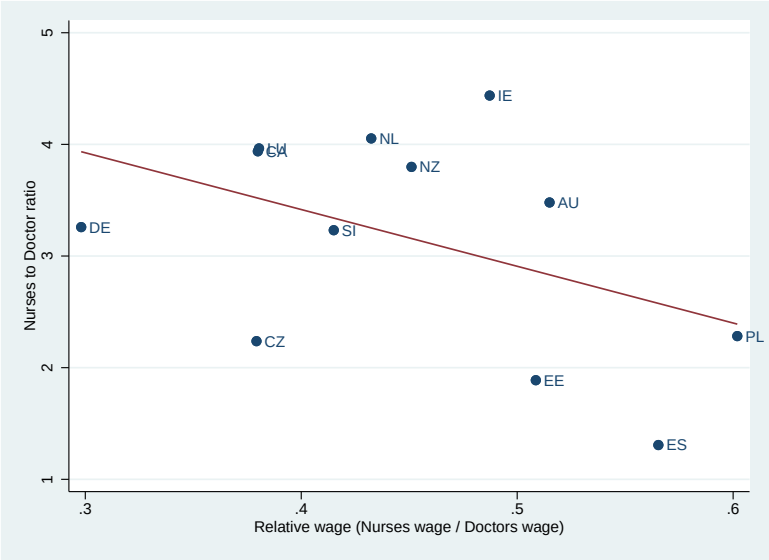


Figure 3.9: Relation between nurses to doctor ratio and relative wages (average values from 2000-2015)

Empirically, one must specify an equation that relates the nurses to doctor ratio with their respective wages, considering this substitutability between inputs. Following the results from Vita (1990), we use a constant elasticity of substitution production function, in which doctors and nurses act as inputs with some degree of substitution in the healthcare production function.

By solving the cost-minimization problem (full details in appendix), we estimate that the elasticity of substitution between doctors and nurses is close to 0.2. This means that a 1% change in the relative nurses to doctor wages, leads to a 0.2% change in the nurses to doctor ratio. This elasticity of substitution is aligned with common estimates from the literature. For instance, such elasticity is in-between the estimates from Jensen and Morrisey (1986*b*) between nurses and doctors for teaching hospitals (0.55) and non-teaching hospitals (0.16).

Even without considering specific initiatives to increase the span of activities performed by nurses, health systems are intrinsically designed based on relative costs. Countries with large gaps between physicians and nurses' wages, are likely to have relatively more

nurses per doctor.

Using such elasticity as well as wages data, one can derive the optimal nurses to doctor ratio. This ratio is compatible with the cost minimization problem, implying allocative efficiency. The optimal ratio ranges from 3.5 to 4.0 nurses to doctor, depending on the country. New Zealand, Canada, Australia, and Luxembourg exhibit nurses to doctor ratios close to their optimum levels. On the other hand, countries such Spain, Estonia, Poland and Czech Republic display nurses-to-doctor ratios significantly lower than the optimal ones. On average, countries considered are 16% below their optimal level.

Given such deviations one can estimate the current cost faced by the health system with the predicted cost from using optimal nurses to doctor ratios. Not surprisingly, countries close to their optimal ratio have small cost deviations. This shows that countries with a non-optimal ratio face higher costs, failing to achieve the cost minimization benchmark. Details on how to compute the excess cost can be found in the appendix. Figure 3.10 represents this situation. In point 1, the policy-maker is selecting an efficient nurse to doctor ratio $(\bar{\gamma})$, which then leads to the minimum cost $(\bar{C})$, given a certain production level $\bar{Y}$. In point 2, however, a non-optimal ratio is selected (γ). Following the previous section results, a non-optimal ratio can still be compatible with the same output. However, it leads to an excess cost, represented by the difference between the cost lines C and $\bar{C}$.

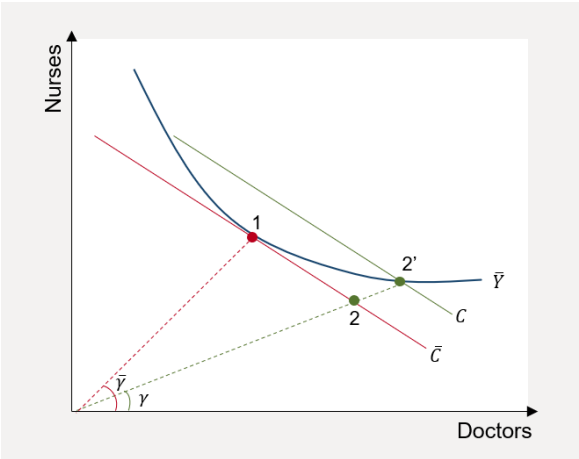


Figure 3.10: Impact of non-optimal ratios on health outcomes (Y) and costs (C)

On average, the estimated excess cost associated with non-optimal ratios represents 8% of HR expenditures across the countries in our sample (table 3.6). This changes significantly depending on how far each country is from its optimal ratio. For instance, Spain has a cost up to 36% higher than the one it would have should it converge to the optimal ratio. Similar results are obtained for Portugal, with an estimated HR excess cost of 28%.

Table 3.6: Optimal ratios and excess costs estimates

Country	Current ratio (Nurse / Doctor)	Relative wage (Nurse / Doctor)	Optimal ratio (Nurse / Doctor)	Deviation	Excess Cost
Australia	3,5	37%	3,3	5%	0%
Belgium	3,2	38%	3,3	-1%	0%
Canada	3,9	29%	3,5	13%	1%
Czech Republic	2,2	51%	3,1	-29%	7%
Denmark	4,4	42%	3,2	36%	6%
Estonia	1,9	49%	3,1	-40%	14%
Finland	4,7	42%	3,2	43%	9%
France	2,4	35%	3,3	-27%	6%
Germany	3,3	45%	3,2	2%	0%
Hungary	2,0	51%	3,1	-36%	11%
Ireland	4,4	34%	3,4	32%	5%
Italy	1,6	42%	3,2	-50%	27%
Netherlands	4,1	29%	3,5	17%	2%
New Zealand	3,8	51%	3,1	22%	3%
Norway	3,8	62%	3,0	26%	3%
Poland	2,3	64%	3,0	-24%	4%
Portugal	1,4	65%	3,0	-54%	28%
Slovenia	3,2	41%	3,2	-1%	0%
Spain	1,3	54%	3,1	-58%	36%
United Kingdom	3,8	42%	3,2	17%	2%

Hence, improvements on HR practices might result in significant savings in healthcare systems' budgets. Promoting efficiency in HR allocation might contribute to slow down the growth of health expenditure.

3.2.4 Conclusion

Since 2000, there was a significant increase of more than 40% in the employment on the health and social work sector, representing over 10% of total labour force in OECD countries. The increase in the health work force, reflected for instance in the increase in

the number of doctors and nurses, imposes a significant burden in health expenditures. Estimates show that around 38% of healthcare spending is related to human resources in developed economies.

Fragile economic conditions, shortage of physicians, and increasing needs for follow-up on multi-morbid patients, have raised concerns regarding whether nurses can replace doctors in some functions. This task shifting discussion is extremely controversial, but hinges on the principle that there is at least some degree of substitution between doctors and nurses.

Using a stochastic frontier model, we confirm that countries that devote more resources to healthcare (beds, doctors, nurses) and have better technology achieve better health outcomes – here captured by life expectancy. We also find that air quality and alcohol consumption may negatively impact life expectancy. Still, not all countries are technically efficient, in the sense that they are not always on the production function – producing the maximum possible life expectancy given the resources they have.

Inefficiencies range from 26% to 0% depending on the country and on the variables considered. However, no evidence is found that different nurses to doctor ratios explain such inefficiencies. Still, regardless of being able to achieve the same outcomes, different nurses to doctor ratios lead to different costs.

Using a constant elasticity of substitution production function, we observe that the substitution between nurses and doctors is already a reality. Countries where the wage gap between nurses and doctors is larger are also countries that use nurses more intensively.

Finally, we investigate whereas non-optimal nurses to doctor ratio would lead to higher costs if the optimal production were to be achieved. We estimate that countries face, on average, up to an 8% excess cost due to non-optimal nurses to doctor ratio. Our results suggest that ignoring substitution effects between nurses and doctor increases the allocative inefficiency of the health system, leading to higher costs.

3.3 The Portuguese NHS Sustainability[6]

This section presents an analysis on the Portuguese NHS financial sustainability and a forecast for health spending growth. In this analysis, financial sustainability is a function of economic growth, and depends on the level of control of other public spending. Results show that under two alternative definitions – both related to fiscal space and compliance with sound public finances - public health spending growth is limited.

3.3.1 Background on the Portuguese NHS

The Portuguese constitution defines access to health care as universal and virtually-free at the point of use to the population. To ensure this objective, the Portuguese State provides health care through a National Health Service (NHS). Additionally, two other layers of protection systems co-exist: profession-based health insurance schemes (known as health-subsystems, the largest one covers civil servants), and private voluntary health insurance.

The NHS is responsible for ensuring universal access to health care, mostly through the direct provision of primary and hospital care. The NHS primary care system is a network of small units across all territory. In these units, GPs provide day-to-day care to the population enrolled and act as gatekeepers for hospital care access. Hospital care provides acute and specialized care. Hospitals are usually located on larger urban centres. Additionally, a national network for social care provides long-term care, social support, and palliative care. This network includes teams from the public sector, the for-profit, and the not-for-profit private sector.

Dental consultations, diagnostic services, and rehabilitation are more commonly provided

[6]Original research published in: Costa, E., Santos, R. and Barros, P.P. (2021), "The Financial Sustainability of the Portuguese Health System", Baltagi, B.H. and Moscone, F. (Ed.) *The Sustainability of Health Care Systems in Europe (Contributions to Economic Analysis, Vol. 295)*, Emerald Publishing Limited, Bingley, pp. 209-229. https://doi.org/10.1108/S0573-855520210000295017

by the private sector – although highly subsidised by public funding in the latter. Private health providers also deliver primary and hospital care.

Overall, the Portuguese health system ranks relatively well when compared to other health systems. For instance, the World Health Organization (Evans et al., 2000) places the Portuguese Health System as the 12th best health system out of 190 different countries. Although some health indicators such as life expectancy at birth have shown a notable improvement over the last decades, there are still significant caveats in other areas – such as mental health, health inequalities or dealing with an aging society.

Health spending in Portugal

Portugal' health spending represents 9% of its GDP (OECD, 2019*b*). Although this value is aligned with OECD average, it does not seem particularly efficient in the production of life expectancy (figure 3.11). In fact, Poland or Estonia achieve similar efficiency levels with lower expenditures[7]. On the other hand, for the same efficiency level, Portugal spends less than Germany, Belgium, or Denmark.

[7]Efficiency estimated using a stochastic frontier estimation of life expectancy as a function of health expenditure (% of GDP).

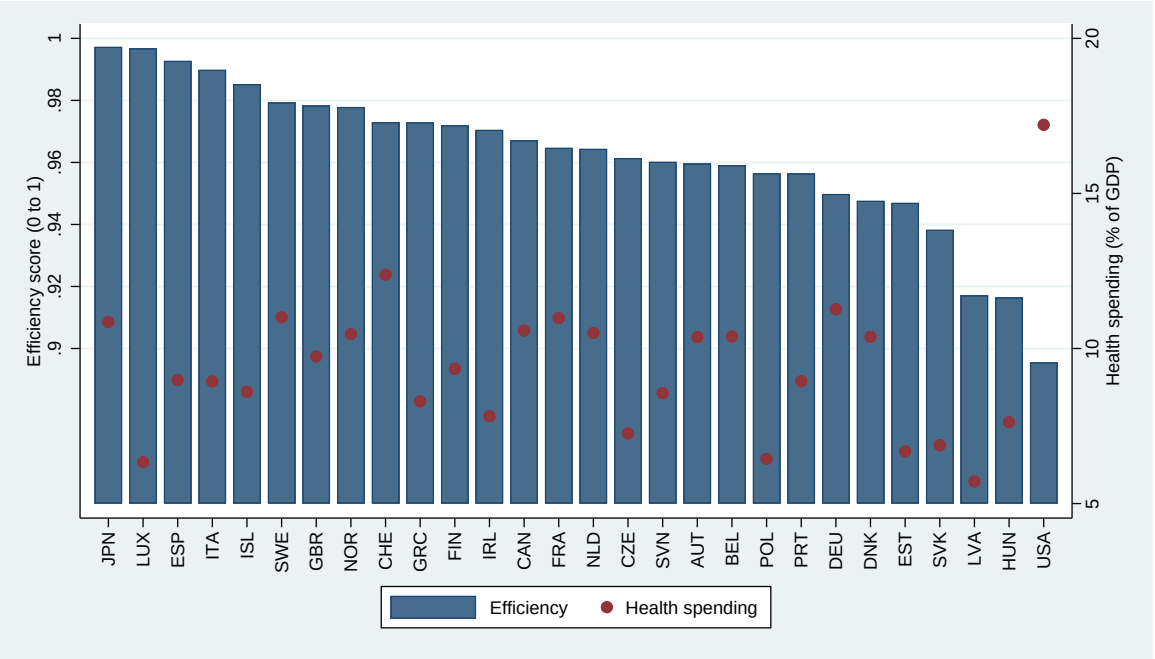


Figure 3.11: Health spending (2016; % of GDP – right axis) and efficiency in the production of life expectancy (2000-2016; % - left axis)

In per capita terms (economy-wide PPP), Portugal health spending amounts to 2,861 USD (below the OECD average of 4,210 USD). Per capita health spending in Portugal has increased at an annual rate of 3.1% since 2000, well below the OECD average (4.7%) (Figure 3.12). In fact, countries with similar efficiency levels had substantially larger increases in health spending relative to Portugal (take for instance the 6.7% annual increase in Poland or the 4.4% increase in Denmark).

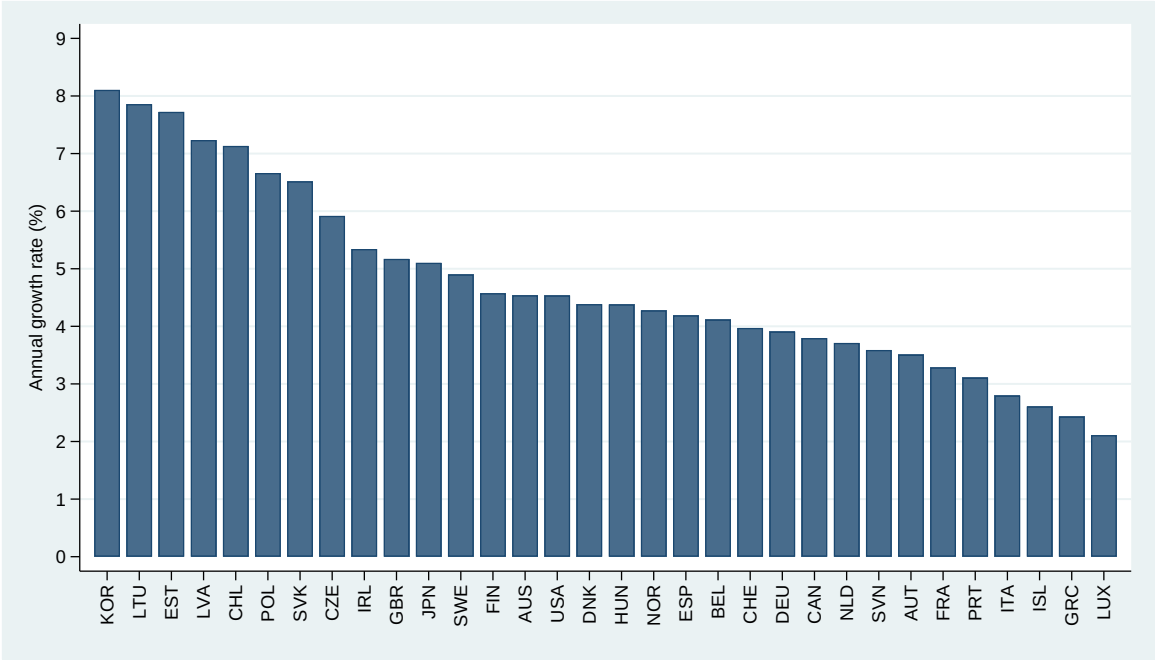


Figure 3.12: Per capita health spending annual growth rate (%; economy-wide PPP, 2000-2018)

The Portuguese NHS is financed mainly through taxation and managed directly, with some exceptions, by the government. Small user fees are charged in services where the contact is initiated by the patient to control for moral hazard, but most of the population is exempt from paying them. Still, Portugal is the 8th OECD country with highest share of private out-of-pocket spending. Out-of-pocket payments and private health insurance premiums have been increasing over time and represented in 2018 about a third of total health expenditure (Figure 3.13). Such payments are largely explained by co-payments for private care, drugs, and direct payments to private providers.

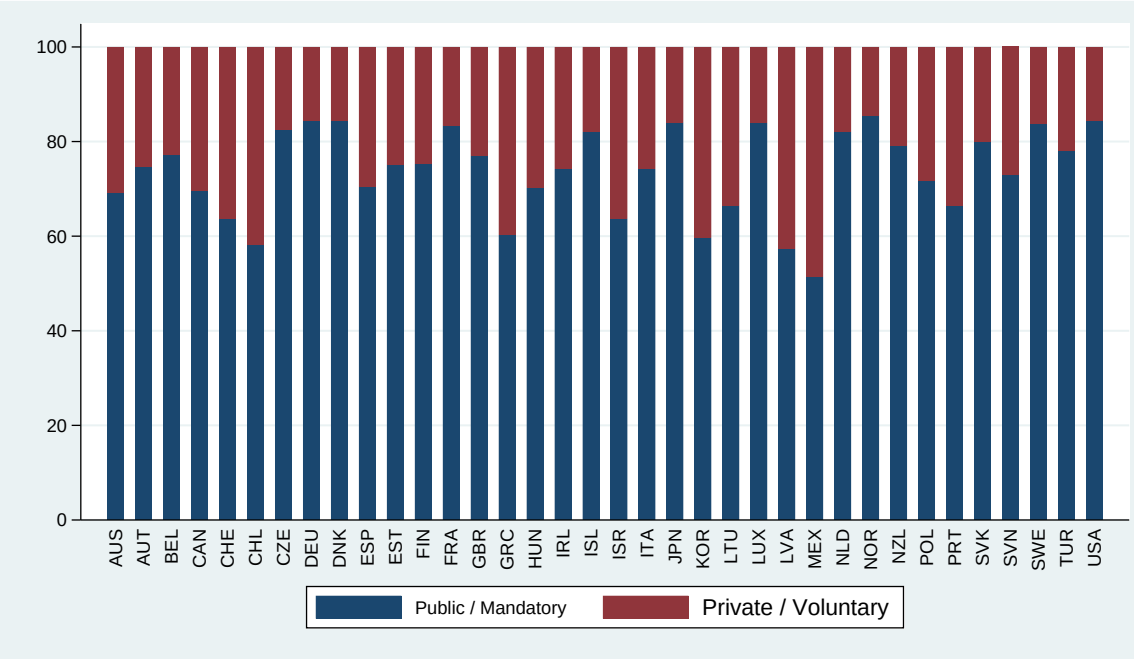


Figure 3.13: Private and public health expenditures (2018)

Despite the recent growth in the private health care sector (particularly in outpatient care), the public sector still represents about three fourths of total hospital spending, and more than half of total medical spending – inpatient and outpatient care (Figure 3.14). The magnitude of the NHS expenditure is reflected on its activity. In a country with a population of 10 million, the NHS employs over 130 thousand employees, who manage around 50 million appointments in primary care, 12 million appointments in hospital care, 6 million emergency room visits, 800 thousand hospital admissions and around 700 thousand surgeries every year (ACSS, 2019*b*).

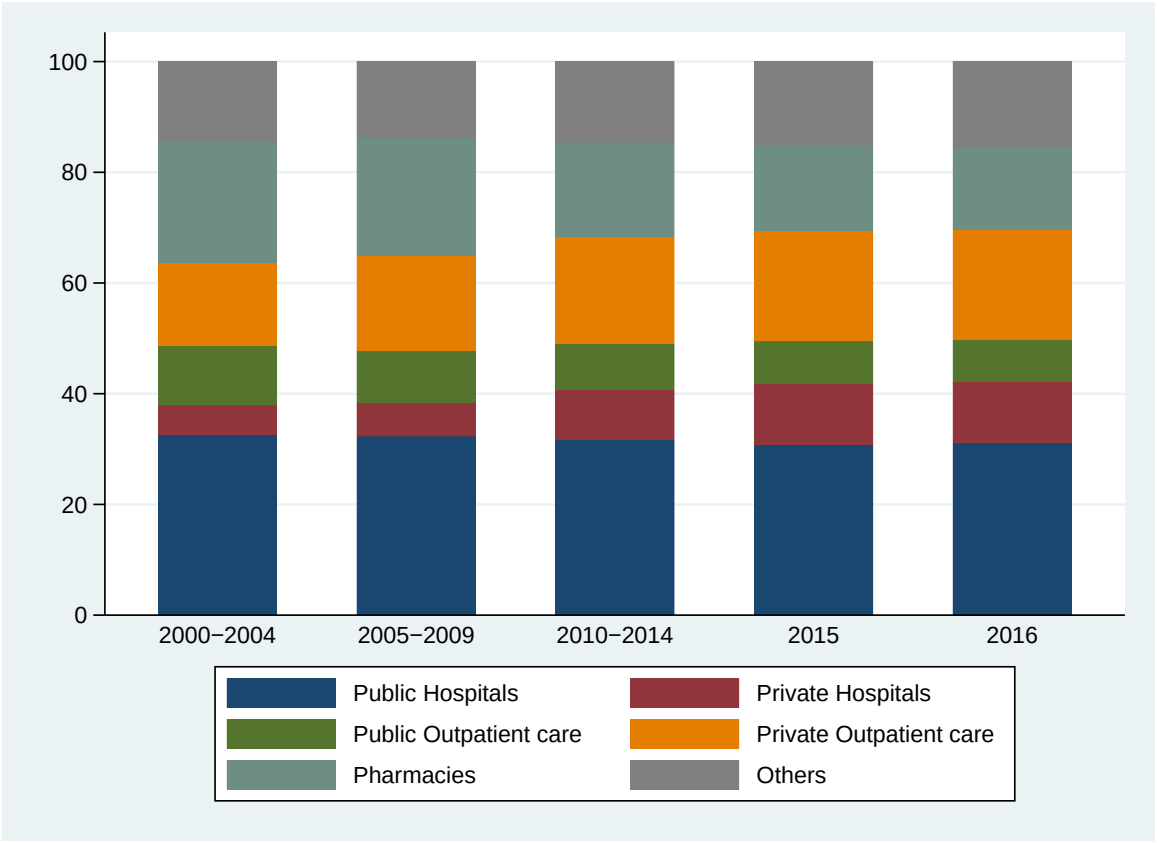


Figure 3.14: Breakdown of health spending in Portugal (%; 2000-2016)

When compared to other countries, Portugal has a higher proportion of doctors in the population (4.5 per thousand individuals compared to 3.1 OECD average), and a lower proportion of nurses (6.7 per thousand individuals compared to 8.5 OECD average). This implies a ratio of nurses to doctor which is amongst the lowest ratios in OECD countries (1.4 compared to 2.8 OECD average).

Access to healthcare is closely monitored in the Portuguese NHS. The proportion of patients with an assigned GP in a primary care unit has increased from 82% in 2010 to 93% in 2018 (ACSS, 2019*b*). Waiting times for outpatient appointments have remained relatively stable. The median days for appointments in the NHS was 80 days in 2010 and 81 days in 2018 (ACSS, 2019*b*).

Waiting times have increased modestly for elective surgery (median increased from 3.3 months in 2010 to 3.6 in 2018 (ACSS, 2019*b*)). However, waiting times in Portugal are

better than the OECD average for some procedures. For instance, in cataract surgery, the average waiting in 2017 was of 123 days, slightly below the OECD average of 129 days. In hip replacement surgery, waiting times in Portugal was of 130 days, one month below the OECD average. Also, in knee replacement surgery, Portugal waiting time was, on average, 207 days, below the OECD average of 227 days (OECD, 2019*b*).

New policies in the Portuguese NHS

Over the last decades multiple reforms have been implemented to improve access and efficiency of the National Health Service.

In 2006, a new organizational model for primary care units was launched. The new "family health units" are responsible for coordinating and delivering primary care for a predefined patient list. Such units are smaller than the traditional primary care centres and have a more flexible internal organization. This new model funding scheme includes a significant share of pay-for-performance incentives. So far, the introduction of these units – not yet covering all population – had a positive impact in patient outcomes. In 2018, Portugal had 532 family health units covering 60% of the population (ACSS, 2019*c*). The creation of such family health units is voluntary, proposed by the health team, and must be approved given a set of previously defined criteria. The government intends to generalize and adapt this model to fully cover the whole of the population, replacing traditional primary care centres, although no specific deadline has yet been defined (Government, 2019).

Primary care units have been expanding the roles of its workforce with the provision of dental care or mental health care in some units. Plans have been made to provide additional services in primary care such as obstetrics, pediatrics, ophthalmology, nutrition and physical rehabilitation[8].

[8]Despacho 200/2016, Portuguese Health Ministry (2016)

In hospital care, mergers and new governance schemes have also been implemented. Hospitals are funded with global budgets and activity-based funding using DRGs. In six regions of the country, covering one million individuals, an attempt for vertical integration has been made with the launch of "local health units", combining primary and hospital care within the same organization. However, the benefits of such model remain yet to be proven (Simões et al., 2017).

A national network for Long-term care has been launched in 2006 to improve access to those services in the public health care system (NHS). The network uses public funding to pay for a set of beds distributed among the public, for-profit and not-for-profit private sector. The number of beds in the network as grown from 646 in 2006 to 8.678 in 2018 (ACSS, 2019*c*), however this number is still insufficient for the current and projected population needs. The number of beds for palliative care has also increased over time: from a total of 106 available bends in 2007 to 381 in 2018 (ACSS, 2019*c*; CNCP, 2017).

In 2011, Portugal was affected by the international crisis. Fragile public finances and an adverse macroeconomic environment led to an agreement on a set of reforms and austerity measures in exchange for a loan granted by three international institutions. During the following years a set of reforms were implemented across all sectors in society – including health care. These measures included cuts in public pharmaceutical expenditure, a new regulatory framework for generics usage, and price reviews on private institutions with contracts with the NHS, among other measures.

The control of public pharmaceutical expenditures and regulation for generic usage implied a decrease on public pharmaceutical expenditures during the crisis (2.371 million euros in 2011 to 2.130 million in 2014). However, since 2014, nominal public pharmaceutical expenditures have increased 16%, reaching a total of 2.461 million euros in 2018 (Infarmed, 2019*a*). This increase was driven by strong growth in hospital pharmaceutical spending (26%), relative to a modest increase in ambulatory pharmaceutical spending (7%).

Two new policies were introduced to decrease waiting times. A policy with maximum waiting times was implemented from 2013 onwards, allowing patients who exceed their waiting time for surgeries to be referred to private sector institutions. This policy was built upon the national IT system for managing waiting lists introduced in 2004, which already allowed for explicit transfers of patients between institutions when needed to meet target times for maximum waits (Siciliani, Borowitz and Moran, 2013).

Since 2016, patients are now able to choose the NHS treatment hospital, i.e., patients can choose with their GP the NHS hospital they want to go for specialty appointments (instead of being automatically enrolled in the local area hospital). This policy is expected to contribute to the decrease of waiting times.

The Portuguese NHS faces significant challenges such as an aging population with increasing prevalence of chronic diseases, requiring new multidisciplinary responses from the NHS. In the last years, Portugal experienced shortage and difficulties in retaining some health professionals.

Moreover, modest economic growth and fragile public finances act as barriers for increasing expenditure in the NHS. All these challenges raise concerns regarding the financial sustainability of the Portuguese National Health System.

3.3.2 Challenges for the NHS and the sustainability problem

The previous section highlights that countries spend an increasing proportion of their resources in the health sector. However, there is no consensus about how to analyse whether health spending growth is sustainable.

Health spending can be thought to be sustainable if the resources used by the present generation to meet its needs do not compromise the ability of future generations to meet their own needs. However, this concept is not easily measurable.

The financial sustainability is linked to public and private health spending since public spending influences private spending and vice-versa. For instance, it is not unreasonable to think that a tight control of public health spending may lead to a larger increase in private health spending. Thus, when thinking about public health spending levels, one should consider potential spill overs into private health spending. We will deal with this issue in our projections, and further discussion on the topic may be found in the next section.

Financial sustainability should be thought as a constraint when designing the health system. Financial unsustainability is simply an imbalance between expenditure and revenue. The NHS in Portugal aims on achieving certain goals such as universal access, virtually free system at the point of use, as well as to provide a relatively wide range of services. Financial sustainability will be a constraint in this framework, preventing unlimited resources to be allocated to the health system. Hence, when thinking about this problem one should think about the available space in the government budget for increases in health spending without crowding out other public spending, in such a way that health system objectives are accomplished. Such complex problem may not have always a solution. If the constraint is binding, then some of the goals of the health system might not be achieved in order to comply with financial sustainability. Thus, the policymaker may have to trade-off achieving some health system goals and risking its financial sustainability.

The literature has not yet provided a consensual indicator to assess health systems sustainability. Olsen (1998) introduces a conceptual framework with threes clusters – contextual, activity and organisational – to analyse the sustainability of health services in developing countries. If there is an organisational system with the long-term ability to mobilize and allocate sufficient resources for activities that meet individual or public health needs then the health services are considered sustainable. However, the distribution of health services might be unequal under this sustainability definition.

OECD (2015) also discusses the problematic of health system sustainability. In their

view, the problem of sustainable health spending can be framed by comparing the benefits gained from health spending against other sectors of public expenditure. Also, the extent to which societies are willing to pay for health care on a collective basis will also determine whether a higher level of health spending is sustainable. OECD recognizes that governments unable or unwilling to increase revenue, will have to cut spending, which means a potential reduction in coverage and in the ratio of public to private spending. The fact that resources are limited implies that a decision needs to be made between health care system interventions. For instance, choosing between early prevention, improving the control of chronic diseases, new technologies and drugs that might cure or prolongate the population life,...

Liaropoulos and Goranitis (2015) recognizes the current WHO definition of financing in health care to be "A good health financing system raises adequate funds for health, so that people can use needed services protected from financial catastrophe or impoverishment associated with having to pay for them. It provides incentives for providers and users to be efficient". Such definition is also intuitive but hard to analyse in practical terms.

In Portugal, a technical commission proposed defining NHS financial sustainability based on a balanced government budget target (Comissão para a Sustentabilidade do Financiamento do SNS, 2006). According to this report, public health spending growth would not be sustainable if it would lead to a government deficit above 3%. This limit was related to the commitments made by Portugal with international institutions regarding the stability of its public finances. Thus, the definition of public health spending financial sustainability would be closely related to public finances sustainability.

The analysis of the Portuguese NHS sustainability is essential in an era of additional pressure on health spending, due to new technologies, new drugs, and an aging and unhealthy population with a complex health profile. New technologies and medicines tend to have higher prices, increasing health systems expenditures. The literature is relatively consensual on defining technology as the main driver for health spending growth. Cutler (1995),

for instance, argues that over 50% of such growth can be attributed to technology and more expensive innovations.

Portugal has a particularly elderly population (over 20% of the population is older than 65 years old (OECD, 2019*a*)), reporting one of the highest rates of limitations on day-to-day tasks (67% of elderly people report some or significant limitations on daily activities (OECD, 2019*a*)) and with an expected increase in dementia prevalence (OECD, 2019*a*). The unhealthy lifestyles and behaviours of the Portuguese population are expected to lead to an increase in the prevalence of chronic diseases. Almost two out of three individuals report high cholesterol levels, one third of the population has high blood pressure, and almost 60% are overweight (SNS, 2019).

The production of healthcare is quite different from the production of other goods and services since it needs specialised workforce to deliver most of the healthcare. Therefore, the productivity in the health system seems to grow at a slower pace from the remaining economy (Baumol, 1986). Such lower growth contributes to the increasingly need for a higher health systems expenditure.

3.3.3 Forecasting expenditures in the Portuguese NHS

As discussed before there is a lack of consensus on how to compute a financial sustainability indicator for health systems. In this section, we analyse different indicators to assess the risk of unsustainable health spending in the long run for the Portuguese Health system.

In this context, we frame the discussion of sustainability on whether the government budget has available room to accommodate further growth of health spending without compromising public finances stability and without crowding-out other public spending. Thus, we aim to determine the range of health spending growth which is compatible with

healthy public finances. Our definitions of health spending sustainability explicitly recognize the political choice that has to be made.

With relatively modest levels of economic growth, the only way to increase public health spending and ensuring public finances stability, will be either through tax increases or through reallocation of public spending.

Current tax levels in Portugal are already in historical maximums. This implies that further significant tax increases will not be likely. If this is the case, and to keep public finances stability, significant increases of public health spending will imply a decrease (or at least a smaller increase) of the remaining public spending. In other words, with modest economic growth and without compromising public finances stability, if the government decides to substantially increase the budget for the NHS, then other public spending – such as education or pensions, will have to decrease.

Such political decision would be based on the population willingness to sacrifice other public spending for more public health spending, and since that does not appear to reunite consensus, we will assume the current split between public health and other public health spending will not have severe changes. The Covid-19 pandemic, however, is likely to affect society willingness-to-pay for healthcare, and macroeconomic projections. Both factors can then influence the financial sustainability of the Portuguese NHS.

Health spending sustainability and government deficit

Our first definition of public health spending sustainability will be related to the equilibrium of the government budget. Public health spending will be sustainable as long as its growth does not aggravate permanently the government deficit. We will assume that the remaining public spending will grow at a reasonable rate. This means that we are not allowing for an explicit choice of the policymaker to prioritize health spending relative to other public services.

To apply such definition, one needs to make assumptions regarding the future growth rates of some key variables. The result of the forecast will be highly dependent on the assumptions made. We consider different scenarios, with more optimistic and pessimistic assumptions, to analyse potential paths for public health spending. We then analyse how does the government deficit change with such growth rates. Table 3.7 displays the key growth rates for the three scenarios considered in this analysis[9].

Table 3.7: Scenario assumptions (nominal growth rates) for 2025-2070 projections

	A. Previous government trends	B. Government projections	C. COVID projections
(nominal) GDP growth	4.17%	3.50%	3.30%
Public health spending growth	4.47%	3.80%	4.00%
Private health spending growth	4.64%	3.50%	3.30%
Other public spending growth	0.39%	2.80%	3.00%

The first scenario (A) is based on the historical growth rates observed during the 2015-2019 Portuguese government. During this period, a relatively strong economic growth and public health spending growth was registered. Other public spending was reduced in real terms. This should be seen as a very optimistic scenario since the assumption of permanently frozen other public spending (in nominal terms) seems unrealistic.

The second scenario (B) can be thought as the as-is scenario before the Covid-19 pandemic. This is based on the government projections for 2019-2023. Such projections were created before the pandemic and would represent the government's medium-run forecast for the economy. In this scenario, economic growth is still relatively high, although other public spending grows more than in the former scenario. Public health spending growth

[9]Previous government trends computed based on historical growth rates during the 2015-2019 government; Government projections estimated based on the Stability Plan for 2019-2023 presented by the Government (before the COVID-19 pandemic); COVID projections estimated based on European Commission estimates for economic growth, Stability Plan for 2019-2023, Portuguese Public Finance Council, and own assumptions. All the scenarios are built in nominal terms and assume an inflation rate of 2%. Government revenues equal to 42.5% of GDP.

outpaces other public spending growth. We use these predicted growth rates as if they would be kept constant until 2070.

Finally, scenario C includes the unexpected impact of the Covid-19 pandemic. This scenario includes a long-run economic growth lower than the projected before the pandemic. Also, it projects higher public spending (both on health and other sectors). This scenario has significant uncertainty, but it aims on representing a situation under which public finances remain with significant challenges in the long run: lower economic growth but higher public spending.

We use historical data until 2019 and perform our forecast from 2020 to 2070. The growth rates from table 3.7 are applied from 2025 to 2070. For the forecast between 2020 and 2025, we use different growth rates to account for the impact of the pandemic. The following table displays our assumptions regarding the short run impact of COVID-19 – which are common to all scenarios. Projections to 2020 are based on existing forecasts from the Revised State Budget, the Portuguese Public Finance Council, and the European Commission. In 2020, we expect a strong decline of the economy, a substantial increase of public spending, as well as a decline of taxes collection. Such estimates reflect the role of automatic stabilizers, investment in the NHS, and other programs related to fight the health, social and economic impacts of the pandemic. After a rebound in 2021, we assume the economy converges to the long-term projections made in table 3.7.

Table 3.8: Assumptions on nominal growth rates for the COVID-19 impact (2020-2024)

Year	GDP	Public health spending	Private health spending	Other public spending
2020	-11.75%	8.10%	2.50%	15.10%
2021	8.00%	2.00%	2.70%	3.00%
2022	4.60%	2.50%	2.90%	2.50%
2023	3.30%	3.00%	3.30%	2.00%
2024	3.30%	3.50%	3.50%	2.00%

Based on such assumptions, one can predict the government deficit behaviour over time,

as well as public health spending. According to our definition, our health spending growth assumptions are compatible with a financially sustainable health system if and only if the government budget is balanced.

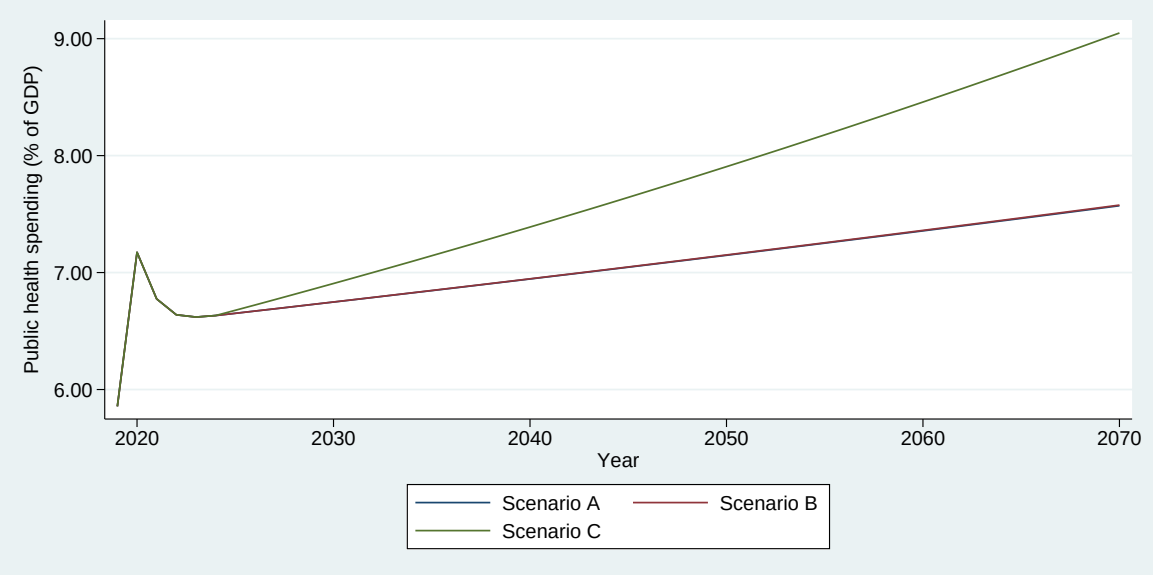


Figure 3.15: Public health spending forecast from 2020 – 2070 (historical values for 2019; % of GDP)

All scenarios display an initial increase in public health spending, related to the COVID-19 pandemic sanitary efforts. According to previous government trends (scenario A) and government projections scenarios (scenario B), the share of GDP dedicated to public health spending is predicted to slowly increase. Under both scenarios, public health spending will increase from 5.9% to 7.6% of GDP (figure 3.15). Under the most pessimistic scenario (C), public health spending will increase significantly, reaching 9% of GDP in 2070. However, sustainability must be accessed based on the impact of such scenarios on the government budget, as illustrated by figure 3.16.

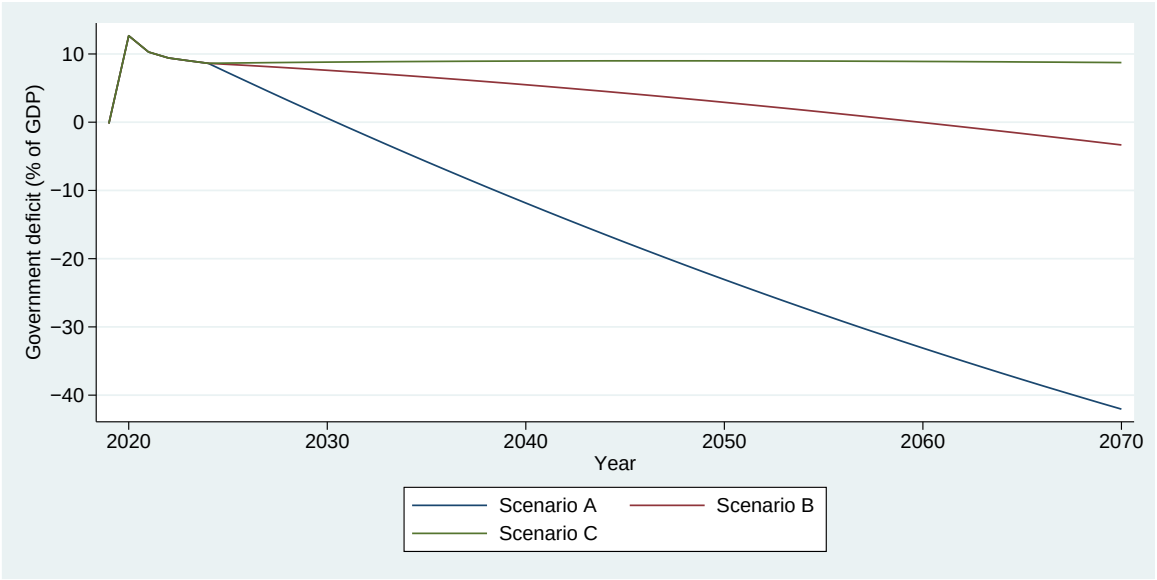


Figure 3.16: Government deficit forecast from 2020 – 2070 (historical values for 2019; % of GDP)

Under scenario A, other public spending was kept almost constant in nominal terms. If such low growth rates would be kept until 2070, a significant fiscal space would be generated – given the predicted economic growth. In that context, the predicted annual increase of 4.47% on public health spending – above GDP growth - would be easily accommodated without risking the sustainability of public finances. However, this does not seem a very plausible scenario, since it is not reasonable to assume that other public spending will be kept permanently frozen until 2070.

Growth projections under scenario B impose additional pressure to public finances. Public health spending grows slightly above the economy, while other public spending grows slightly below the economy. Such pattern generates increasing space in public finances to accommodate higher levels of public health spending growth. However, despite such additional fiscal space, the government deficit is only eliminated in 2060, after the initial imbalance in 2020.

The pessimistic case (scenario C) predicts a lower economic growth than in previous scenarios. Increasing health spending and other public spending are too large and do

not contribute to solid public finances. Thus, throughout time, the government deficit is expected to remain relatively unchanged. Under this scenario, a balanced government budget is not compatible with the predicted growth rates.

The following figure illustrates the concept of financially sustainable public health spending. In our simplified setting, sustainability – defined as public health spending growth compatible with a balanced government budget in 2070 - depends on the level of economic growth and other public expenditure growth. Obviously, higher economic growth levels or lower growth for other public spending, improve the sustainability of health spending. The lines in the plot, represent the possible combinations of economic and other public spending growth, compatible with four different nominal health spending growth rates. Thus, according to our goal of having a balanced budget by 2070, these lines can be thought as the sustainability frontier for each level of public health spending. Any allocation below those lines, will then be financially sustainable. Conversely, allocations above those lines imply that such health spending growth is not sustainable given the macroeconomic context.

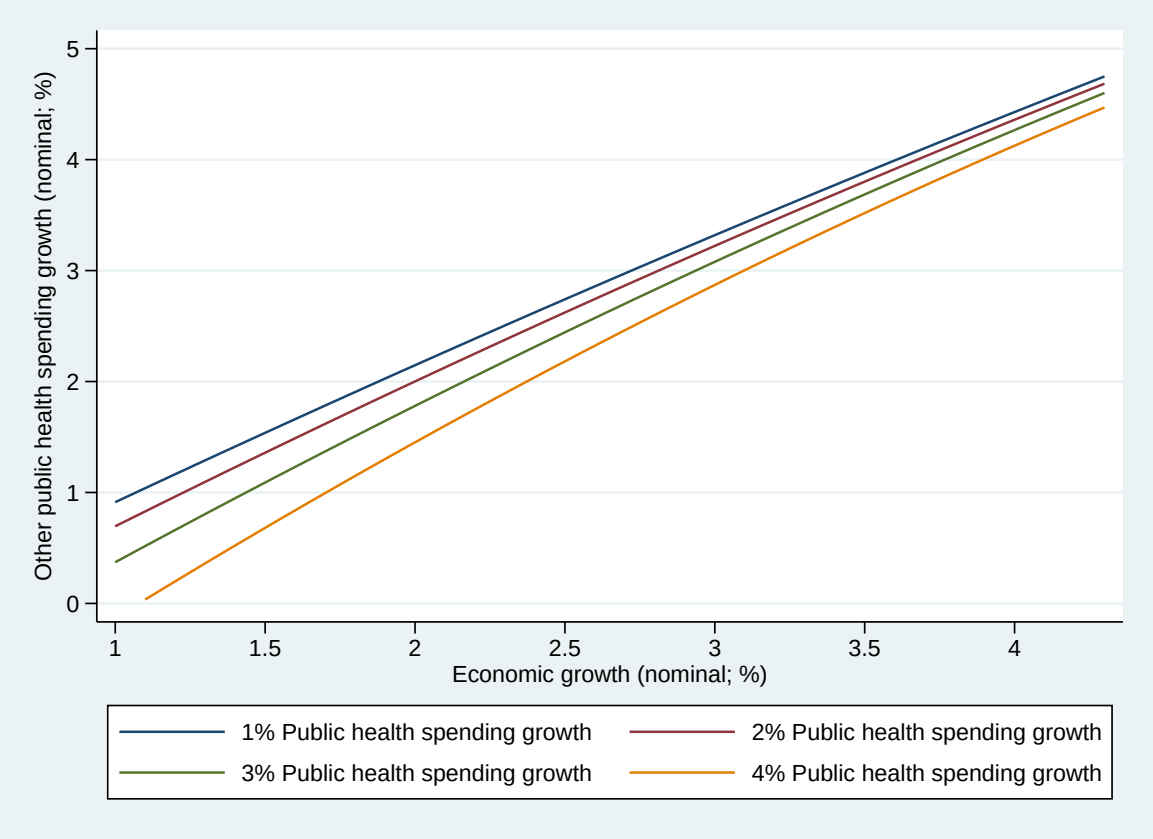


Figure 3.17: Public health spending growth sustainability frontier (for nominal growth rates of 1%, 2%, 3% and 4%; balanced budget sustainability definition)

Health spending sustainability and public debt

A second definition of public health spending sustainability is related to public debt. Public health spending will be sustainable if its growth is compatible with repaying the public debt, without crowding-out other public spending. In such context, it will be possible to compute the maximum growth rate compatible with a sustainable health system. For this purpose, we set a zero public debt target in 2070 (a timeframe long enough). Then, we compute the government surplus that one must have to achieve such target. Finally, given such surplus and other public spending growth, we will have the maximum rate at which public health spending can grow.

Table 3.9 represents maximum public health spending annual growth rates until 2070

for three different scenarios. All these growth rates are compatible with repaying all public debt by 2070. All scenarios assume a 3.5% nominal GDP growth, but each of them assumes different nominal growth rates for other public spending. Thus, when other public spending grows less than GDP (optimistic scenario) there is room for a larger public health spending growth. Conversely, if other public spending grows slightly above GDP, then public health spending must grow at a lower pace to comply with the repayment of public debt by 2070.

Table 3.9: Forecast for sustainable public health spending growth (nominal variables)

	Baseline	Optimistic	Intermediate	Pessimistic
Public health spending growth (%)	4.5	4.8%	4.0%	2.8%
Private health spending growth (%)	4.6	4.4%	4.5%	4.6%
Total health spending growth (%)	4.5	4.7%	4.2%	3.7%
Health spending (% of GDP)	9.1	16.9%	13.4%	10.5%
Public health spending (% of total health spending)	66	66.3%	55.7%	39.0%

Notes: Baseline based on 2015-2019 data; assuming a 2% inflation rate

Different public health spending growth rates leads to different levels of health spending as percentage of GDP. For all scenarios, even when public health spending grows less than GDP, total health spending on GDP increases. This happens because of the increase on private health spending – reducing the share of public spending in total health spending. In our estimates we allow private health spending to be influenced by public health spending. In fact, it is reasonable to assume that tightening public health spending may result on an increase in private health spending.

The pessimistic scenario can be thought as Covid-19 related. In fact, under this scenario we assume that other public spending growth surpasses economic growth. Given the reduction on the fiscal space, to comply with the public debt repayment goal, the maximum level at which public health spending can grow will be reduced.

Estimates hinge on the assumptions made on other health spending and economic growth. Table 3.10 represents how maximum nominal growth rates for public health spending change depending on those two variables. The available budget for health spending increases will largely depend on such variables.

Table 3.10: Sensitivity analysis for sustainable public health spending growth (nominal terms)

		Nominal GDP Growth								
		2.7%	**2.9%**	**3.1%**	**3.3%**	**3.5%**	**3.7%**	**3.9%**	**4.1%**	**4.3%**
Nominal other public spending growth	**2.7%**	3.0%	4.1%	5.0%	5.7%	6.3%	6.8%	7.2%	7.7%	8.0%
	2.9%	1.3%	3.3%	4.4%	5.2%	5.9%	6.5%	7.0%	7.4%	7.9%
	3.1%	-	2.0%	3.5%	4.6%	5.4%	6.1%	6.7%	7.2%	7.6%
	3.3%	-	-	2.3%	3.8%	4.8%	5.7%	6.3%	6.9%	7.4%
	3.5%	-	-	-	2.6%	4.0%	5.1%	5.9%	6.5%	7.1%
	3.7%	-	-	-	0.7%	2.8%	4.3%	5.3%	6.1%	6.8%
	3.9%	-	-	-	-	1.3%	3.1%	4.5%	5.5%	6.3%
	4.1%	-	-	-	-	-	-1.0%	3.4%	4.8%	5.8%
	4.3%	-	-	-	-	-	-	1.7%	3.6%	5.0%

The previous table shows that higher levels of public health spending growth will only be sustainable given a tight control on other public spending allied with strong economic growth. Otherwise, public health spending growth will have to be lower to ensure sustainability. A lower public health spending growth poses a risk to accomplish some of the objectives of the health system (for instance, universal access, timely response, and service quality, among others).

Following the same logic as before, we can represent graphically the set of allocations for a given level of public health spending growth financially sustainable, given combinations of economic and other public spending growth. The following figure represents the sustainability frontier based on our definition of public debt repayment by 2070. Again, any allocation below these lines should be considered financially sustainable. By the same token, any allocation above these lines will imply failing to repay the public debt by 2070. The shape and format of these frontiers is similar under both definitions.

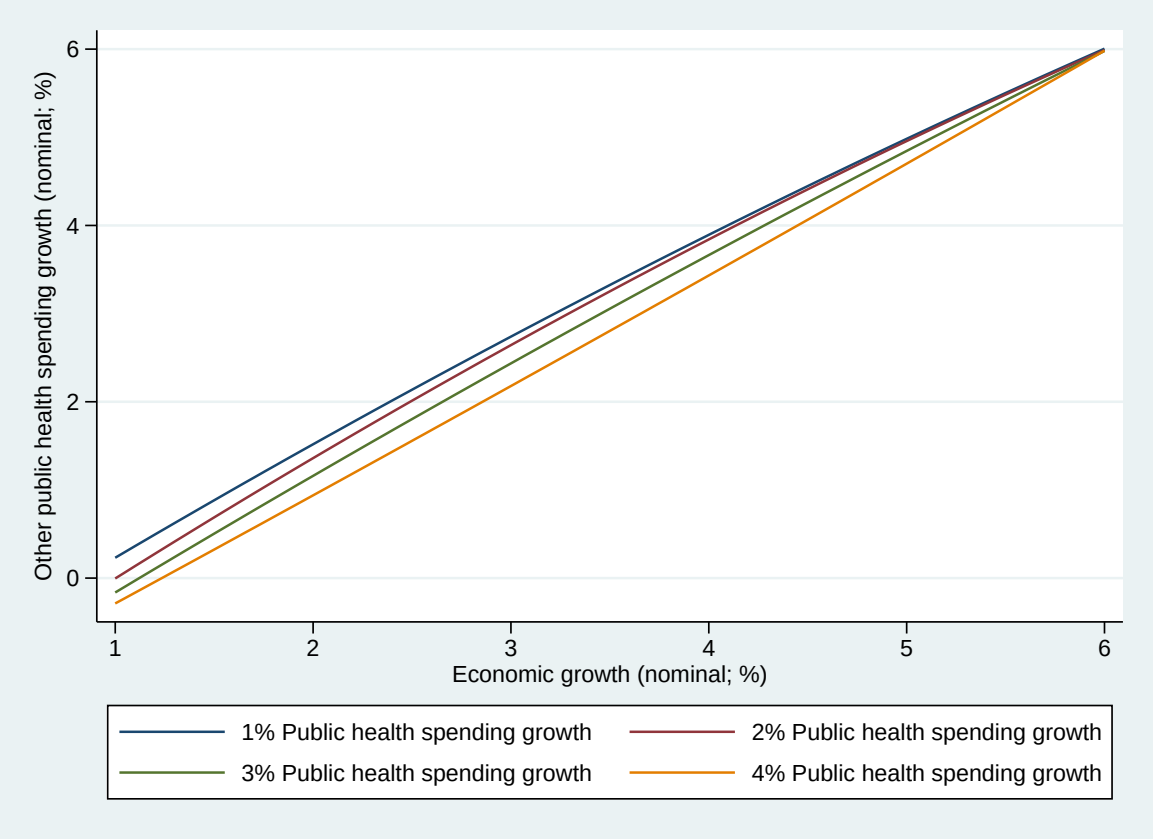


Figure 3.18: Public health spending growth sustainability frontier (for nominal growth rates of 1%, 2%, 3% and 4%; public debt repayment sustainability definition)

3.3.4 Is there room to improve the NHS financial sustainability?

In the previous sections we have dived into the concept of financial sustainability and its application to the Portuguese NHS. In a context of low economic growth and without margin to increase taxes substantially, the room to expand the NHS budget, without threating public finances, is somewhat limited.

Under two alternative indicators, we have computed a benchmark for a financially sustainable level of public spending – compatible with solid public finances. Based on the first indicator, we have seen that only the Covid-19 scenario poses a significant risk to the government deficit. The second approach shows, under three scenarios, that a nominal public health spending annual growth between 2.8% and 4.8% could be compatible

with repaying the public government debt on a long-enough horizon. Such estimates will largely depend on the economic growth level, as well as on the growth level for the remaining public expenditure.

However, there is a set of factors pressuring health spending – reflecting higher needs and higher prices in the health care sector. The Portuguese population is getting older, with a higher prevalence of chronic diseases and more comorbidities. Even, if such effects are not directly translated into higher costs, they will at least require an adaptation of the response provided by the NHS. Moreover, technology costs pose a significant threat to the stability of health spending. New drugs, medical devices, and other innovations are increasingly more expensive. All these effects are expected to place additional pressure on public health spending (and on total health spending).

In order to assess whether the financially sustainable benchmark estimated is enough to cover the expected needs in the health system we must translate these needs into costs. To do so, it is important to analyse how the literature has investigated the past growth in health spending, to understand how to forecast health spending growth.

The historical growth in health spending has motivated researchers to look into the drivers of such growth. Several studies have tried to explain the observed growth of health spending as a function of key variables. Although the discussion has not yet reached a conclusion, there is enough consensus around the key drivers of health spending.

The seminal contribution from Newhouse (1992) decomposes the US health spending growth into several effects: population aging, increased insurance coverage, increased income, supplier-induced demand and lower productivity growth in the health care sector. The remaining fraction of growth not explained by these factors is attributed to technology. In his study, technology seems responsible for accounting for at least half of the observed growth. Other studies, with different approaches, have confirmed technology as the main driver for health spending growth. For instance, Cutler (1995) and Smith, New-

house and Freeland (2009); Smith, Heffler and Freeland (2000) suggest that technology is responsible for almost 50% of the US health spending growth. They also confirm that the effect of demographic change was very small, accounting for less than 10% of total growth.

Applying this framework to the Portuguese NHS, we can forecast future health spending based on the evolution of key drivers. For this exercise, we will assume that the level of coverage of the NHS is kept constant. In other words, we are assuming that the split between the public and private care sector is constant. Therefore, any increase in expenditure can not be attributed to the coverage of new services (for instance, the inclusion of dental care in the NHS), neither to the exclusion of services for the NHS.

Changes in the demographic structure are usually pointed as the key reason for concern regarding future health expenditure. However, such claim is not confirmed when looking to the numbers. In Portugal, health spending data shows that an elderly person spends, on average, 2.5 times more in health than a younger person. Also, we know that in 2015 the proportion of elderly population was 21%, which is projected to reach 37% by 2080. Keeping the level of expenditure constant, one can compute what would be the additional cost per capita due to aging. We estimate that the change in the demographic structure of the population will increase per capita health spending by 19%. Although this may seem a relevant increase, we will see ahead that this factor contribution to total health spending growth is almost neglectable.

A second factor, often forgotten in the public discussion, is the impact of economic growth on health spending. With economic growth, consumers spend part of their additional income in consumption of goods and services. Studies show that consumption in health services will increase at least proportionally to the income. This suggests that income elasticity for health services consumption does not fall below one. Assuming a 1.5% real annual economic growth – as assumed in the scenarios of the previous sections – economic growth will rise per capita health spending by 126% by 2080. Such effect from

economic growth is significantly larger than the previous effect attributed to aging.

A third concern regarding health care spending is the rate at which productivity in the health sector grows relative to the rest of the economy. This problem was framed by Baumol (1986), which argued that if productivity gains are lower in the medical care industry than in the rest of the economy, then health expenditures would increase – given the same demand for health services. In this context, a 0.5% difference between overall annual productivity in the economy and in the health sector, would result in an increase of health spending of 91% by 2080.

Finally, as explained above, technology is usually considered to be a key driver for health spending growth. Many empirical studies attribute the residual of past health spending growth to technology. However, since we are projecting health spending towards 2080 it is not possible to estimate such residual.

An alternative to surround such issue is to look to historical data from 2000 to 2015. If we apply the same methodology to this historical data, we can estimate the residual attributed to technology. Then, we can use such residual to project the technology effect into the future. By doing so, we observe that per capita health spending increased 50% over that period. Most of that effect (39%) is attributed to income growth, and smaller effects are attributed to productivity and ageing (8% and 4% respectively). Thus, we are left with no residual – which would imply that technology did not contribute to explain health spending growth over this period.

Results are puzzling and might tell different stories. On one hand, some of the other three factors might be over-estimated. For instance, it might be the case that in Portugal the income elasticity is well below one. On the other hand, it might be the case that technology did not play a relevant role over that period – but we cannot conclude that such effect will not exist up to 2080. Additionally, we might have other effects which our variables are not capturing. If those effects would have a negative impact on health

spending, then the residual (technology effect) could be positive and significative.

In order to deal with the uncertainty regarding technology effects we consider different cases. International literature estimates that technology explains around 50% of health spending growth – this will be our upper bound. We will have a lower bound in which technology explains 10%, and an intermediate case where technology explains 25% of health spending growth.

The following figure summarizes the estimated impact of each variable, including the different alternatives for the impact of technology.

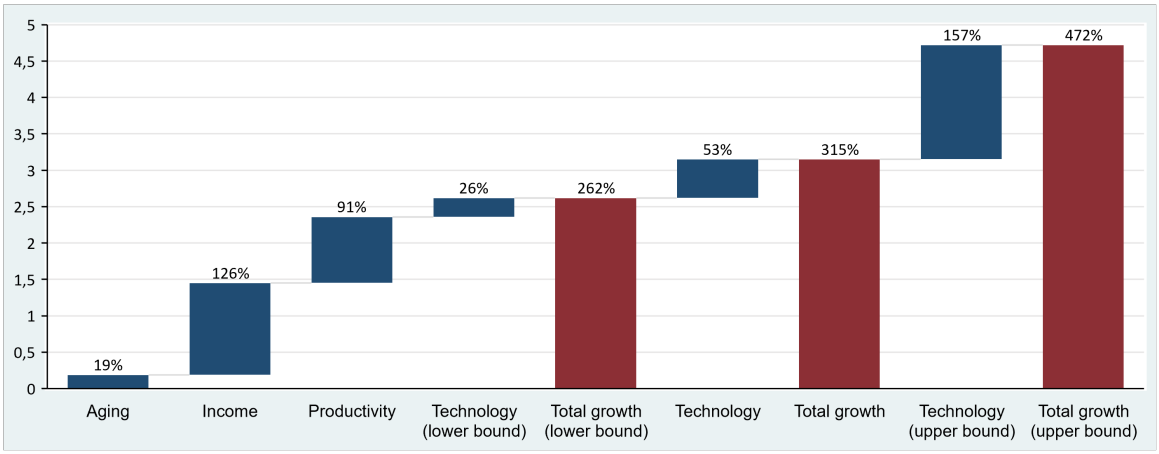


Figure 3.19: Forecast of per capita health spending growth (2015-2080)

According to our estimates, per capita health spending growth from 2015 to 2080 will range from 262 to 472%. The relative position within this range will depend on the assumptions made on technology growth. As predicted, aging explains only a tiny fraction of total growth. While income, productivity and technology have more significant impacts.

An increase of 262 to 472% on per capita health spending between 2015 and 2080 might seem excessive. However, one must consider that the Portuguese population is predicted to decrease almost a third until 2080. This means that total health spending growth will be smaller (ranging from 128 to 314%). Also, one should note that over time more resources

become available in the economy, as the economy grows. Overall, this would mean that while the economy grows, in real terms, 186%, health spending will grow 128%-314%.

Such health spending growth until 2080 implies an average real annual growth rate of 1.3 to 2.1%. How does this forecast of annual health spending growth compares with the financially sustainable benchmarks?

Given our results in the previous section, the growth rate of 2.1% seems relatively compatible with the maximum health spending growth rates (table 3.9). In fact, we had that in an optimistic scenario, a financial sustainable level for public health spending would imply a real total health spending growth of 2.8% - above our forecast estimate. Also, the intermediate scenario would yield a 2.0% real total health spending growth. However, in the pessimistic scenario real total health spending growth would be significantly below our forecast (0.8%).

3.3.5 Conclusion

The provision of universal healthcare by the Portuguese NHS depends on the allocated government budget to health. Several reforms have been implemented over the last decades to improve access and efficiency of the healthcare system. These reforms need to consider the cost and the benefits of new and existing healthcare services and the population that will potentially use them. Improving the Portuguese NHS while aiming for financial sustainability implies a trade-off between the number of healthcare services, the co-payments and the size of the population that uses it, i.e., it requires sustainability of the four NHS linked dimensions: the technical, the social, the political and the financial.

A practical and usable definition of public health sustainability is not consensual and hard to find. We have shown that under two alternative definitions – both related to fiscal space and compliance with sound public finances - public health spending has limited room

to increase. Financial sustainability is defined as a public health spending growth level compatible with a balanced government budget by 2070, or with repaying the public debt by 2070.

We argue that financial sustainability of public health spending is a function of economic growth and depends on the level of control of other public spending. Stronger economic growth – keeping everything else constant, will generate additional fiscal space that can be used to accommodate higher levels of public health spending. Conversely, higher levels of other public spending (such as education, pensions,...) reduces the maximum level at which public health spending can grow. We also argue that public health spending growth is not independent of private health spending. There is a relation between these expenditures forms that must be considered – blind cuts on public health spending can be partially reflected in increases of private health spending.

There is a clear trade-off between stricter definitions – which are limited but easier to apply and translate into practical indicators, and broader definitions – more consensual and complete but difficult to reflect into a meaningful indicator.

Sustainability of public health spending can also be ensured if society is willing to prioritize such spending relative to other forms of public spending. Ultimately, this will depend on voter's preferences. Explicit preferences towards a higher level of health spending, will be translated into lower growth rates for other public sectors. In our analysis, we assume preferences to remain unchanged – we are not allowing public health spending to significantly crowd-out other forms of public spending.

The Covid-19 pandemic is an example of a plausible shock in society preferences towards health spending. Still, even if a greater preference is placed in the health sector, it is not clear whether its sustainability will be ensured. A higher willingness to pay for health, sacrificing other sources of public expenditure, facilitates achieving sustainability. However, the pandemic situation also triggers mechanisms which harm health spending

sustainability. In fact, the pandemic has a direct impact on health services demand – implying higher spending levels to provide covid-related health provision. Also, the pandemic situation implies lower economic growth prospects and increases in other public spending (social support schemes, unemployment benefits,...), as predicted in our projections. These effects move in opposite directions in what respects the financial sustainability of public health spending. The net effect on future health spending sustainability remains to be seen.

Chapter 4

Modelling Public Health Spending Sustainability

Abstract

In most OECD countries, health spending has been increasing over the last decades, often surpassing GDP growth. Current challenges faced by health systems – including the Covid-19 pandemic - pose additional concerns regarding whether societies can sustain continuous health spending growth. Such problem is particularly relevant in the context of public health spending. In the absence of significant economic growth, the room for further increases in public health spending without constraining other public spending is somewhat limited.

On this paper I propose an exploratory analysis on the concept of financial sustainability of public health spending. I relate the sustainability concept with fiscal space of public finances and with the crowding-out of other public expenditures. I develop a static model where health contributes directly both to utility and output.

The model suggests that increases on public health spending are not necessarily undesirable from a public finances' standpoint: the crowding-out of non-health public expenditures depends on the tax rate and coverage level of public health spending. Thus, economic growth is not a sufficient condition to achieve financial sustainability of health

spending. Moreover, achieving financial sustainability by adjusting coverage levels might compromise ensuring the social sustainability of public health spending. Hence, this paper contributes to the debate on whether current increases of public health spending are desirable and sustainable.

4.1 Introduction

Health care expenditures have been increasing over time. In the US, for instance, total health spending as a share of GDP more than tripled over the last half-century (Acemoglu, Finkelstein and Notowidigdo, 2013). Such increases are typically larger than GDP growth, raising concerns regarding the sustainability of such spending.

This paper explores the concept of public health spending sustainability within a Static Model where health plays a role both on the agent utility and on the aggregate production for the economy. These features imply that higher levels of public health spending are not necessarily undesirable from a public finances' standpoint.

The model predicts that increases in public health spending will be sustainable as long as they do not imply a crowding-out of other public expenditures. This will only be true if the fiscal space increases substantially. Such sustainability threshold depends on the tax rate and coverage level of public health spending. Short and medium-run deviations from the optimal path, arising from rigidities on other public expenditures, can induce unsustainable paths for public health spending. Thus, this paper aims to provide a basic framework in which health spending growth can be analysed.

The sizeable health spending growth has motivated researchers to disentangle and determine its drivers. Although some controversy remains, a couple of conclusions are relatively well established in the literature, which can be grouped in supply and demand factors. In the supply side, technological change is a key factor driving costs. The seminal contribution from Newhouse (1992) attributes to technology more than half of health spending growth. These estimates are reinforced by further studies (Cutler, 1995; de Meijer et al., 2013; Dybczak and Przywara, 2010; Smith, Newhouse and Freeland, 2009). Despite being increasingly expensive, technology also brings health gains. Still, the net gain might not always be obvious. In fact, quality-adjusted prices have increased for

most recent innovations (Chandra and Skinner, 2012; Hult, Jaffe and Philipson, 2018). Additionally, lower productivity growth in the health sector, compared to the rest of the economy, may lead to a higher share of health spending on GDP (Baumol, 1986).

On the demand side, ageing populations are expected to impose an additional burden on health systems (Gray, 2005; Schneider and Guralnik, 1990). However, research shows that such financial burden is relatively small. Instead, studies suggest a "red herring" hypothesis, according to which, proximity to death should explain most of observed increase in health spending at the end of life (Cylus, Normand and Figueras, 2018; Cylus, Permanand and Smith, 2018; Cylus et al., 2018; Cylus, Figueras and Normand, 2019; Stearns and Norton, 2004; Zweifel, Felder and Meiers, 1999).

At a country level, rising income should also play a role on explaining health spending growth. This steams from the fact that health care can be seen as a luxury good - resulting in disproportional increases in health spending as countries become richer (Barros, 1998; Newhouse, 1992; Smith, Newhouse and Freeland, 2009). Still, the relation between health expenditures and income is not consensual, with studies arguing that rising income is unlikely to be a major driver of health expenditures and questioning the "health as a luxury good" assumption (Acemoglu, Finkelstein and Notowidigdo, 2013; Baltagi et al., 2017). This results from the dichotomy relative to individual level estimates, where demand for health care tends to be very rigid.

Such historical growth has been the basis for the construction of forecasts for health spending. Indeed, international institutions often display concerns regarding such growth, claiming that health care might become unaffordable by mid-century. The methodologies used on these forecasts vary considerably, although most projections point to a significant growth in OECD countries. Appleby (2013) provides a review on several multi-country and country-specific health spending projections.

WEF (2012) estimates that health spending would account for 13.4% to 17.6% of GDP

of OECD countries by 2040. Additionally, the same study predicts financing gaps to the health care system by 2025 due to the projected decrease in government expenditure along with the expected increase in public healthcare cost. OECD projections estimate public health spending and long-term care to increase by 3.3 and 7.7 percentage points of GDP between 2010 and 2060 (de la Maisonneuve and Martins, 2013). Later studies from the European Commission found that EU countries are expected to significantly increase health spending, posing a risk of fiscal sustainability challenges (European Commission, 2014, 2019; Medeiros and Schwierz, 2013).

In the US, CBO (2008) projections suggest that the share of GDP devoted to health care would increase to 31 percent by 2035, and 49 percent by 2082. Heffler et al. (2019) updates such estimates using more recent data and a new set of refined assumptions. The health sector share in 2093 is projected to be roughly three times the size it has today, increasing to 33% of GDP. Some of these forecasts, based on historical data, may yield unrealistic predictions and their results should be interpreted with caution, since they ignore some important macroeconomic dynamics (Friedman, 2010; Sheiner, 2014).

These projections usually argue that public health spending growth will became unsustainable. However, the definition of unsustainability varies greatly across studies, and is far from being consensual in the literature (Costa, Santos and Barros, 2021; Roehrig, 2012). Nonetheless, financial sustainability implies that someone must pay for healthcare. However, this should be seen as a constraint and not as a health system objective (Thomson et al., 2009). Thus, how governments achieve fiscal sustainability matters: the policy maker may have to trade-off achieving some health system goals and risking its financial sustainability.

Some of the available definitions are difficult to materialize into practical and testable concepts. For instance, Olsen (1998) suggests that if a system has the long-term ability to mobilize and allocate sufficient resources for activities that meet individual or public health needs then it is sustainable. OECD (2015) argues that the problem of sustainable

health spending can be framed by comparing the benefits gained from health spending against other sectors of public expenditure. In this setting, the extent to which societies are willing to pay for health care on a collective basis will determine whether higher levels of health spending are sustainable. Still, from a fiscal space perspective, long-term commitments are inherently unwise, whether they are for pensions or medical care. Citizens, however, may strongly prioritise these guarantees. The study from OECD (1998) shows precisely that societies often express greater willingness to contribute more for health care than other areas of government spending. Contrarywise, Chernew, Hirth and Cutler (2003) questions whether American consumers will be willing to accept paying the forecasted growth on American health spending.

A significant share of health expenditures is paid through public funding. This has created a fiscal challenge, with health care being one of the largest public sectors and with significant underlying momentum towards higher costs (WEF, 2012). Since most of health spending is publicly financed, its sustainability will depend on public finances sustainability. These two concepts are in fact intertwined: the economic downturn of 2008-2009 clearly highlighted the need to build more resilient health systems to negative economic shocks (Hou et al., 2013; Liaropoulos and Goranitis, 2015). Despite controversy on the definition of health spending sustainability, the definition of public finances sustainability is more established. In fact, government budget constraints and fiscal space are seen as key instruments for fiscal policy and debt sustainability (Adedeji et al., 2016; Afonso, 2006). By contrast, Rieth (2014) argues that debt can be seen as the result of myopic fiscal policy. OECD (2015) lists three alternative definitions of fiscal sustainability. OECD defines it as ”the ability of a government to maintain public finances at a credible and serviceable position over the long term.”. The definition for the European Commission is ”the ability to continue now and in the future current policies without causing public debt to rise continuously as a share of GDP.”. The IMF on the other hand defines fiscal sustainability on a more financial perspective: ”a set of policies is sustainable if a borrower is expected to be able to continue servicing its debt without an unrealistically large future

correction to the balance of income and expenditure".

Forecasts for health spending growth are based on historical analysis on long-run trends and fail to recognize the relation with other macroeconomic variables. The impact of health on economic growth is consensual, although sometimes ignored by literature on health spending growth – which assumes income as exogenous. Still, there are multiple channels through which health can influence economic growth. On one hand, health is a major economic sector. On the other hand, it safeguards economic growth, by allowing for later retirements, promoting lower school drop-out rates and avoiding higher absenteeism (Barbiero and Cournede, 2013; Bloom, Kuhn and Prettner, 2019; Cylus et al., 2018). The recent Covid-19 pandemic emphasized the importance of public health for promoting and restoring economic growth. The role of the relations between these macroeconomic variables remains a black box, given the absence of a theoretical framework that addresses these issues. This paper aims precisely to contribute to this debate.

Nevertheless, a few papers have looked to health spending from a macro perspective. An important contribution was made by Becker, Philipson and Soares (2005) which incorporates longevity in an overall assessment of inequality. The paper accounts both for quality-of-life improvements, captured by rising per capita GDP, but also for increases in the quantity of life, through changes in life expectancy. The paper main contribution is to explicitly recognize the role of health spending on increasing longevity.

The paper from Hall and Jones (2007) suggests that as people get richer and consumption rises, the marginal utility of consumption falls rapidly. In their model, health spending allows individuals to live longer, benefiting from additional periods of utility. Since, the marginal utility of life extension does not decline, the health share grows along with income.

Ciaschini et al. (2014) use a general equilibrium model to quantify the impacts of health care expenditure in the long term and along the income circular flow. Finally, Yagihashi

and Du (2015) builds a general equilibrium model that distinguishes health care demand from the demand for other goods. Using the model, the paper can replicate health inflation and cyclicality, as well as to analyse those implications on monetary policy.

Overlapping generation models have also been used within a health economics perspective. An important contribution was made by Chernew, Hirth and Cutler (2003), introducing endogenous mortality for a small open economy. Fanti and Gori (2012), expanded the model to show that increases in health investments, despite contributing to life expectancy, can also reduce income. Ehrlich and Yin (2013) extends the literature by incorporating both income growth and population aging as endogenous variables. Frankovic, Kuhn and Wrzaczek (2016) adds realism to the model by incorporating a demographic structure. More recently, Bolin and Caputo (2018) used a health-capital model to show that agents do not necessarily implement optimal health investment policies.

This paper builds a static model to highlight the different channels underlying the agent's decision on her health spending level. It also proposes an extension towards an Overlapping Generations model. The model acknowledges the role of health spending on improving the agents' utility through higher longevity. It also explicitly recognizes the role of health spending on increasing aggregate productivity for the economy. Given that public health will not be considered merely as a consumption good, the model suggests that higher levels of public health spending might not compromise other public expenditures. The challenge of financially sustainable public health arises when public health spending prevents countries from meeting their public finances' constraints. Thus, this paper aims to frame the macroeconomic discussion on health spending and provide a soundboard for future research.

This paper unfolds as follows: the next section introduces the static model to develop main intuition. Section 3 discusses the model implications regarding financial sustainability. Section 4 proposes the expansion of the previous model with the introduction on labour choice, and time dynamics - within an OLG framework. Finally, the last section

concludes.

4.2 A Static Model for Public Health Spending

I build a stylized model to develop some intuition regarding health spending growth and its implications for public finances' sustainability. In this model, health has two main roles. On one hand, it enters the utility function, being directly valued by the consumer. On the other hand, it contributes to the economy aggregate production through two channels. First, I specify a two-sector model, in which health and private goods are both produced. This recognizes health as a major economic sector – which employs workers and contributes to aggregate income. Second, health affects the private good production by increasing its productivity. This reflects its role on decreasing absenteeism, school drop-out rates, mental diseases, among other problems which could hamper productivity.

Consider a household with an expected utility given by: $EU = \gamma CG$, where $\gamma = \theta(\pi_0 + \pi_1 H)$. Utility is a function of private consumption (C) and government transfers (G), which can be though as social security transfers, or public services provision such as education or defence. Additionally, this consumption bundle (CG) is weighted by the household health status (γ), following the specification from Hall and Jones (2007).

In this model, γ can be thought as the household health status or life expectancy. This is affected by an unanticipated negative shock component (θ) – representing unexpected events affecting life expectancy, and independent from the current level of health consumption. This could for instance reflect a car accident or the Covid-19 pandemic. This shock component is bounded between zero and one. A zero value for this parameter implies a shock so strong that led to the agent's death. Conversely, if this parameter is equal to one, there is no negative shock, and the agent has perfect health. This shock distribution can be a function of the household age: older individuals, regardless of their health status, have higher risk for adverse health shocks.

Additionally, life expectancy - or quality of life - is also affected by health consump-

tion (H). Individuals with higher health consumption will have higher life expectancies – achieving higher utilities. Parameter π_0 is the inherent baseline life expectancy for an individual with no health consumption. This can be thought to reflect biological characteristics: individuals with serious pre-conditions will require higher health consumption to enjoy higher life expectancies. Parameter π_1 represents the multiplier effect of health consumption in life expectancy. In this setting, the household can influence her own life expectancy. Because health status depends on health consumption, utility also will be a function of health consumption. In this static model, I assume no negative random shocks ($\theta = 1$) and normalize the baseline life expectancy to zero ($\pi_0 = 0$).

Households maximize their utility subject to a budget constraint given by:

$$C + P_h H = (1 - \tau)(w_h N_h + w_y N_y) \tag{4.1}$$

The left-hand side represents the household consumption expenditures of private goods and health. Note that private consumption price was normalized to one. Thus, one can interpret P_h as the price of health relative to private consumption. Consider, for now, that health care is directly purchased by the consumer. The government has no influence on the health sector. The right-hand side represents the household's disposable income. The household has an inelastic health and non-health labour supply. Endowments are fixed and exogenous, representing the share of total employment devoted to the health sector and to other non-health sectors. The household makes no decision regarding her labour choice, considering both sectors to be heterogeneous. Thus, wages in both sectors do not need to be equal - since there is no mobility across sectors. Moreover, full employment is assumed. Unemployment can be introduced in the model, without changing main results significantly.

Income tax rate, τ, is exogenous and public spending, G, is set by the government according to a balanced budget constraint. If households select the optimal level of private

and health consumption, then, in equilibrium, private consumption spending must equal health spending according to:

$$C = P_h H \tag{4.2}$$

One firm produces private goods using labour, supplied inelastically by the household, according to the following production function:

$$Y = A\gamma N_y^{\alpha} \tag{4.3}$$

The production of the private good depends on labour quantity (N_y) but also on its quality. A healthier workforce is a more productive one. The introduction of health in the production function recognizes an additional role for health consumption. Not only it affects utility, but it also affects households' income – through higher wages. This can be thought to reflect decreasing absenteeism and the effect of having healthier workers.

The second firm produces health care using labour, supplied inelastically by the household, according to the following production function:

$$H = BN_h^{\beta} \tag{4.4}$$

Under perfect competition, workers will be paid at their marginal productivities. Profit-zero condition, and constant returns to scale, imply that α and β must be equal to one.

Finally, the government obeys to a balanced budget constraint, in which public spending must equal tax revenues.

$$\tau(w_h N_h + w_y N_y) = G \tag{4.5}$$

Using the budget constraint and the household equilibrium condition, together with market clearing conditions and firms' optimality conditions, one can find the closed-form

solution for our main variables:

$$P_h = \frac{1-\tau}{2-\beta+\tau\beta}\alpha A\pi N_y^{\alpha} = \frac{1-\tau}{1+\tau}A\pi N_y \tag{4.6}$$

$$C = \frac{1-\tau}{2-\beta+\tau\beta}\alpha AB\pi N_y^{\alpha}N_h^{\beta} = \frac{1-\tau}{1+\tau}AB\pi N_y N_h \tag{4.7}$$

4.3 Health spending sustainability

Introducing Public Health Spending

The issue with sustainability and affordability arises when the government has some degree of responsibility for health spending. Departing from the previous setting, let us know assume that health spending is, to some extent, financed by the government. There are multiple reasons that can justify public intervention in the health sector. For instance, to ensure adequate access to health services. In this model no particular reason is specified. This makes the model compatible with several health systems' designs and interpretations. In particular, the government can be seen as providing health care directly to the population or buying health care from private providers and offering public health insurance. I assume that the government provides a lump-sum transfer to the household to compensate for her health spending. The household, who sees such transfer as exogenous, faces now the following budget constraint:

$$C + P_h H = (1-\tau)(w_h N_h + w_y N_y) + \phi \tag{4.8}$$

Where ϕ represents the lump-sum transfer received by the household from the government. Such transfer corresponds to public health spending and is equal to $\phi = \rho P_h H$, with $\rho < 1$ being the coverage level. In this setting, health spending is now financed by the government. The government sets subsidies in such a way that the proportion of out-of-pocket payments made by the patient become equal to $1-\rho$. When $\rho = 0$, the

government does not play a role on the provision or financing of health care. All health spending is bought privately and directly by the household. Conversely, when $\rho = 1$, the government fully covers the household health expenditures. Any intermediate situations imply the existence of out-of-pocket payments.

The modified household budget constraint implies the following closed-form solutions for the relative price of health care and private good consumption:

$$P_h = \frac{1-\tau}{2-\rho-\beta+\tau\beta}\alpha A\pi N_y^{\alpha} = \frac{1-\tau}{1-\rho+\tau}A\pi N_y \tag{4.9}$$

$$C = \frac{1-\tau}{2-\rho-\beta+\tau\beta}\alpha AB\pi N_y^{\alpha}N_h^{\beta} = \frac{1-\tau}{1-\rho+\tau}AB\pi N_y N_h \tag{4.10}$$

If $\rho = 0$, these conditions become identical to the ones presented in the previous section - with fully private health spending. Note that the relative price for healthcare is inversely related with the share of out-of-pocket payments. Higher coverage levels from the government reduce the health care cost faced by the individual. This increases demand for health care which, for a given supply, results in higher relative prices.

The change in the household budget constraint also affects the government, which must now obey to a modified budget constraint given by:

$$\tau(w_h N_h + w_y N_y) = G + \phi \tag{4.11}$$

Technology and health spending growth

Consider now the case of a technological improvement in the production of the private good. It is easy to see that an increase in A, increases both the private good consumption level, as well as the relative price of healthcare. Because health technology and employment are kept constant, production and consumption of healthcare remain constant as well. The larger availability of the private good, implies that healthcare becomes scarcer in relative terms – thus, becoming more expensive. For a given tax rate, the increase in

production will increase income, which in turn allows for a higher level of government spending. Based on these functional forms, an increase in A leads to an increase in overall health spending – through a price effect.

Similarly, an increase in the health sector technology (B) leads to an increase in the production of health care. However, because health is an input in the private good production, this will also increase the production of the private good. Because the production for both goods increase, the relative price of healthcare remains unchanged. As before, such shock results in an increase in health spending - through a quantity effect.

It is likely to observe an increase in both private goods and in health production technologies. However, as noted by Baumol (1986), technology in the health sector seems to grow at a lower pace than in the rest of the economy. To illustrate such issue, define $B = \eta A$, where η is the share of health technology in overall technology. If the health sector evolves at a lower pace, then $\eta < 1$. In a context of technological growth in both sectors, one can observe an increase in health production, as well as an increase in private good production. The latter increases more than the former, given the compounding effect that health care has on the private good production. Thus, even though health production is increasing, the relative price for healthcare increases as well. Hence, this simplified setting shows that technology contributes to an increase in health spending, here both with a price and a quantity effect.

Nonetheless, the share of health spending on GDP, s_h, is not affected by the technological level. Instead, it will depend on the tax rate, coverage level, and diminishing marginal returns parameters, as described by the following condition.

$$s_h = \frac{\alpha - \alpha\tau}{3 - \rho - \beta + \tau\beta - \tau} \tag{4.12}$$

In the case of no public health spending and constant returns to scale, the share of health spending is a linear function of the tax rate. When the tax rate is 0%, there is no non-

health public spending (G). In that case, the household optimality conditions imply that income will be equally divided in private consumption and health spending. Hence, the share of health spending is equal to 50%. As the tax rate increases, the share of health spending decreases. When the tax rate is 100%, there is no health spending - since all income is used to finance non-health public spending (G).

Defining Public Health Spending Sustainability

The definition of health spending sustainability is far from being consensual. In this paper, I interpret such concept as whether public health spending levels are compatible with sustainable public finances. This is aligned with international institutions' definitions as it relates the concept of financial sustainability with the ability to afford health spending in the long run.

Unsustainability arises when an increase in public health spending conducts towards an explosive path for public debt. Such violation of the government budget constraint forces a future sudden adjustment back to equilibrium. Nonetheless, whether public health spending growth results in an explosive path for the public debt or not, depends on fiscal space. Firstly, it depends on whether fiscal space is increasing as well - facilitating the financing of higher levels of public health spending. Secondly, it depends on the expected trajectory of the remaining non-health public spending (G). If the remaining non-health public spending is expected to be kept constant, or even increase, then the increase in the fiscal space might not be enough. Thus, if the model predicts that health spending growth would lead to a crowding-out of other public expenditures, then such growth is unsustainable. This happens because non-health public spending is expected to be relatively sticky. Downward adjustments on these expenditures are unlikely to be feasible since citizens may prioritize health care services, but they still value other public services.

Financial sustainability of public health spending is inherently a dynamic concept. For

public health spending growth to be affordable, such growth needs to be followed by a fiscal space expansion or by an adjustment in other public expenditures. If such adjustments or fiscal space expansions are not enough, then public health spending will lead to the accumulation of government deficits. Such accumulation entails an explosive trajectory for the public debt, which would violate the transversality condition specified in a dynamic macro model. This would eventually lead to a sudden stop and a sharp fiscal adjustment.

The current static model is able to cast such dynamic environment through the government budget constraint. Since there is no time dimension in this setting, the concept of public debt is not directly specified. Instead, an explosive path for the public debt would arise following systematic violations of the balanced budget condition. Thus, this model can be interpreted as a long-run model where the stability of the public debt is ensured by the existence of non-negative government balances.

This definition of health spending sustainability has obvious limitations since it does not consider access, or equity considerations. Nonetheless, it has the useful benefit of being practical and easy to validate. According to such definition, and within the scope of this model, public health spending level is unsustainable if it leads to the crowding-out of other public expenditures. Because this crowding-out is unlikely to be feasible, this would imply the violation of the government budget constraint. In a dynamic setting, this would be equivalent to the violation of the intertemporal government budget constraint – through the accumulation of higher levels of debt.

Consider, as discussed before, an exogenous increase in technology - assuming that technology in the health sector grows at a lower rate that in the rest of the economy. In such setting, the model predicts exogenous economic growth, as well as health spending growth. To understand whether such dynamics create a fiscal challenge, one needs to assess its implication for non-health public expenditures. The following expression describes the impact of technology growth - which induces health spending growth - on

non-health public expenditures.

$$\frac{\partial G}{\partial A} = \frac{2\tau - \rho}{1 - \rho + \tau} 2\pi\eta A N_y N_h \tag{4.13}$$

Such technological improvement leads to economic growth, which increases fiscal revenues. Nonetheless, the impact of this on other public expenditures is ambiguous. It will depend on the sign of the numerator, $2\tau - \rho$, which depends on the tax rate and on coverage level.

There are two interesting cases worth exploring. The first one is the case of fully private health spending, $\rho = 0$. In this case, the impact of technology in public spending is positive. Technology increases fiscal space which is only used to finance higher levels of public spending. In this context, by definition, health spending is sustainable since health is directly purchased by the household. There is no trade-off between higher health spending and lower non-health public spending. Higher (private) health spending leads to an increase in tax revenues - increasing G. Even if higher health spending is not optimal from the household perspective, it creates no threat to public finances sustainability.

The second case happens when health is fully financed by the government, $\rho = 1$. In this case, the impact on non-health public spending is ambiguous. Depending on the tax rate, an increase in public health spending might trigger an increase or decrease of other public expenditures. Still, under some circumstances, increases in health spending can increase fiscal space substantially. This would not happen in a model where health would not contribute to the production of the private good.

When the tax rate is higher than 50%, the increase in the fiscal space is large enough to accommodate both public health spending growth, as well as higher levels of other public expenditures. In this case, sustainability would also be ensured. However, for tax levels below 50%, the increase in health spending would imply a crowding-out of the remaining public expenditures. This would be the case of an unsustainable path for public health

spending.

The model suggests that sustainability depends on both the coverage level and the tax rate. To avoid crowding-out of non-health public expenditures, higher levels of coverage need to be followed by higher taxes. The model predictions rely on a set of strict assumptions. Nonetheless, it is useful to clearly highlight this connection between the desired coverage required by the population and the way such coverage must be financed.

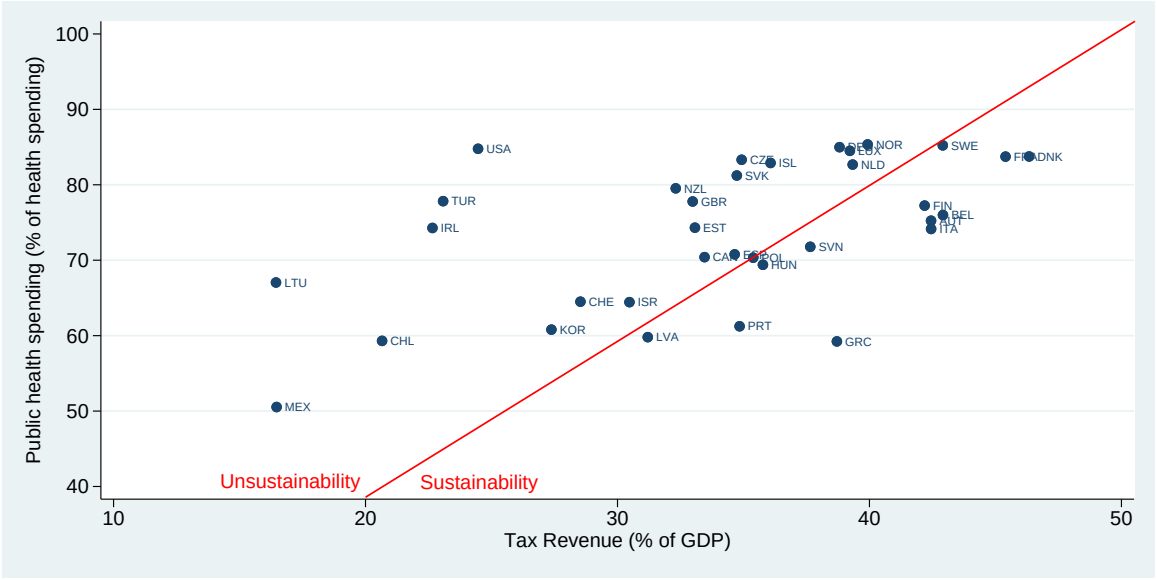
To understand the relative strength of these effects, consider the following illustration. On average, OECD countries' tax revenues amount to 33.8% of their GDP (data for 2019). According to the model, to achieve sustainability, one would need incomplete coverage of public health care systems. No more than 67.6% of health spending should be publicly financed. If such condition would not be respected, then increases in health spending could impose a reduction on the remaining public expenditures - or a failure to comply with budgetary rules. Figure 4.1 estimates this sustainability threshold for a set of 34 OECD countries. According to this model, 13 of these have room to increase public health spending - following economic growth - without compromising other public expenditures growth.

The remaining countries have health systems with high public protection levels relative to their tax revenues. For these countries, economic growth can trigger health spending growth and force a reduction on other public expenditures. The model predicts that increases in public health spending could only be compatible with the government budget constraint if followed by reductions on other public expenditures. If such adjustment does not occur, then the government budget constraint must be violated, and the model would not be in equilibrium. An expansion towards a dynamic model implies that such accumulation of government deficits would result in higher levels of debt. Such debt levels would eventually violate the transversality condition, entering an explosive and unsustainable trajectory. Thus, despite being a static model, this setting allows to derive conclusions regarding the long run sustainability of public finances – and implicitly, on the financial

sustainability of public health spending.

The red line in the following figure represents a situation in which other public expenditures remain unchanged following public health spending growth. One could also specify minimum growth rates for the other public expenditures. In such case, the financial sustainability threshold would move to the right of the original red line. Hence, if the growth rate for other public expenditures increases, achieving financial sustainability for public health spending growth becomes increasingly difficult.

Figure 4.1: Public health spending financial sustainability as a function of coverage level and tax rate

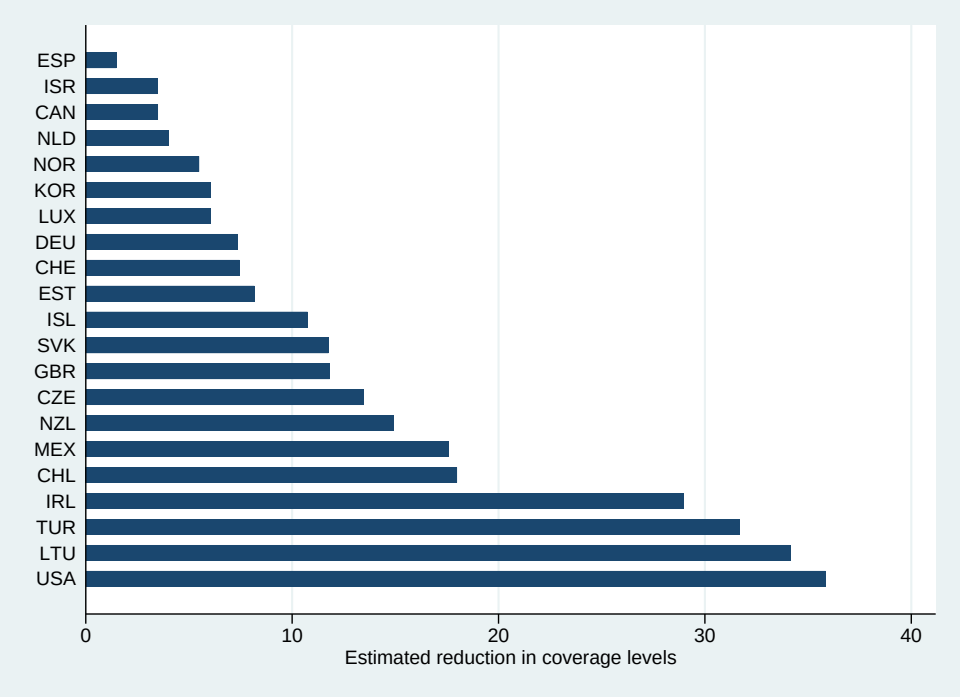


Note: Estimation for a set of 34 OECD countries with 2019 data. The red line represents the sustainability threshold estimated by the model described.

According to the previous example, countries in an unsustainable path could converge back to the sustainability threshold either through a tax rate increase, or through an adjustment on the coverage level. These changes are far from being consensual and from having a null impact. Changes in the coverage level imply a reduction in the protection that the government provides to its population - increasing the direct burden on citizens (such as out-of-pocket payments). This reduction would create equity and access con-

cerns - risking the social sustainability of the health system. A tension between these two sources of sustainability arises: promoting financial sustainability may prevent social sustainability to be ensured - and vice-versa. If taxes were to remain constant, coverage levels' adjustments would have to be substantial for some countries (figure 4.2). The following figure represents, for the countries above the financial sustainability threshold, the distance towards a coverage level compatible with such threshold.

Figure 4.2: Estimated reduction in coverage levels to achieve the sustainability threshold



The model suggests as well that economic growth is not a sufficient condition to ensure public health spending sustainability. An equilibrium between taxation and coverage levels is required to prevent economic growth to induce crowding-out of other public expenditures. To some extent, this is a strong result - suggesting that unlimited economic growth could still lead to unsustainable trajectories of public health spending. Such conclusion steams from the fact that the model assumes health to have a linear and constant impact on the productivity of the private good, according to the γ function.

4.4 Extensions

4.4.1 Introducing Labour choice

The previous setting assumed a fixed labour endowment for the health sector and the private good production. On one hand, such assumption would capture the fact that work in these two sectors is differentiated. In developed countries the number of workers to available to work in the health sector is limited and contingent on their qualifications. On the other hand, such strict assumption also implies that the household has no role on her labour allocation.

Relaxing this assumption does not affect the main conclusions substantially. I now assume that the household is free to allocate her time on both sectors according to the following time constraint.

$$\bar{L} = N_h + N_y \tag{4.14}$$

In such setting, labour is a homogeneous input which can be used in both sectors. There is still no unemployment. Such extension implies that wages must be identical across sectors. This is an arbitrage condition to avoid that all workers move to one sector only.

The household and firms' optimality conditions are the same as before. However, now the household must also decide on how to allocate her labour time. Market clearing conditions imply that employment in each sector will be a function of total labour endowment and taxes.

$$N_h = (1 - \tau)N \tag{4.15}$$

$$N_y = \tau N \tag{4.16}$$

Exogenous economic growth - through an increase in technology - leads to an increase in

public health spending. Such increase has two opposite effects on other public expenditures: a positive effect resulting from the increase in fiscal revenues, and a negative one following the increase in health spending. The following expression describes the impact on other public expenditures:

$$\frac{\partial G}{\partial A} = (\tau - \rho + \rho\tau)(2(1-\tau)\pi\eta A N^2) \tag{4.17}$$

The sign of the expression is ambiguous, and it depends on the sign of the first term: $\tau - \rho + \rho\tau$. As before, the tax rate still needs to increase to allow for higher levels of public health coverage. Also, the two cases analysed before remain the same: health spending will always be sustainable in the case of no public coverage ($\rho = 0$); and in the case of full public coverage ($\rho = 1$) it is sustainable only when the tax rate is higher than 50%. Otherwise, increases in health spending trigger a crowding-out of other public expenditures. However, even though the relation is still monotonic, the connection between the tax revenue and coverage level is no longer linear. Such non-linearity arises following the introduction of labour choice in the model.

4.4.2 Introducing dynamics: an OLG framework

The static model of the previous section has a set of limitations. Among others, it has no explicit time dynamics, considers no heterogeneity across agents, and assumes labour supply to be inelastic, without a role for leisure. Nonetheless it provides an intuitive way to see how the introduction of health as an input of the aggregate production function affects the government budget constraint. When accounting for the impact of health on economic growth, fiscal space might increase or decrease following increases in public health spending.

I briefly propose an extension to the previous framework, which is described in detail in the appendix. I build a two-period overlapping generations model, introducing some

heterogeneity on agents and a labour choice. The OLG setting allows also to introduce time dynamics, particularly relevant to analyse public health spending sustainability – which, by definition, is a dynamic time-related concept. The downside is that the model becomes more complex, and its interpretation is not as straightforward as before.

The OLG setting is more complete than the static version discussion before. An extended analysis based on such model allows to understand the effects of health care consumption on the labour-leisure decision. Since health improves production, it can be seen as a substitute for labour. Improvements in health care production, for instance through technology, can also impact the allocation of working time across both sectors. Finally, this model can also be used to analyse simplified changes in the population demographic structure. Random shocks – such a pandemic or a vaccine – can change the survival probability and the proportion of older individuals relative to young individuals.

4.5 Conclusion

Health spending has been increasing across countries. Because health spending represents a significant share of public spending, this creates a fiscal sustainability challenge. Countries struggle to improve their health systems efficiency to cope with increasing costs. However, it is not clear whether countries will be able to sustain a continuum growth of public health spending.

On this paper I build a static model to frame such question in a general equilibrium framework. The model includes two main ingredients which are often analysed separately in the literature. Firstly, I explicitly recognize the role of health in improving the economy's aggregate productivity. This implies that an increase in health care increases the overall production and income of the economy. Secondly, health accumulation contributes to extend the individual's life expectancy, which impacts her utility function. The combination of both these features implies that health can be seen with a consumption and investment perspective.

This paper aims to provide a framework in which public health spending sustainability can be analysed. It highlights the main channels through which health spending influences the economy. Proper understanding of these channels and of the interconnections between the main variables can be the basis for further research.

The paper defines financial sustainability as an increase in public health spending which does not pose a threat to public finances, in the sense that it does not lead to an explosive path for public debt. Because the model has no explicit time dynamics, such concept is interpreted as systematic compliance with the government balanced budget constraint. Thus, public health spending is financially sustainable if it does not imply the crowding-out of other public expenditures - such as social security transfers, education, and other public services. For this condition to hold, the increase in public health spending needs to

trigger a substantial increase in the available fiscal space.

The model suggests that the crowding-out of non-health public expenditures depends on the relation between the tax rate and coverage level of public health spending. Higher protection levels from public health systems require higher taxation levels to be considered sustainable. For the extreme case of a fully public health spending system, without out-of-pocket payments, the tax rate would need to be equal to 50% to prevent crowding-out of other public expenditures.

Economic growth is not a sufficient condition to achieve financial sustainability of health spending. It contributes to the expansion of the fiscal space, but whether such expansion is enough depends on the relation between taxes and coverage levels. The model hinges on a strict set of assumptions. Nonetheless, an application to 34 OECD countries suggests that only 13 countries are in a financially sustainable trajectory.

Financial sustainability can be achieved by adjusting coverage levels. This implies the increase of out-of-pocket payments, reducing the health-related protection provided by the government. These changes might be socially undesirable. Thus, achieving financial sustainability might compromise ensuring the social sustainability of public health spending.

Hence, increases on public health spending are not necessarily undesirable from a public finances' standpoint. The question on whether countries will be able to sustain increasing levels of public health spending requires an integrated analysis in a general equilibrium framework, as this paper suggests.

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Appendix

A.1 Appendix Chapter 1

A.1.1 Additional summary statistics

Table 4.1: Regional admission statistics

Regions	Hospital Centres	Hospital mortality (%)	Urgent 30-days readmission (%)	Hospital Admissions		
				Outpatient (%)	Inpatient (%)	Total (million)
North	15	2.38	4.87	45	55	4.35
Center	11	3.24	5.52	40	60	1.99
Lisbon	15	2.83	5.43	43	57	4.35
Alentejo	4	3.67	5.58	46	54	0.45
Algarve	1	4.57	7.85	39	61	0.36
National	46	2.82	5.32	43	57	11.50

Table 4.2: Summary statistics for the main variables

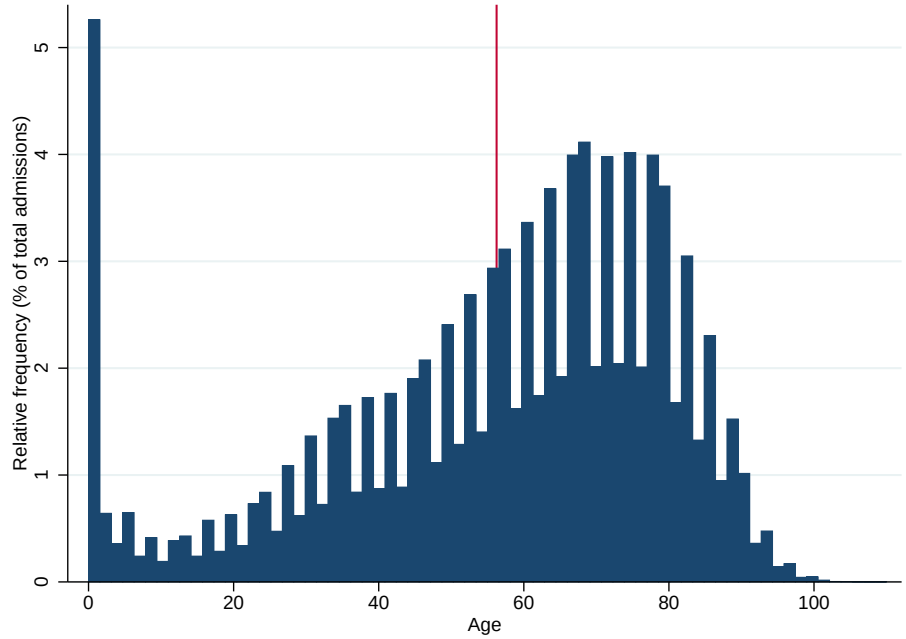
Variable	Mean	Standard Deviation
Age	56.2	23.9
Proportion of females (%)	53.0	49.9
Length of stay (days)	4.8	9.2
Inpatient care admission (%)	56.7	49.6
Urgent admission (%)	34.7	47.6
Surgical service admission (%)	32.8	46.9
Long admissions (>30 days) (%)	1.9	13.8
Hospital mortality (%)	2.8	16.5
Urgent 30-days readmission (%)	5.3	22.4
Urgent 15-days readmission (%)	4.2	20.0
Urgent 7-days readmission (%)	3.1	17.3
Total admissions	11,504,302	

Notes: Averages of all admissions across all hospital and years.

Table 4.3: Healthcare strikes

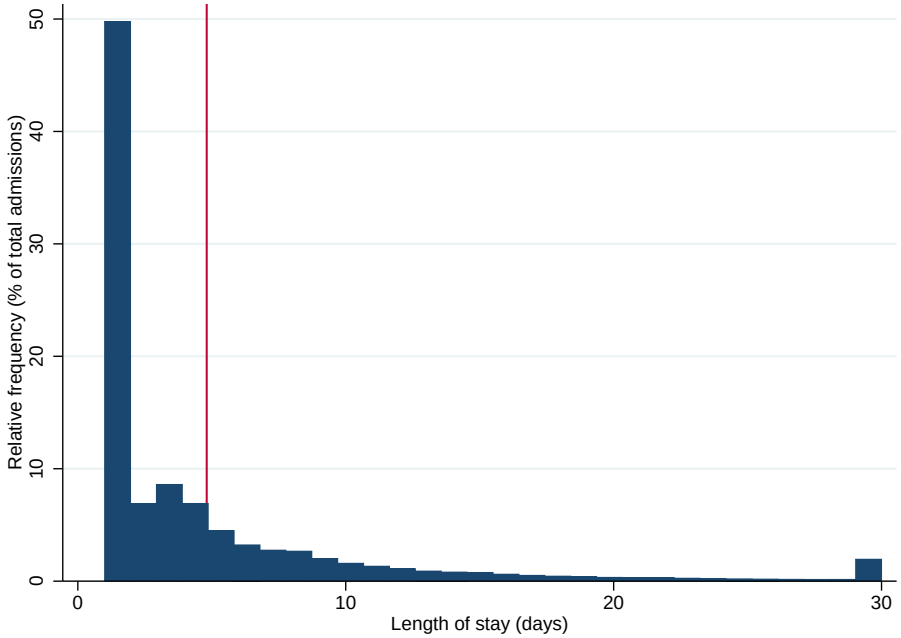
Year	Physicians	Nurses	DTT	Total Strikes
2012	3	2	2	7
2013	2	11	1	14
2014	1	9	2	12
2015	2	8	2	12
2016	0	19	3	22
2017	4	2	7	13
2018	1	36	10	47
Total	13	87	27	127

Figure 4.3: Histogram for Age



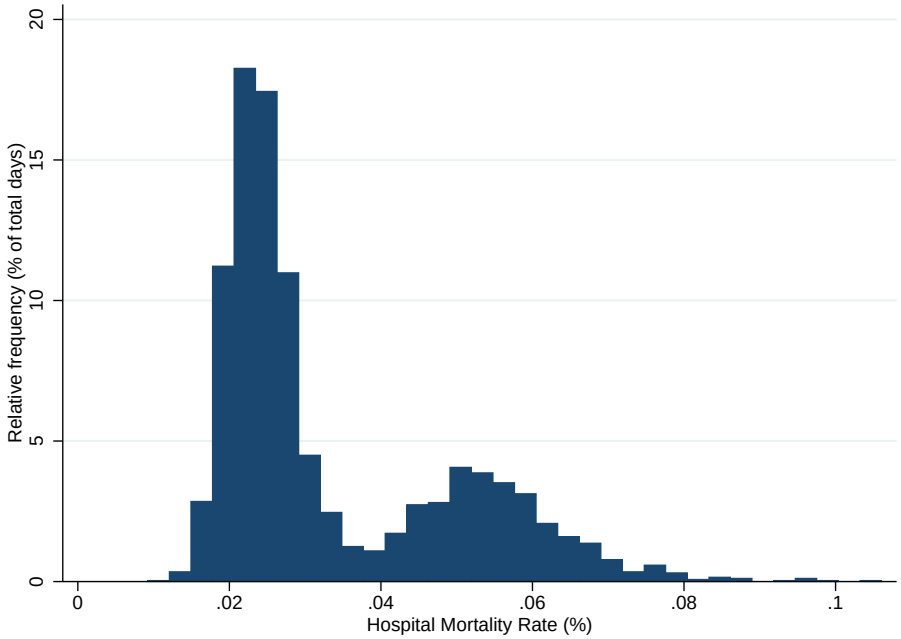
Note: Mean represented by the vertical red line. Regression models include age grouped in 10-year intervals to account for potential coding errors (suggested by spikes at the beginning of each decade).

Figure 4.4: Histogram for Length of Stay



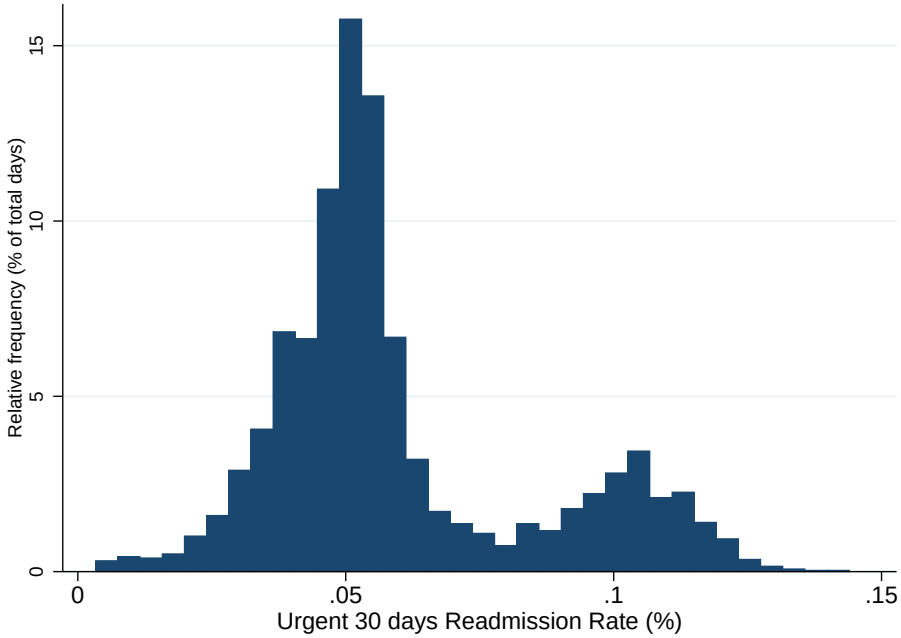
Note: Mean represented by the vertical red line. Right truncation for hospital stays larger than 30 days.

Figure 4.5: Histogram for Hospital Mortality Rate



Note: Frequency computed across days: each column represents the proportion of days with each hospital mortality rate.

Figure 4.6: Histogram for Urgent 30 days Readmission Rate



Note: Frequency computed across days: each column represents the proportion of days with each urgent 30 days readmission rate.

A.1.2 Severity of Illness and Risk of Mortality

Table 4.4: Impact of strikes exposure in admission on Severity of Illness and Risk of Mortality indicators

	Exposure to strike on the admission day	
	Severity of Illness (SOI)	Risk of Mortality (ROM)
Physicians' strike	-0.0020	0.0003
	(0.0033)	(0.0035)
Nurses' strike	0.0038	0.0080**
	(0.0033)	(0.0033)
DTTs' strike	0.0001	0.0000
	(0.0022)	(0.0026)
Age x Female	-0.0000	0.0001
	(0.0001)	(0.0001)
Female	-0.0118***	-0.0349***
	(0.0016)	(0.0025)
Surgical admission	-0.1272***	-0.1262***
	(0.0099)	(0.0097)
Urgent admission	0.0886***	0.1021***
	(0.0121)	(0.0121)
Number of diagnoses	0.0772***	0.0911***
	(0.0032)	(0.0029)
Number of procedures	0.0245***	0.0328***
	(0.0019)	(0.0018)
Observations	5,298,977	5,298,977

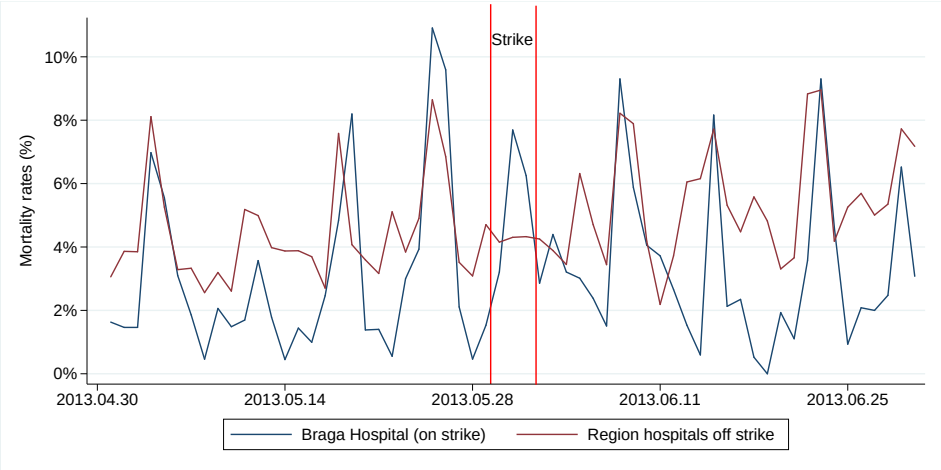
*,**, *** indicate significance at 10%, 5% and 1% level, respectively.

Notes: Standard errors in parentheses, clustered at the hospital level. Includes all inpatient care admissions from 2013 to 2018 (SOI and ROM not available for 2012 admissions). Long admissions (more than 30 days) excluded. Female is equal to 1 if the admitted patient was a female, and equal to 0 otherwise. Surgical admission is equal to 1 if the admission was coded with a surgical DRG, and equal to 0 if the admission was a medicine DRG. Urgent admission is equal to 1 if the admission was coded as urgent, and equal to 0 otherwise. Each model includes the dummy variables for each of the 10 age groups, 26 diagnoses categories, 46 hospitals, 5 regions, year, month, week, weekday, and year-month-region. Severity of illness (SOI) refers to the degree of loss of function or physiologic decompensation of an organ system. Risk of mortality (ROM) reflects the likelihood of dying.

SOI and ROM are measured in a scale from 1 to 4 and are determined by an algorithm. The algorithm considers the principal and secondary diagnoses, age, presence of operating-room procedures, non-operating room procedures, and multiple operating-room procedures. Despite the influence of nearly all patient features, secondary diagnoses representing co-morbidities and complications are what typically drive SOI and ROM levels Souza et al. (2020).

A.1.3 Example of hospital mortality during physician strikes

Figure 4.7: Mortality rates for Braga Hospital during a physician strike versus nearby non-strike hospitals



Note: Exposure to physicians' strikes on admission. Braga Hospital was on strike on May 30th and 31st. Outcomes compared to hospitals in the North region

A.1.4 Heterogeneous strike's effects

This paper analyses the effect of strikes depending on the professional category on protest. Different effects for physicians, nurses and DTTs' strikes are found. However, there might be heterogeneity across other dimensions. Table 4.5 displays regression estimates on hospital mortality for some subgroups.

The first panel (Overall) displays the impact of strike exposure in admission on hospital mortality. These are the same coefficients as the ones estimates by the main model. The second panel distinguishes between regions. The third panel divides the sample according to the type of emergency department available at the hospital. The fourth panel investigates admissions with different length of stay, while the next two panels analyse both urgency and severity indicators of those admissions. Finally, the last panel focuses on the top diagnostics registered on patients admitted through the emergency department.

Estimates lose precision when looking at subgroups. For the majority of those, it is not possible to reject the hypothesis of null impact from strikes. Main changes are observed when decomposing admissions according to their severity scores and length of stay.

For patients admitted during physicians' strikes, strikes seem to have negative impacts on relatively long admissions (between one and two weeks). Additionally, critical patients' mortality rates are lower during physician strikes, while the remaining patients face higher mortality rates. To some extent, this result might reflect higher prioritization of critical patients during strikes.

Severe patients also face higher mortality rates during nurses' strikes. Regarding length of stay, admissions longer than two weeks are negatively affected, while patients which stay in the hospital for one to two weeks have lower hospital mortality rates.

The impact of strikes can be reflected in factors other than mortality rates - namely lower quality of care. This quality of care will often not be captured by the type of administrative data this paper uses. Nonetheless, for some diagnoses groups, some proxies for lower quality of care can be found. The example for childbirth related diagnoses is paradigmatic. Data shows that, controlling for time trends, hospital and regions, complications during births increase for patients admitted on a strike. In fact, complications for women admitted during physicians' strikes in vaginal deliveries and caesarean sections increase by 12% and 30% respectively. This example reinforces the hypothesis that such protest might lead to the under-provision of care, even if not always reflected in mortality or readmission rates.

Table 4.5: Heterogeneous effects from exposure to strikes on admission day

Dimension	Variable	Baseline hospital mortality rate	Exposure to strike on admission day			Observations
			Physicians' strike	Nurses' strike	DTTs' strike	
	Overall	0.0497	0.0025**	0.0003	-0.0007	6,176,264
		(0.2172)	(0.0012)	(0.0007)	(0.0007)	
Region	North	0.0434	0.0030	0.0007	-0.0013	2,243,861
		(0.2038)	(0.0018)	(0.0011)	(0.0011)	
	Centre	0.0541	-0.0003	0.0010	0.0001	1,142,422
		(0.2261)	(0.0031)	(0.0018)	(0.0018)	
	Lisbon	0.0494	0.0030	0.0001	-0.0001	2,367,537
		(0.2168)	(0.0019)	(0.0011)	(0.0012)	
	Alentejo	0.0683	-0.0019	0.0006	0.0028	223,565
		(0.2522)	(0.0077)	(0.0048)	(0.0047)	
	Algarve	0.0751	0.0144*	-0.0042	-0.0104**	198,879
		(0.2636)	(0.0082)	(0.0049)	(0.0053)	
ED Type	No ED	0.0281	0.0067***	0.0016	0.004	551,839
		(0.1653)	(0.0007)	(0.0022)	(0.0009)	
	Small ED	0.0586	0.0025	0.0005	-0.0001	2,644,710
		(0.2348)	(0.0020)	(0.0011)	(0.0009)	
	Major ED	0.0457	0.0017	-0.0003	-0.0016	2,979,715
		(0.2089)	(0.0016)	(0.0011)	(0.0011)	
Length of stay	1 day	0.0242	-0.0005	0.0022*	0.0003	763,577
		(0.1536)	(0.0016)	(0.0011)	(0.0012)	
	<4 days	0.0381	0.0016	0.0030	-0.0007	1,685,791
		(0.1915)	(0.0023)	(0.0018)	(0.0013)	
	<1 week	0.0383	0.0030*	-0.0013	-0.0001	1,999,295
		(0.1920)	(0.0016)	(0.0014)	(0.0011)	
	<2 weeks	0.0587	0.0098***	-0.0031**	-0.0023	1,181,896
		(0.2351)	(0.0036)	(0.0015)	(0.0021)	
	>2 weeks	0.1145	-0.0026	0.0082**	0.0008	570,935
		(0.3183)	(0.0054)	(0.0037)	(0.0032)	
Urgent admissions	Non-urgent	0.0102	0.0011	0.0018	0.0004	2,849,128
		(0.1007)	(0.0009)	(0.0012)	(0.0006)	
	Urgent	0.0747	0.0046*	0.0003	-0.0021*	3,327,136
		(0.2629)	(0.0023)	(0.0014)	(0.0012)	
Severity index	Low	0.0038	0.0010**	-0.0001	0.0001	3,716,824
		(0.0618)	(0.0005)	(0.0002)	(0.0002)	
	Average	0.0768	0.0035	-0.0012	-0.0011	1,002,198
		(0.2662)	(0.0041)	(0.0024)	(0.0023)	
	Severe	0.2186	0.0152*	0.0111**	-0.0089	465,822
		(0.4133)	(0.0089)	(0.0046)	(0.0053)	
	Critical	0.4582	-0.0403**	-0.0011	0.0126	114,153
		(0.4983)	(0.0200)	(0.0128)	(0.0119)	
Top 10 ED diagnoses	Respiratory system	0.1505	0.0047	-0.0019	-0.0003	535,798
		(0.3576)	(0.0075)	(0.0056)	(0.0047)	
	Pregnancy and Childbirth	0.0001	0.0000	-0.0001	0.0001	454,611
		(0.0078)	(0.0000)	(0.0000)	(0.0001)	
	Circulatory system	0.0607	0.0083	0.0030	-0.0122**	362,049
		(0.2388)	(0.0069)	(0.0047)	(0.0034)	
	Digestive system	0.0601	0.0046	-0.0010	-0.0046	324,721
		(0.2377)	(0.0063)	(0.0048)	(0.0045)	
	Musculoskeletal system	0.0170	0.0001	0.0006	0.0002	276,229
		(0.1291)	(0.0040)	(0.0029)	(0.0029)	
	Nervous system	0.0893	0.0104	0.0046	-0.0079	274,559
		(0.2852)	(0.0076)	(0.0051)	(0.0044)	
	Kidney	0.0529	0.0028	0.0043	0.0041	218,106
		(0.2238)	(0.0082)	(0.0043)	(0.0041)	
	Pancreas	0.0692	-0.0133	0.0045	0.0131	170,429
		(0.2538)	(0.0115)	(0.0069)	(0.0082)	
	Infectious diseases	0.2281	0.0121	-0.0111	-0.0086	86,298
		(0.4196)	(0.0196)	(0.0134)	(0.0133)	
	Skin disorders	0.0270	0.0047	0.0032	-0.0042	83,741
		(0.1620)	(0.0115)	(0.0075)	(0.0074)	

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.

Notes: Standard errors in parentheses, clustered at the hospital level. Includes all inpatient care admissions from 2012 to 2018. Long admissions (more than 30 days) excluded. Each model includes the following controls: age groups, gender, age x gender, surgical admissions, urgent admissions, number of diagnoses, number of procedures, hospital, region, year, month, week, weekday and year-month-region. Severity index not available for 2012.

A.2 Appendix Chapter 2

A.2.1 Pharmaceutical price and reference price

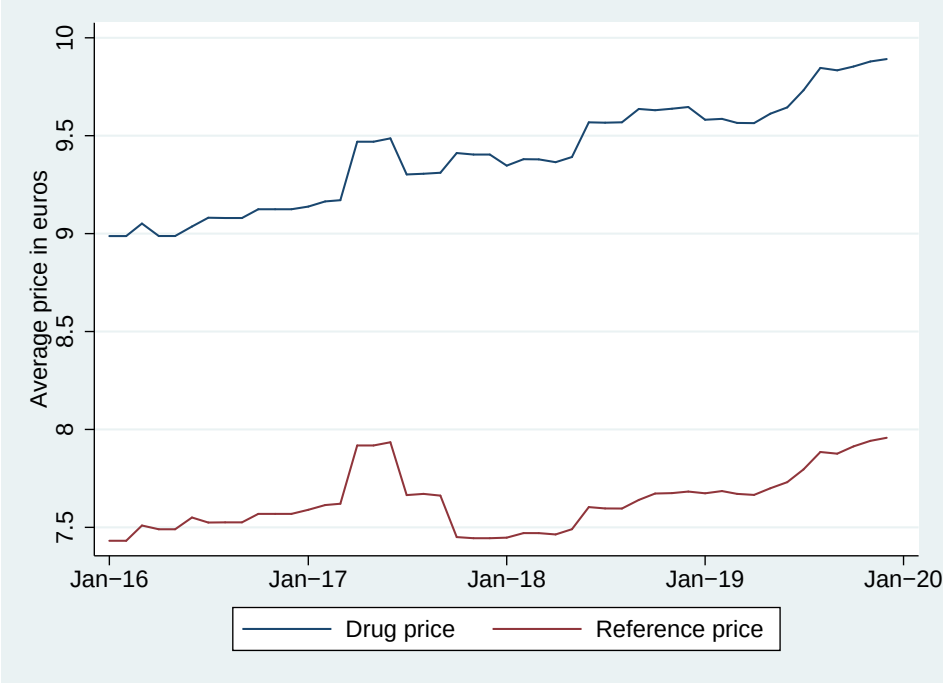


Figure 4.8: Pharmaceutical price and reference price (unbalanced panel; 2016 - 2019; euros)

A.2.2 Pharmaceutical price and reference price

Figure 4.9: Reference price for the affected drugs (unbalanced panel; 2016 - 2019; euros)

A.2.3 Parallel trend assumption test

Table 4.6: Parallel trend assumption test (balanced panel)

	Branded drugs		Generic drugs	
	Drug price	Patient Price	Drug price	Patient Price
Trend	-0.0147***	-0.0132***	-0.0003	0.0023***
	(0.0022)	(0.0024)	(0.0005)	(0.0008)
Trend x affected	0.0035	0.0029	0.0012*	-0.0055
	(0.0045)	(0.0049)	(0.0006)	(0.0035)
N	14,511	14,511	92,106	92,106
Product FE	x	x	x	x
Competition control	x	x	x	x
Month-year FE	x	x	x	x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level

A.2.4 Patient prices estimation (in levels)

Table 4.7: Impact on patient prices (in euros) for branded and generic drugs

	Branded Drugs			Generic Drugs		
Patient Price (in euros)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	0.9133***	0.9316***	1.1959***	0.6675***	0.6808***	0.6932***
	(0.1743)	(0.1759)	(0.1857)	(0.0845)	(0.0838)	(0.0869)
Competitors		-0.0639	-0.1231		0.0662	0.0625
		(0.1093)	(0.1086)		(0.0429)	(0.0418614)
Generic competitors		0.3181**	0.3061**		-0.0023	-0.0242
		(0.1336)	(0.1279)		(0.0452)	(0.0459)
N	31,104	31,104	31,104	205,680	205,680	205,680
			Unbalanced Panel			
Policy	1.2152***	1.2129***	1.4230***	0.7697***	0.7829***	0.6901***
	(0.1904)	(0.1896)	(0.2066)	(0.0806)	(0.0786)	(0.0844)
Competitors		-0.0179	-0.0877		-0.0163	0.0084
		(0.0999)	(0.0972)		(0.0419)	(0.0401)
Generic Competitors		0.3121**	0.3730***		0.1345**	0.1335
		(0.1486)	(0.1395)		(0.0569)	(0.0559)
N	43,942	43,942	43,942	275,256	275,256	275,256
Product FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

A.2.5 Drug prices estimation (in logarithms)

Table 4.8: Impact on drug prices (in logs) for branded and generic drugs

	Branded Drugs			Generic Drugs		
Drug Price (log)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	-0.0086***	-0.0078***	0.0139***	0.0003	0.0012**	0.0085***
	(0.0024)	(0.0023)	(0.0041)	(0.0004)	(0.0005)	(0.0020)
Competitors		-0.0042	-0.0089		0.0058	0.0041
		(0.0068)	(0.0065)		(0.0043)	(0.0041)
Generic Competitors		0.0158**	0.0149**		-0.0033	-0.0041
		(0.0073)	(0.0068)		(0.0045)	(0.0044)
N	31,104	31,104	31,104	205,680	205,680	205,680
			Unbalanced Panel			
Policy	-0.0085***	-0.0082***	0.0230***	0.0001	0.0005	0.0098***
	(0.0020)	(0.0020)	(0.004)	(0.0004)	(0.0005)	(0.0017)
Competitors		0.0043	-0.0043		0.0063*	0.0038
		(0.0058)	(0.0056)		(0.0034)	(0.0032)
Generic Competitors		-0.0120*	-0.0048		-0.0069*	-0.0063*
		(0.0068)	(0.0062)		(0.0036)	(0.0034)
N	43,942	43,942	43,942	275,256	275,256	275,256
Product FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

A.2.6 Patient prices estimation (in logarithms)

Table 4.9: Impact on patient prices (in logs) for branded and generic drugs

	Branded Drugs			Generic Drugs		
Patient Price (log)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	0.1358***	0.1387***	0.1460***	0.4256***	0.4303***	0.4200***
	(0.0137)	(0.0136)	(0.0169)	(0.0736)	(0.0733)	(0.0731)
Competitors		0.0061	0.0042		0.0215	0.0234*
		(0.0141)	(0.0148)		(0.0134)	(0.0135)
Generic Competitors		0.0213	0.0209		-0.0052	-0.0039
		(0.0168)	(0.0168)		(0.0142)	(0.0144)
N	31,104	31,104	31,104	205,680	205,680	205,680
			Unbalanced Panel			
Policy	0.1725***	0.1731***	0.1826***	0.5516***	0.5568***	0.5007***
	(0.0142)	(0.0140)	(0.0162)	(0.0728)	(0.0719)	(0.0721)
Competitors		0.0105	0.0065		-0.0173	-0.0029
		(0.0122)	(0.0130)		(0.0174)	(0.0173)
Generic Competitors		0.0119	0.0155		0.0705***	0.0692***
		(0.0138)	(0.0143)		(0.0224)	(0.0218)
N	43,942	43,942	43,942	275,256	275,256	275,256
Product FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

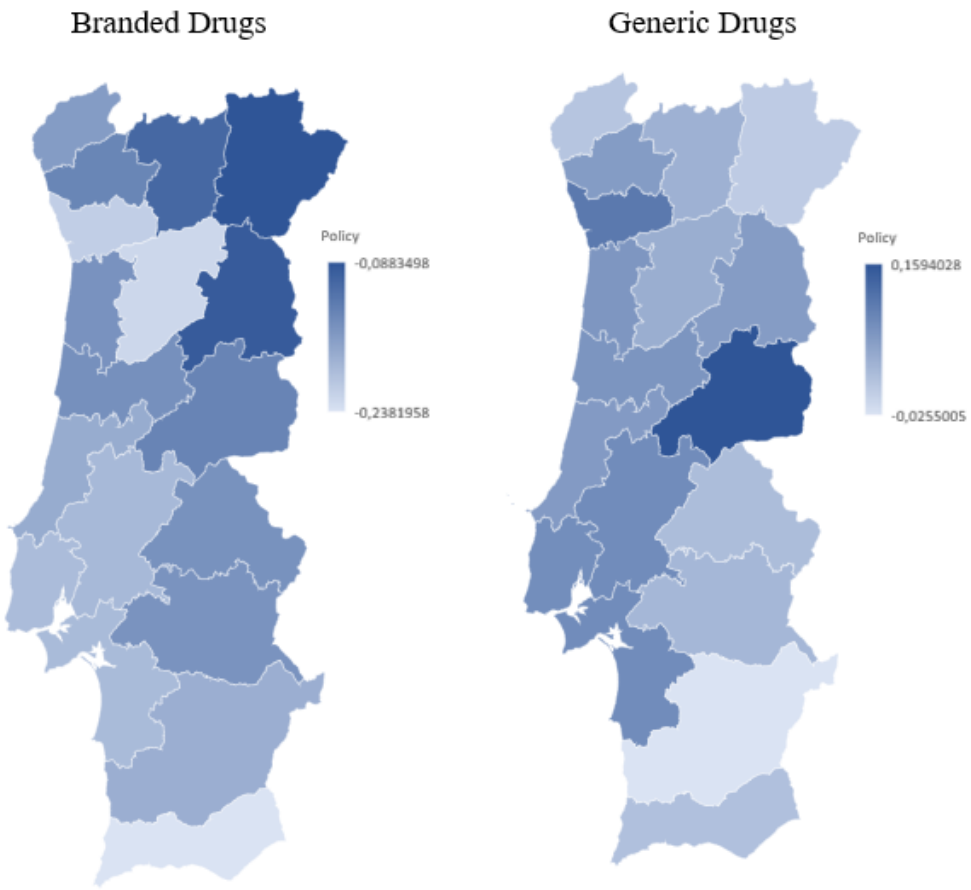
A.2.7 Consumption estimation in levels

Table 4.10: Impact on drug sales (in levels) for branded and generic drugs

	Branded Drugs			Generic Drugs		
Drug sales (million units)	(1)	(2)	(3)	(4)	(5)	(6)
			Balanced Panel			
Policy	-15.1041***	-15.0231***	-19.7967***	-1.9558	-2.1271	-2.7265
	(5.5984)	(5.6697)	(7.4143)	(1.2916)	(1.2969)	(1.7659)
Competitors		5.5456	5.5583		-2.0090	-2.0050
		(5.5693)	(5.4267)		(1.4648)	(1.6445)
Generic competitors		-8.8299	-8.6908		1.8109	1.8388
		(5.8595)	(5.4865)		(1.6029)	(1.5870)
N	572,208	572,208	572,208	3,484,944	3,484,944	3,484,944
			Unbalanced Panel			
Policy	-11.8683***	-11.1672**	-14.4789**	-0.2485	-0.3385	-0.4681
	(4.3282)	(4.4383)	(5.8188)	(1.1235)	(1.1306)	(1.5069)
Competitors		10.8752	10.7488		-1.4998	-1.4952
		(6.6498)	(6.7022)		(1.1956)	(1.3710)
Generic competitors		-14.5299**	-14.9439**		1.6277	1.5244
		(6.8627)	(6.8733)		(1.2916)	(1.3338)
N	794,842	794,842	794,842	4,537,370	4,537,370	4537,370
Product FE	x	x	x	x	x	x
Region FE	x	x	x	x	x	x
Competition controls		x	x		x	x
Month-year FE			x			x

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses, clustered at the equivalent drug group level. Policy: products affected by the policy change from October 2017 to December 2019.

A.2.8 Drug sales by region



Note: fixed effect model with all controls

Figure 4.10: Drug sales by region (balanced panel; 2016 - 2019)

A.3 Appendix Chapter 3

A.3.1 Public Health Spending Efficiency

Table 4.11: Variables description

Variable	Definition	Units
Life Expectancy at 65	Life expectancy at age 65	Years
Healthy life Expectancy at 65	Healthy life Expectancy at age 65	Years
Potential years of life lost	Per 100 000 age-standardized population under age 70	Years Per 100 000
Unmet health care needs	Proportion of self-reported unmet needs for health care (Financial reasons, distance or transportation, waiting list)	%
Catastrophic health expenditures	Population with household expenditures on health greater than 10% of total household income	%
Public health spending	Health expenditure from compulsory government financing schemes	PPS per inhabitant
Other health spending	Total current health expenditure net of Health expenditure from compulsory government financing schemes	PPS per inhabitant
Poverty	Proportion of population at risk of poverty or social exclusion	%
Low education levels	Proportion of people with education level lower than primary and lower secondary education (levels 0-2)	%
Obesity	Proportion of obese people according to reported BMI	%
Low fruit & vegetables intake	Proportion of people that do not consume daily fruit and vegetables	%
Daily smokers	Proportion of daily smokers in the population	%

Table 4.12: Stochastic frontier estimates for production function (2018 or closest available year)

	(1)	(2)	(3)	(4)	(5)
	Life expectancy at age 65	**Healthy life expectancy at age 65**	**Potential Years of Life Lost**	**Unmet health care needs**	**Catastrophic Health Expenditures**
Compulsory public insurance	0.0544**	0.1579*	-0.0995*	0.4501***	0.4564***
	(0.0228)	(0.0816)	(0.0586)	(0.0777)	(0.0790)
Compulsory private insurance	0.0348*	-0.0741	-0.0299	0.2278***	0.3857***
	(0.0188)	(0.0681)	(0.0489)	(1.3377)	(0.0870)
Voluntary insurance x NHS	0.7965**	-0.9626	-2.4816***	4.5521***	6.5758***
	(0.3309)	(1.2576)	(0.9320)	(1.3377)	(1.2516)
Voluntary insurance x Other	0.0137	0.2255***	0.0133	-0.1528**	-0.8459***
	(0.0200)	(0.0761)	(0.0549)	(0.2683)	(0.1325)
Out-of-pocket payments	-0.1951**	-0.0656	0.2730	-1.5243***	-0.1821*
	(0.0847)	(0.2753)	(0.1960)	(0.2683)	(0.1008)
Government Balance x NHS	0.0893*	-0.1690	-0.0264	0.9212***	0.9749***
	(0.0512)	(0.1803)	(0.1301)	(0.1855)	(0.1064)
Government Balance x other systems	0.0042	-0.0134	-0.0880	0.0020	-0.0238
	(0.0087)	(0.0275)	(0.0181)	(0.0227)	(0.0294)
NHS	-3.874**	4.4576	13.3709***	-22.3682***	-31.9993***
	(1.6544)	(6.3396)	(4.7031)	(6.6893)	(6.5528)
NHI	-0.2847***	-0.3735	0.1623	-1.7238***	-0.8132***
	(0.0980)	(0.3198)	(0.2255)	(0.3183)	(0.2361)
SHI	0.0072	-0.2075	-0.1656	-0.0060	1.5613***
	(0.0574)	(0.1992)	(0.1350)	(0.2333)	(0.2228)
Public insurance x NHS	0.0002**	0.0005	-0.0008***	0.0007**	-0.0017***
	(0.0001)	(0.0003)	(0.0002)	(0.0003)	(0.0004)
Public insurance x NHI	0.0002**	-0.0001	-0.0002	0.0011***	0.0010***
	(0.0001)	(0.0003)	(0.0002)	(0.0003)	(0.0002)
Public insurance x SHI	0.0005	0.0019	-0.0002	0.0048***	-0.0084***
	(0.0004)	(0.0012)	(0.0008)	(0.0013)	(0.0009)
Poverty	0.0739	0.2316	0.5887***	1.2626***	1.6751***
	(0.0553)	(0.1885)	(0.1326)	(0.1637)	(0.3100)
Low education levels	-0.0020	-0.0689	-0.5430***	-0.2677**	0.4590
	(0.0557)	(0.1692)	(0.1107)	(0.1342)	(0.3064)
Obesity	-0.3225**	-0.3456	0.3000	-0.6879**	0.8928***
	(0.1407)	(0.3941)	(0.2546)	(0.3320)	(0.2259)
Low fruit & vegetables intake	-0.1651**	0.2928	0.3289**	-1.2307***	-1.0323***
	(0.0649)	(0.2023)	(0.1383)	(0.2000)	(0.1820)
Tobacco consumption	0.2664**	0.0490	-0.2817	1.3607***	0.1235
	(0.1299)	(0.4415)	(0.3204)	(0.4781)	(0.1820)

A.3.2 The Economic Impact of the Health Workforce in Health Systems

Table 4.13: Key variables descriptive statistics

Variable	Units	Mean	Standard Deviation	Minimum	Maximum
Life Expectancy at birth	Years	78,8	3,0	70,1	83,3
Life Expectancy at 65	Years	20,2	1,5	16,6	24,0
Life Expectancy at 80	Years	9,2	0,9	6,9	12,0
Doctors	Per 1000 population	3,1	0,6	2,0	5,1
Nurses	Per 1000 population	9,2	3,4	2,8	18,0
Beds	Per 1000 population	5,2	1,8	2,4	9,1
Transplants	Per million population	7,0	5,1	0,0	23,6
Air Pollution	Tonnes per capita	8,9	4,3	2,9	24,6
Alcohol consumption	Litres per capita	10,2	2,0	5,5	15,2

Stochastic Frontier Estimation

Production functions estimation, using classic linear regression models assumes that different countries are equally efficient in the production of health care. Any difference, positive or negative, between the true production and that predicted by a linear model, would be captured by an error term. A stochastic frontier analysis approach, whose methods have been extensively developed, among others by Kumbhakar and Lovell (2000), allow us to deviate from such strong assumption. Instead, when estimating the production function of healthcare, we allow countries to be efficient (on the frontier) or not (below the frontier).

These methods are particularly useful in health care (Ferrier, 2014; Jacobs, Smith and Street, 2006). Existing literature provides different statistical models for stochastic frontier analysis. All these models hinge in the same principle: the error component will be based on two elements: a non-positive element capturing inefficient allocations and a stochastic (random) error to capture exogenous factors. This allows to control for situations in which a country, or a hospital, is operating efficiently but is subject to an exogenous environmental factor, that affects its output. In such case, the country best possible

practice, the production frontier, will be randomly shifted regardless of its inputs.

The inefficiency term captures wasteful allocations of inputs, which can represent effects such as lack of teamwork among staff, incorrect proportion of doctors and nurses, or poor management practices. This inefficiency is usually associated with lower health outcomes, as argued by McKay and Deily (2008).

Our final stochastic frontier model, with time-invariant inefficiency, yields the following estimates for our sample of OECD countries (variables in logs).

Table 4.14: Stochastic frontier model - time-invariant inefficiency

Life expectancy	**At birth**	**At 65**	**At 80**
Constant	4,252*	2,687*	1,600*
	(0,027)	(0,072)	(0,129)
Doctors	0,186*	0,501*	0,856*
	(0,032)	(0,086)	(0,152)
Nurses	0,047*	0,170*	0,309*
	(0,015)	(0,039)	(0,069)
Doctors2	-0,029*	-0,070*	-0,038
	(0,009)	(0,023)	(0,041)
Nurses2	0,002	0,002	0,031
	(0,006)	(0,016)	(0,027)
Doctors x Nurses	-0,044*	-0,138*	-0,360*
	(0,015)	(0,042)	(0,072)
Transplants	0,003*	0,002	0,002
	(0,001)	(0,002)	(0,004)
Beds 2001	0,001	0,004	0,003
	(0,001)	(0,002)	(0,003)
Beds 2002	0,001	0,000	-0,007
	(0,001)	(0,002)	(0,003)
Beds 2003	0,002	0,000	-0,013*
	(0,001)	(0,002)	(0,004)
Beds 2004	0,005*	0,014*	0,011*
	(0,001)	(0,002)	(0,004)
Beds 2005	0,007*	0,016*	0,013*
	(0,001)	(0,002)	(0,004)
Beds 2006	0,009*	0,026*	0,033*
	(0,001)	(0,002)	(0,004)
Beds 2007	0,010*	0,029*	0,040*
	(0,001)	(0,002)	(0,004)
Beds 2008	0,012*	0,034*	0,049*
	(0,001)	(0,002)	(0,004)
Beds 2009	0,013*	0,037*	0,054*
	(0,001)	(0,002)	(0,004)
Beds 2010	0,015*	0,042*	0,063*
	(0,001)	(0,003)	(0,005)
Beds 2011	0,018*	0,048*	0,076*
	(0,001)	(0,003)	(0,005)
Beds 2012	0,018*	0,043*	0,064*
	(0,001)	(0,003)	(0,005)
Beds 2013	0,019*	0,048*	0,073*
	(0,001)	(0,003)	(0,005)
Beds 2014	0,022*	0,056*	0,088*
	(0,001)	(0,003)	(0,005)
Beds 2015	0,021*	0,049*	0,071*
	(0,001)	(0,003)	(0,004)
Air Pollution	-0,005	-0,037*	-0,053*
	(0,004)	(0,006)	(0,011)
Alcohol consumption	-0,017*	-0,028*	-0,025
	(0,004)	(0,009)	(0,015)

*,**, *** indicate significance at 10%, 5% and 1% level, respectively.
Notes: Standard errors in parentheses.

Optimal Nurses-to-Doctor ratio and Excess cost

A policymaker wants to minimize costs, while ensuring that the production of health is efficient and does not go below a certain threshold. This definition is stricter than the technical efficiency presented before, which only requires that production is maximized given the set of available inputs. Since the policymaker considers now the input cost (doctors and nurses' wages), a solution for this problem must be allocative efficient. Following Barros (2005) and Gouveia and Pereira (1997), the problem faced is formalized below:

$$\min_{D,N} w_D D + w_N N s.t. Y = A[\alpha N^{\rho} + (1-\alpha)D^{\rho}]^{\frac{1}{\rho}}$$

Where D and N represent the number of physicians and nurses, w_D and w_N their respective wages, Y is the health output, A is the aggregate technology level, α is the share parameter, and ρ measures the degree of substitutability between both inputs.

Such cost minimization problem yields the following equilibrium condition:

$$\frac{N}{D} = \left[\frac{1-\alpha}{\alpha}\frac{w_N}{w_D}\right]^{\frac{1}{\rho-1}}$$

In this simplified framework, the cost of the system is simply the wage expenditures of nurses and doctors. Therefore, using the equilibrium condition, compatible with a constant elasticity of substitution production function, we can derive the cost as a function of the wages and the nurses to doctor ratio (λ).

$$C = (w_D + w_N\lambda)\frac{Y}{A}\frac{1}{(\alpha\lambda^{\rho} + (1-\alpha))^{\frac{1}{\rho}}}$$

The excess cost that each country faces is given by the following expression, where λ is the current nurses to doctor ratio, and $\bar{\lambda}$ represents the optimal nurses to doctor ratio,

derived from the stochastic frontier estimation.

$$\frac{C}{C^*} = \frac{w_D + w_N\lambda}{w_D + w_N\bar{\lambda}} \left(\frac{\alpha\bar{\lambda}^\rho + (1-\alpha)}{\alpha\lambda^\rho + (1-\alpha)} \right)^{\frac{1}{\rho}}$$

A.4 Appendix Chapter 4

A.4.1 An OLG model for Public Health Spending

Young agents of measure one are born each period with a time endowment of one unit. Such time can be employed in the labour market or in leisure. A generation-t individual gives birth to one offspring at the end of t. This new individual enters the labour market at the beginning of $t+1$; and does not inherit her parent's health stock. Her accumulated health capital by the end of t+1 determines her survival probability to be alive in the second period. This survival probability depends not only on her health care consumption, but also on an exogenous random shock. Thus, the probability at the end of the first period of an individual born in t surviving into the second period is given by:

$$\gamma(h_{1t}^d) = \theta_{1t}(\pi_0 + \pi_1 h_{1t}^d) \tag{4.18}$$

This expression is identical to the health status defined before, applied to a dynamic context. Parameter γ is the survival probability from the first to the second period and is thus bounded between 0 and 1. Such probability is based on an unanticipated negative shock component (θ_{1t}) and on a function of the individual health care consumption in the first period (h_{1t}^d), similar to Fanti and Gori (2012). Healthier individuals, with higher health care consumption, will have higher probabilities of surviving into the second period. In this model, and contrary to the Grossman model (Grossman, 1972), I am not allowing individuals to enhance their survival probability through leisure time – which would allow them to implement healthier lifestyles. I assume that health status is only a function

health care consumption.

To ensure that the survival probability is bounded between 0 and 1, health care consumption in the first period needs to obey to the following conditions:

$$\frac{\pi_0}{\pi_1} \leq h_{1t} \leq \frac{1-\pi_0}{\pi_1} \tag{4.19}$$

The left-hand side represents the minimum level of health care required to ensure a non-negative probability of surviving. Conversely, the right-hand side represents the level of health care which, in the absence of a random shock, implies surviving into the second period.

Parameter π_0 is the inherent baseline survival probability for an individual with no accumulated health. This will be a non-positive value, which in turn implies a required minimum level of health care such that the survival probability becomes positive. This parameter can be thought to reflect biological characteristics. Parameter π_1 represents the positive contribution of higher health care to the survival probability. This parameter can be affected by the efficacy of health systems. The existence of unanticipated random shocks prevents the individual from being able to exactly determine her life expectancy.

Such uncertainty raises questions regarding carrying savings from the first to the second period. To deal with the risk associated with partially uncertain lifetimes, I assume a perfect annuities market, following the work of Blanchard (1985); Chakraborty (2004); Yaari (1965). Specifically, at the end of her youth, each individual deposits her savings in a mutual fund. The mutual fund invests these savings and guarantees a gross return on the second period of $\hat{R}_{2t}$. Given that not all individuals survive to the second period, the gross return to the surviving old is given by: $r_{2t} = \frac{\hat{R}_{2t}}{\gamma_t}$.

In each period, utility is a function of leisure time, consumption of private goods, and government spending (non-health related). As mentioned before, γ is the survival proba-

bility from the first to the second period. Individuals in the second period are retired and do not work. Thus, the impact of second period leisure on the household's utility is constant, given that $L_{2t} = \bar{L}$. Utility can be represented by the following additively separable function:

$$U = ln(\bar{L} - N_{1t}^h - N_{1t}^y) + ln(C_{1t}) + ln(G_{1t}) + \gamma[ln(C_{2t+1}) + ln(G_{2t+1} + ln(\bar{L}))] \quad (4.20)$$

Utility maximization is bounded by two budget constraints, as well as a time constraint. In the first period, the individual divides her time into leisure, labour employed in health production, and labour employed in the private good production. In the second period, the individual is retired and therefore leisure time in the second period is normalized to L.

$$\bar{L} = L_{1t} + N_{1t}^h + N_{1t}^y \quad (4.21)$$

In the first period, the household faces the following budget constraint:

$$P_t C_{1t} + P_t^h h_{1t} + S_{1t} = (1 - \tau_t)(w_{1t}^y N_{1t}^y + w_{1t}^h N_{1t}^h) \quad (4.22)$$

The right-hand side represents the household disposable income. This is made of labour return net of taxes, both from health and private goods' production. It is assumed that taxes are proportional to the household income, where τ_t represents the tax rate. The left-hand side represents the choice made in the first period: the household can either consume private goods, health care, or save for future consumption in the following period. As before, for this baseline model, I am assuming that the household purchases healthcare directly. The government plays no role in the provision or financing of health care.

In the second period, the household born in t faces the following budget constraint:

$$P_{t+1} C_{2t+1} = (1 + r_{t+1}) S_{1t} \quad (4.23)$$

Again, the right-hand side represents the available income in the second period. Because individuals do not work in the second period, disposable income is determined by savings from the first period, accrued with interests. Such savings can be used to finance second period consumption of private goods. Note that the household purchases no health care in the second period. This happens because health care loses its relevance after determining the proportion of individuals surviving to the second period. The intertemporal household budget constraint can be written by combining the two previous expressions:

$$P_t C_{1t} + P_t^h h_{1t} + \frac{P_{t+1} C_{2t+1}}{1 + r_{t+1}} = (1 - \tau_t)(w_{1t}^y N_{1t}^y + w_{1t}^h N_{1t}^h) \tag{4.24}$$

The economy produces two goods, a physical good and health care. The production function for the private consumption good is a function of labour and health, with an exogenous technology level (A). Again, this explicitly recognizes a role for health on economic growth. In this function, health will be represented as the survival probability, which in turn is a function of health care consumption. The production function can be written as:

$$y_{1t} = A_t(\pi_0 + \pi_1 h_{1t}) f(N_{1t}^y) = A_t(\pi_0 + \pi_1 h_{1t})(N_{1t}^y)^\alpha \tag{4.25}$$

Health care is produced with a given exogenous technology (B) and labor time. The combination of these allows to provide clinical facilities, inoculation, and disease control programs, according to the following production function:

$$h_{1t}^s = B_t j(N_{1t}^h) = B_t (N_{1t}^h)^\beta \tag{4.26}$$

On period t, the government collects proportional income taxes from the generation born in t, which are then used to finance government spending. The government provides non-health public services for all individuals currently alive: all individuals born in t, and all surviving individuals born in $t-1$ enjoying their second period. These can be thought as public education services, parks, or defence. At this point, the government provides no

health care. Thus, the government obeys to a balanced budget condition:

$$G_{1t} + G_{2t} = \tau_t(w_{1t}^y N_{1t}^y + w_{1t}^h N_{1t}^h) \tag{4.27}$$

Under perfect competition, with given technologies and market clearing conditions, one can derive the equilibrium conditions. In the steady-state, variables will be stable over time. As before, we normalize the private good price to one. Consider the case where non-health government expenditures (G_{1t} and G_{2t}) are given. This implies a certain tax rate to ensure compliance with the government budget constraint. Hence, equilibrium is described by a set of five equations and five variables.

The first two equations concern input's choice. In the private good industry, labour supply from the households must equal labour demand – determined by the marginal productivity. Note that labour demand for the private good production depends also on health care. This is the multiplier effect arising from the fact that health is an input in private goods production. In standard models without health, such effect would not exist. On the other hand, the lab or supply displays the utility trade-off between higher consumption levels and lower leisure time.

$$\alpha A(\pi_0 + \pi_1 B(N_{1t}^h)^\beta)(N_{1t}^y)^{\alpha-1} = \frac{(1-\tau)C_{1t}}{\bar{L} - N_{1t}^h - N_{1t}^y} \tag{4.28}$$

The same holds for the health care industry. In this sector, labour demand must also equal labour supply. The labour supply for the healthcare sector represents the trade-off between leisure time and health care consumption. In this setting, health care consumption allows individuals to experience second period consumption and leisure.

$$\beta B(N_{1t}^h)^{\beta-1} = \frac{1}{\bar{L} - N_{1t}^h - N_{1t}^y} \frac{1}{(ln(C_{2t+1}) + ln(G_{2t+1}) + ln(\bar{L}))(1-\tau)\theta\pi_1} \tag{4.29}$$

The last three equations relate to consumption choice. Firstly, we have the inter-temporal condition for consumption of private goods. This Euler equation defines the consump-

tion path as a function of the interest rate and of the survival probability – influenced by health status. Increases in the interest rate promote future consumption, as expected. The same happens for increases in the health care consumption – which affects positively the survival probability. Thus, health care consumption affects intertemporal consumption decisions. This effect comes from endogenizing household's longevity: health status determines survival probability, which affects the utility function.

$$\frac{C_{2t+1}}{C_{1t}} = (1+r)\theta(\pi_0 + \pi_1 B(N_{1t}^h)^\beta) \tag{4.30}$$

The household needs also to decide how to allocate between private good consumption and health consumption in the first period. Such choice is mediated by the relative price of health care. An increase in the relative price of health care, increases the marginal utility of health relative to consumption. Such increase, results on higher private good consumption and lower health care consumption. This is described by the following intratemporal condition:

$$C_{1t}\theta\pi_1(ln(C_{2t+1}) + ln(G_{2t+1}) + ln(\bar{L})) = P_t^h \tag{4.31}$$

Finally, the last equation represents the resource constraint for the economy.

$$P_t C_{1t} + G_{1t} + \frac{P_{t+1}C_{2t+1}}{1+r_{t+1}} + G_{2t+1} = A(\pi_0 + \pi_1 B(N_{1t}^h)^\beta)(N_{1t}^y)^\alpha \tag{4.32}$$

Just as it was done before for the static model, one can extend this setting by introducing a role for the government in the financing of the health care system. The first change occurs in the household budget constraint. The individual receives a subsidy from the government as a reimbursement for health expenditures.

$$P_t C_{1t} + P_t^h h_{1t} + \frac{P_{t+1}C_{2t+1}}{1+r} = (1-\tau_t)(w_{1t}^y N_{1t}^y + w_{1t}^h N_{1t}^h) + \phi_t \tag{4.33}$$

This implies also a change in the government budget constraint, which is now given by:

$$G_{1t} + G_{2t} + \phi_t = \tau_t(w^y_{1t}N^y_{1t} + w^h_{1t}N^h_{1t}) \tag{4.34}$$

Where $\phi_t \leq P^h_t h_{1t}$. Health care impacts now both the revenue and expenditure side of the government budget constraint. Because the government reimburses the consumer, public expenditure is a direct function of health spending. However, health care consumption also implies higher production of both health and private goods. This will, in turn, contribute to a higher income, generating higher tax revenues. Thus, the government budget constraint is no longer a linear relationship. Sticky taxes or government expenditures might lead to the violation of such constraint in the context of increasing health spending.