Ageing, mortality and health care expenditures

The case of Norwegian hospitals and ambulances

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I alone remain responsible for any errors or shortcomings.

Preface

In autumn 2010, I started as a PhD candidate in a project entitled "PREDICTING HEALTH CARE COSTS, *The use of simulation models in the Norwegian Health Care System*". Before the Nordic Health Economic Conference the following year, we succeeded in building a model to predict the future health care expenditures for Norway based on age, gender and regional differences, a so-called 'age-only model' (also referred to as the 'naïve approach'). Based on feedback from several participants at the conference and the new data I received later that year, I was able to further develop my model to also take into account mortality. Subsequently I became part of the so-called "end of life costs debate".

Going forward I had the privilege to join Geir Godager and Hans Olav Melberg in their project regarding end of life costs for the Ministry of Finance in Norway. The project later resulted in the publication of "Hospital expenses towards the end of life", which become part of my thesis. Later the same year, I started to work with Terje Hagen on his project assessing ambulance transports in Norway. Together with David McArthur, we wrote the paper "Modeling and predicting the cost of providing ambulance services in Norway".

I got the idea for the "steepening paper" during a lecture I gave in the course HMM4202 in 2012 at the University of Oslo. Some of the students had some problems understanding the concept of the "red herring"; eager to try to make the concept more understandable, I wrote what later became a major part of the introduction to the steepening paper. Connecting this to a discussion I had with some colleagues earlier, I formed the foundation of this paper.

During my period as a PhD candidate, I also had the privilege to write two other papers; one with Kim-Rand Henriksen on Statistics Norway's population projections and one on health care expenditures projections with Hans Olav Melberg. Both of the papers have been submitted, and hopefully will be found in Google Scholar soon. They are both highly relevant to the topics discussed in this thesis.

Finally, please also note that paper 3 refers to a previous version of paper 2 called "Hospital expenditures and the red herring hypothesis: Evidence from a complete national registry".

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Summary

In order to predict future health care expenditures and to understand the current financial situation, key variables that drive the expenditures have to be estimated. The aim of this thesis is to identify and estimate the impact of variables driving the health care expenditures within secondary care—in particular, the impact of age and mortality. Both the hospital expenditures and the emergency services are examined.

In order to quantify the impact of mortality and age on the expenditures, data covering all inpatient hospital admissions in Norway from 1998 to 2010 and all ambulance transports for the South-Eastern Regional Health Authority (Helse Sør-Øst) for 2009 and 2010 were applied. For hospitals, both age and mortality are suggested to drive current hospital expenditures. For ambulances, distance to hospitals and age are central in explaining the variation in costs. For hospitals and ambulances, health care expenditures are found to be higher for newborns and the elderly as compared to the rest of the population.

We estimate that approximately 10% of total hospital expenditures are allocated to decedents within a calendar year. With data from 2010, the share is estimated to be 10.6% (for inpatient and outpatient care), while with data from 1998–2009, the estimated share is 9.0% (for inpatient care). Furthermore, our analysis suggests that mortality-related hospital expenditures are a decreasing function of age.

The connection between the concepts of *steepening* and the *red herring hypothesis* are also discussed. The *red herring hypothesis* states that it is time to death and not age per se that drives health care expenditures, while *steepening* states that health care expenditures grow faster for the elderly population than the rest of the population over time. The two concepts are found to be independent. The empirical analyses also suggest that *steepening* is present for the Norwegian hospital sector for the time period 1998–2009 if newborns are excluded. Furthermore, I put forth the hypothesis that *steepening* will be present for countries with high per capita health care expenditures in periods of increased per capita expenditures.

Norwegian Summary (Sammendrag på norsk)

For å forstå hvilken innvirkning eldrebølgen vil på det fremtidige helsevesenet, er det viktige å forstå i hvor stor grad aldring påvirker dagens helsekostnader. Formålet med denne doktorgraden er å estimere effekten av aldring og mortalitet (dødelighet) på helseforbruk.

I doktorgraden anvendes data for ambulanseoppdrag i Helse Sør-Øst i 2009 og 2010 og somatiske sykehus innleggelser i perioden 1998-2010 i Norge. Analyser basert på data for dag- og døgnpasienter ved somatiske sykehus i perioden 1998-2009 viser at 9,0% av behandlingskostnadene ved norske sykehus gikk til personer i sitt siste leveår. Deskriptiv statistikk viser videre at 10,2% av alle behandlingskostnadene ved somatiske sykehus gikk til personer i sitt siste leveår i 2010 for dag- og døgninnleggelser og polikliniske konsultasjoner. Det er også slik at for alle aldersgrupper viser analyser og deskriptiv statistikk at per capita forbruket av helsetjenester for personer i sitt siste leveår er høyere enn for den øvrige befolkningen. Videre viser analyser og deskriptiv statistikk at kostnader knyttet til død er fallende med alder.

For ambulansetjenesten finner jeg at reisetid til sykehus og alderssammensetningen til befolkningen har stor betydning for kostnadene knyttet til drift av tjenesten. Både nyfødte og eldre bruker tjenesten mer enn den øvrige befolkningen. Videre er det slik at lang reise vei til sykehus øker kostnadene for drift av ambulansetjenesten.

Jeg finner også at begrepene *red herring hypotesen* og *steepening* er uavhengige. Det er med andre ord ikke slik at *red herring hypotesen* forkaster *steepening* eller motsatt. *Red herring hypotesen* sier at det høye helseforbruket knyttet til høy alder ikke blir drevet av alder i seg selv, men tid til død. *Steepening* er at helseforbruket per capita for eldre vokser fortere enn for den øvrige befolkningen. Videre viser analyser av data fra sykehussektoren i perioden 1998 til 2009 at man ikke kan forkaste *steepening* i den aktuelle perioden, hvis man ekskluderer nullåringer. Jeg lanserer også hypotesen at *steepening* kan bli drevet av svingninger i helseforbruk. I perioder med stigende helseforbruk per innbygger vil det i følge hypotesen være *steepening*, mens det i perioder med avtakende helseforbruk ikke vil være *steepening* for land med i utgangspunktet høyt helseforbruk per innbygger slik som eksempelvis Norge og andre europeiske land.

List of papers

Paper 1: Hospital expenses towards the end of life, Melberg, Godager and Gregersen, 2013, Tidsskrift for Den Norske Legeforening
Norwegian title: Sykehusutgifter mot livets slutt

Paper 2: The association between age and mortality related hospital expenditures: Evidence from a complete national registry, Godager, Gregersen, in press, Nordic Journal of Health Economics

Paper 3: The impact of ageing on health care expenditures: A study of steepening, Gregersen, 2013, The European Journal of Health Economics

Paper 4: Modeling and predicting the cost of providing ambulance services in Norway, Mc Arthur, Gregersen, Hagen, 2014, Journal of Transport Geography

1. Introduction

There are several definitions of health. The World Health Organization (WHO) defines health as:

"… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[1]

Health is again determined by several factors, including (but not limited to); medical treatment, lifestyle, environment, and genetics. Health care expenditures are investments that are intended to improve health. The influence of age and mortality on a society's use of resources to improve health is widely discussed in the literature (see, among others, Cadigan and Bugarin (1989), Kelley et al. (2013), Newhouse (1992), de Meijer et al. (2013) and Rechel et al. (2013)). Age is often considered to impact health in two ways. First, the elderly, in general, have poorer health and therefore are expected to use more health care services. Second, decedents have higher per capita expenditures than individuals with the same age and gender (papers 1–2). As the probability of dying is strongly correlated to age, a higher fraction of the elderly will increase the number of decedents.

In The Organization for Economic Co-operation and Development (OECD), the increasing number of elderly is causing concern due to increasing health care expenditures. In Norway, the fraction of the total population that is 67 years or older is expected to increase from about 13% in 2012 to 17% in 2030 and 20% in 2040, according to Statistics Norway (population forecast September 2012).

This concern about the increasing number of elderly people has been lessened after the introduction of the so-called *red herring hypothesis*. Fuchs (1984) and later Zweifel et al. (1999) suggest that age has little influence on health and thereby on health care expenditures; rather, health care expenditures are driven primarily by the time to death. Several researchers take part in the debate that follow (O'Neill et al., 2000; Zweifel et al., 2004; Breyer et al.,

[1] Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, and 19–22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.

2010; Colombier and Weber, 2011). If the hypothesis holds, an increase in life expectancy will have little influence on individuals' lifetime health care expenditures, and less than previously expected (Stearns and Norton, 2004).

There is also a literature highlighting the growth rate for different age groups over time. A key term in this literature is *steepening* (Buchner and Wasem, 2006; Felder and Werblow, 2008). This refers to the observation that per capita health care expenditures have grown faster for the elderly than for the rest of the population. *Steepening* has been observed in several OECD countries for the past years (de Meijer et al., 2013; Buchner and Wasem, 2006). If the trend continues, the health care expenditures will increase substantially due to both an increased number of elderly people and increased per capita health care expenditures for the elderly.

In contrast, there are several studies (Seshamani and Gray, 2002; Christiansen et al., 2012; Gerdtham et al., 1992) that cast doubt on the impact of demographic factors in general to explain trends in health care expenditures. Other factors, such as the general health condition of the population, technological progress and general economic growth, may overrule the effect of demographic variables. These factors may also vary for different parts of the health care sector. For example, geographical location of both the patients, hospitals and ambulances are crucial in determining expenditures for ambulance services (Norum and Elsbak, 2010).

The main aim of this thesis is to investigate which factors drive health care expenditures and in particular the effect of demographic factors (age and mortality) on the expenditures. Health care expenditures may include medical treatment (e.g., hospitalization), but may also include a wider spectrum of determinants of health (e.g., a healthier diet or increased physical activity). This thesis will focus on medical treatment and in particular on the use of hospitals and ambulance services.

The outline for the thesis is as follows: Section 2 discusses the impact of both demographic factors and non-demographic factors in more detail, as well as a general debate surrounding the reasons for demanding health. Section 3 presents the overall aim of this thesis and specific aims from each paper. Section 4 gives a brief introduction to the Norwegian health care system. Section 5 presents the data applied in the empirical analysis included in the thesis. Section 6 presents the empirical methods applied. Section 7 presents the empirical results.

Section 8 is divided into three parts: limitations, future research and conclusion. The four papers follow at the end of this thesis.

2. Background section: Drivers of health care expenditures

The aim of this section is to introduce the general health economic theoretical and empirical literature in order to discuss the determinants of health care expenditures. While the main focus of this thesis is on the impact of demographic variables, I acknowledge there are other variables that influence health care expenditures.

To understand the mechanism that drives investments in health (health care expenditures) the Grossman model, presented in Grossman (1972), stands as a key theoretical model. This section (section 2) will continue with a brief introduction to the model, followed by the implications of the model in connection to empirical findings and other theoretical papers.
In the model, an individual values health due to three factors: 1) health in itself contributes positively to the individual's utility, 2) more time in good health will increase time spent on labor (income-generating activities) and leisure, and 3) better health will increase length of life. There are two different versions of the model, the investment and the consumption model. The latter model considers length of life as exogenous, and hence ignores the third factor above. In the investment model, the first factor is ignored. The rest of this thesis will, to a large degree, ignore the differentiation between the models and mainly focus on the implications of the model framework.

In the Grossman model, health is regarded as a capital good that may increase by investments. The investment may be medical services such as medication or hospitalization, or other investments such as a healthier lifestyle, diet, etc. The capital depreciates (δ) with age. In the model each individual is born with a health stock (H_0), initial endowment, which they may add on to by investments (I), time and money.

2.1 $H_{0+1} = H_0(1-\delta_0) + I_0$

2.2 $H_{t+1} = H_t(1-\delta_t) + I_t$

The model furthermore assumes no insurance market for health care services. The individual maximized his/her utility for health and other goods given the individual budget constraints for time and money. The individual may spend his/her time working, engaging in health-promoting activity, lost time due to illness (sick days) and leisure. The money may arise from income related to time working or other revenue (A_0). In the rest of section 2, the money disposable for individual will be named wealth.

Within this framework, Grossman (1972) discusses how the optimal level of investments in health (I*) and optimal health stock (H*) vary due to changes in the other factors included in the model. The rest of this section (2) will focus primarily on the effect of changes in ageing (depreciation rate; δ) (section 2.1) and disposable income (wealth) (section 2.2), while it will briefly mention the additional factors (section 2.3).

The reason to focus on wealth apart from ageing, the main topic in this thesis, is three-fold. First, a discussion on the causal effect of wealth upon health is applicable to the methodological debate raised in the Method section in connection with the "endogenity problem". In the Method section it is debated whether mortality in equations 6.3–6.5 may be endogenous. A discussion on the causal effect of wealth upon health will contribute to this debate. Second, research has suggested that wealth may dominate the effect of ageing on future health care expenditures (Christiansen et al., 2012). Third, income is an observable factor that is easy to measure and available both at the national, regional and individual levels in Norway; therefore, it is feasible to incorporate into future research.

2.1 Ageing

The effect of ageing in Grossman's model is seen as an increase in the depreciation rate; hence, the cost of maintaining good health increases as an individual becomes older. This will again reduce the optimal level of health capital demanded by the individual. The investments in health may, however, increase due to inelastic demand. Furthermore, Grossman (1972) states on page 240 that: "Biological factors associated with aging raise the price of health capital and cause the individuals substitute away from future health until death is chosen."

From the empirical literature, there are several papers (including papers 1–4 in this thesis) that suggest that the per capita health care expenditures for the elderly are higher than for the rest of the population, when excluding newborns. There are researchers (Fuchs, 1984; Stearns and Norton, 2004; Zweifel et al., 1999) who suggest that an individual's closeness to death (time to death) and not age per se, is what drives the association between observed health care expenditures and ageing (i.e. the *red herring hypothesis)*.

More than 30 papers have been published on the *red herring* debate. The term *red herring* was introduced by Zweifel et al. (1999). In this paper they studied the health care expenditures for 5000 individuals aged 65 years and older in Switzerland. They concluded that time to death was more important than age in predicting future health care expenditures. This study has, however, been criticized for methodological weaknesses (Salas and Raftery, 2001; Seshamani and Gray, 2002; Felder et al., 2010; Häkkinen et al., 2008). In the years that followed, several papers have been published to further debate this hypothesis; some do not reject the hypothesis (Zweifel et al., 2004) while others do reject it (Colombier and Weber, 2011). A more in-depth description of a sample of papers in the *red herring* debate in connection to methodological issues will be presented in section 6.2.

In the continuation of the *red herring* debate some researchers (Melberg and Sørensen, 2013; Madsen, 2004; Breyer and Felder, 2006) have presented the hypothesis that the high health care expenditures are associated with aging will move to higher age groups as length of life increases. Furthermore, that mortality related expenditures that are suggested to be decreasing by age are expected to move to higher age groups as length of life increases. This is referred to as *shift*. Melberg and Sørensen (2013) test the hypothesis comparing Norway and Denmark.

The countries are similar in many aspects, but have different life expectancy (Melberg and Sørensen, 2013). By comparing the two countries, Melberg and Sørensen (2013), do not reject the *shift* hypothesis.

While the *red herring* examines the connection between age, time to death and health care expenditures, there are also papers that discuss the relationship between age, time and health care expenditures—the *steepening* debate. There are few studies that have *steepening* as their primary topic (paper 3; Felder and Werblow, 2008; Buchner and Wasem, 2006). There are, however, many studies discussing the phenomenon, some of the studies (see, among others, Breyer et al. (2010), Dormont et al. (2006) and de Meijer et al. (2013)) apply the term, *steepening*, and others do not apply the specific term (see, among others, Seshamani and Gray (2002) Meara et al. (2004), Barer et al. (1987), Mendelson and Schwartz (1993) and Cutler and Meara (1998)). All the studies support, apart from Seshamani and Gray (2002) and Felder and Werblow (2008), that there is a bias towards more health care expenditures for elderly people per capita compared to the rest of the population. Seshamani and Gray (2002) study Japan, Canada, Australia, and England and Wales, and for the case of England and Wales for the time period 1993-1997, they do observe a decline in growth in per capita expenditures for the elderly people compared to the rest of the population, for the other countries the opposite holds. Felder and Werblow (2008) is based on data from Switzerland, and do reject *steepening*. The above mentioned studies may, however, be hard to compare due to different age groups included in the studies and methodological differences. In the method section a further description of the methodological issues are presented.

With regard to the underling mechanisms that may induce *steepening*, de Meijer et al. (2013) suggest that the ageing population induces the medical technology to be targeted towards the elderly. This may again lead to health care expenditure growth for elderly. Felder and Werblow (2008) propose that, apart from technology, a potential driver of *steepening* may be biological factors, e.g. changed morbidity patterns. Furthermore, paper 3 summarizes several of the papers on the underling mechanisms of *steepening*, and concludes that the research is vague and points at both biological and technological factors. This may be a target for future research.

Changes in morbidity and mortality patterns are further debated in Fries (1983), Fries and Crapo (1981) and Barer et al. (1987). Fries and Crapo (1981) suggest that mortality compresses over time, i.e., rectangularization of survival curves. Furhtermore, Fries (1983) suggested the hypothesis that morbidity compresses over time. In this study it is suggested that as medical technology becomes better and individuals become healthier, the period of serious illness will be compressed towards a short period of time at the end of life. Barer et al. (1987) discuss how the compression of mortality and morbidity influence on health care expenditures. They argue that, depending on the preferences of the society, the expenditures may either increase or decrease. In a situation where the society accepts "natural death", the expenditures will decrease. Conversely, if the society uses all resources available to reduce morbidity, expenditures may increase.

Another branch of the literature on ageing and health care expenditures discusses the share of total health care expenditures used by decedents. Table 2.1 presents some of these studies that measure care in the last year of life. The studies each include different groups of the population and different sectors of health care; subsequently, direct comparisons may be difficult. For example, Häkkinen et al. (2008), Emanuel (1996) and Hogan et al. (2001) use data containing only the elderly, while the other studies contain data encompassing a wider age range. The only study with Norwegian data within the past 25 years—apart from papers 1 and 2—is Nord et al. (1989), and is based on several restrictive assumptions due to data limitations.

Table 2.1: Share of total health care expenditures used by indivduals in the last year of life

Paper	**Country**	**Share used on decedents**
Polder et al. (2006)	Netherlands	11%
Häkkinen et al. (2008)	Finland	14%
Hogan et al. (2001)	United States	33%
Emanuel (1996)	United States	27%
Nord et al. (1989)	Norway	18–26%

There are, however, researchers who question the effect of age and mortality when investigating trends in health care expenditures. Some claim that the effect of ageing is ruled out, when including other factors such as income and technological changes, when investigating trends in health care expenditures. Christiansen et al. (2012) summarizes the literature on health care expenditures and ageing, and suggests that ageing may only explain a modest increase in health care expenditures, while other factors contribute to the majority of the increase. Seshamani and Gray (2002) state on page 287:

> "[Of the] Many cross national studies that have examined the determinants of health care expenditures in developed countries, only one found the age structure of the population (usually measured by the percentage of population above 65) to be a consistently significant explanatory variable alongside the effects of income, lifestyle characteristics, and environmental factors."

2.2 Wealth

In the Grossman model, higher A_0 will increase the investment in both health care goods and in other goods. In the consumption model, the effect of increased hourly wage is uncertain and depends on the individuals' preferences for health and other commodities. In the investment model higher hourly wage increases the value of time. This will again lead to increased investments in health in order to increase the amount of healthy days. In contrast, the alternative value of time increases, which may lead to reduced investments in health.

Getzen (2000) summarizes the empirical literature on income elasticity on health care expenditures. At the national level increased income (gross domestic product (GDP)) is associated with higher health care expenditures according to the review. This is also supported in the report from the OECD (OECD, 2013). They report a positive correlation between GDP per capita and health care expenditures per capita. Also Baltagi and Moscone (2010) suggest an income elasticity above zero at national level for the majority of countries included in their study. At the individual level, income elasticity (the effect of increased personal wealth on health care expenditures) is by some studies suggested to be close to or even below zero (Getzen, 2000).

The rest of this section will briefly summarize the literature on the causal effects between wealth and health. There are several studies investigating the causal effect from wealth to health and from health to wealth. Kverndokk (2006) investigates the connection between health and wealth. The study summarizes the literature and concludes that there is a strong correlation, but not necessary a strong causal relationship, from increased wealth to increased health.

Wealth may, according to Kverndokk (2006), influence health in several ways. For example, greater wealth may give you more access to health care services. Even under a national health service system—such as the health care systems found in Norway and the United Kingdom—where many health care services are free of charge for the patient, there are still services that require out-of-pocket payments. These services will, to some degree, be more accessible to patients with higher incomes. Kverndokk (2006) also points out that more wealth gives you the opportunity to consume healthier food. Furthermore, individuals with greater wealth may also have more resources to request more health care services.

Furthermore, several empirical studies suggest that there is a causal relationship from wealth to health. Meer et al. (2003) find that inheritance has a small, but positive effect on health. A British study conducted by Attanasio and Emmerson (2003) on the elderly also finds a postive effect from wealth on health and probability of survival. Frijters et al. (2005), which analyses the effect of the reunification of Germany on health with a transfer of wealth from West to East Germany, also find a positive but small effect. There are also studies that do not find a clear positive effect (Adams et al., 2003; Attanasio and Emmerson, 2003). Chapman and Hariharan (1996) suggest that the marginal effect of increased income on increased length of life is decreasing with increased income level. OECD (2013) also report a positive correlation between health care expenditures per capita and expected length of life at birth, but the effect is decreasing with increased health care expenditures per capita.

There may also be a causal relationship from health to wealth. In the Grossman model, improved health will result in more time available for other activities and it may also act as an incentive to invest in health as the probability of living longer increases. Michaud and Van Soest (2008) suggests that there is a causal relationship from health to wealth, but not from wealth to health. The study applies data for elderly in the United States and emphasize the conclusion may change if other age groups are included. Furthermore, both Black et al. (2007) and Behrman and Rosenzweig (2004) find that low birth weight is related to low education and income. This may point in the direction that there may be a casual relationship from health to wealth. With regard to investment (I), good health gives more potential time to health-promoting activities and income-generating ativities. However, the mariginal utility of health decreases with the level of health. As such, the marginal gain from investments in health may decline, which alone points to reduced investments in health.

2.3 Other factors and concluding remarks

Both within the framework of the Grossman model and in other economic literature, it is suggested that several other factors besides ageing and wealth may drive health care expenditures. Other factors may include, for example, changes in prices, and technological changes (Medeiros and Schwierz, 2013; Wong et al., 2012; Newhouse, 1992; Dybczak and Przywara, 2010).

In standard economic theory increased prices for normal goods will reduce the demand for the good. In the Grossman model, increased prices on health care services will make investments in health care services less attractive and will therefore reduce the investments in health. The Rand Health Insurance Experiment investigated how individuals were influenced by the prices of health care services. In the experiment a group of individuals in the United States were randomly assigned to different insurance plans. Based on the experiment, Newhouse et al. (1981) concludes that the individuals with generous plans used more health care services than those who were assigned to plans with more cost sharing. Brook et al. (1984) conclude that the insurance plan of the participants influenced, to a limited degree, the health status of the participants, even though they find a small positive effect of the generous plans.

So far section 2 has mainly focused on demand side effects. Health care expenditures may, however, also be influenced by several supply side effects (Jegers et al., 2002; Gerdtham et al., 1992). Robinson (2001) suggests that the payment mechanisms for physicians may influence the amount of services provided. According to the paper, fee-for-service gives incentives to "rewards bad inappropriate service", while a capitation system rewards "den[ial of] chronically ill". Papers 1–3 are based on data from hospitals in Norway that are compensated by a mix of fee-for-service (activity based financing) and capitation.

In summary, health is determined by many factors, among which medical care is only one. This thesis is limited to analysing how expenditures in medical care and in particular hospitals and ambulances are influenced by age and mortality.

3. Aims

The overall aim of this thesis is to identify and estimate the impact of variables driving health care expenditures for secondary care, by specifically considering the impact of age and mortality on both hospital and ambulance services expenditures.

- Paper 1:

Quantify the share of the total hospital expenditures used on individuals in their last calendar year of life in Norway. Furthermore, investigate differences between different age groups and health care expenditures.

- Paper 2:

The aim is twofold. Firstly, we aim to quantify the impact of age on mortality-related expenditures. Secondly, we aim to assess the influence of changing longevity on hospital expenditures that occur as death is postponed to higher ages where mortality related expenditures are lower.

- Paper 3:

The aim of this paper is three-fold. First, measure changes in health care expenditures over time, in order to test if *steepening* may be rejected. Second, present mechanisms that may induce *steepening,* as presented in the literature. Third, explain the connection between *red herring* and *steepening*.

- Paper 4:

Study how regional demography and accessibility patterns influence the cost of providing ambulance services. Furthermore, project the cost and demand for ambulance services based on population projections.

4. Study setting

The study setting, for example financial incentives for health care providers, may influence both the total amount of health care expenditures and potentially also the distribution on an individual level. The data applied in this thesis are from Norway. Norway has high per capita health care expenditures compared to other countries in the OECD. Only the United States has higher per capita health care expenditures adjusted for purchasing power parity.[2] Life expectancy at birth is also high in Norway with 81.4. In comparison the life expectancy in the United States is 78.7.[2]

Norway has a national health service (NHS). Similar health systems are found in Sweden, Denmark, New Zealand and the United Kingdom. The primary source of financing of the health care in a NHS system is through taxes and many health care services do not require any out of pocket payments. The use of health care services may therefore reflect, to a larger degree than in a health care system financed primarily by out-of-pocket payments, the health condition and not the income of the patient. Karlsson and Klohn (2013) support this view in their paper on long term care and the *red herring hypothesis* in Sweden. The paper claims that the funding system allows the indivudal's health care expenditures to reflect the need (morbidity and physical abilities) rather than income constraints at the individual level. On the contrary, as the price for the health care services faced by the patient (consumer) do not reflect the actual cost, moral hazard problems may be present (Hsiao and Heller, 2007; Colombier and Weber, 2011).

There are two sectors of the health care provision that are included in the empirical part of this thesis: somatic inpatient hospitals and ambulances. The ambulance service is run by the central government together with the hospitals (specialist care) while primary care and community-based models of emergency care (legevakt) and general practitioners (GPs) are organized by the municipalities (local level) (Johnsen and Bankauskaite, 2006). The specialist care is further divided into four health trusts. Patient transport stands for 5.8 % of the total spending of the health trusts, about 4.5 billion Norwegian Kroner. Patient transport takes place both by road (ambulances, taxies and buses), sea (boats) and air (helicopters and

[2] According to The Organization for Economic Co-operation and Development (OECD) statistics (stats.oecd.org) for 2011.

ambulance planes) (NOU, 2008). This section will further focus first on hospitals and then on ambulances.

4.1 Hospitals

Hospital stays are free of charge for patients in Norway in public hospitals. In private hospitals there may be out-of-pocket payments. However, less than 1% of all health care spending for both inpatient and outpatient services is associated with out-of-pocket payments (Huseby et al., 2013). The general practitioners (GP, family doctors) work as gatekeepers for the hospitals, and apart from emergency care treatment all patients must have a referral from a GP.

The hospitals in Norway are financed through a mix of per capita and activity-based financing (ABF), i.e., a mix of prospective fixed and prospective variable payment. Before 1997 the hospitals in Norway were financed only based on per capita funding (global budgets). The per capita funding were based on socioeconomic characteristics of the inhabitants in the catchment area of the hospital (Magnussen and Solstad, 1994). Since 1997 the share financed through ABF has changed several times (The Norwegian Directorate of Health).[3] The aim of the introduction of the activity-based component was to reduce both hospitals cost per treatment and waiting time.

Before the introduction of ABF for all public hospitals in Norway, it was tried at four pilot hospitals in 1991. The result was the pilot hospitals, to a small degree, changed the activity level compared with the fixed grant system (Magnussen and Solstad, 1994). After the introduction Yin et al. (2013) finds that there is a negative correlation between length of stay and the share paid by ABF. In general there are, however, few studies investigating this relationship for the case of Norway.

In the period of observations for hospital in this thesis, 1998–2010, there have also been several other major reforms in the hospital sector. In 2001, the central government took over the management of the hospitals from the counties. In 1999, the Act for Patient Rights was

[3] Share paid by activity based financing (ABF): 1997: 30%; 1998: 45%; 1999: 50%; 2000: 50%; 2001: 50%; 2002: 55%; 2003: 60%; 2004: 40%; 2005: 60%; 2006–2010: 40%.

introduced. The aim of the act was to ensure the inhabitants in Norway received equal and good quality health care services. This may again lead to increased health care expenditures.

4.2 Ambulances

The emergency medical service (EMS) in Norway has undergone several reforms in the past few years (Norum and Elsbak, 2010; Norum and Elsbak, 2011; Langhelle et al., 2004). In 1996, a certificate of competence for ambulance workers (paramedics) was introduced, called "fagbrev". The required training consists of two years of theoretical training in high school, followed by two years of practical training. Prior to the certificate being established, the health trusts themselves organized the training of ambulance staff, and the training was often limited. In 2003, further education for ambulance workers was introduced at the University level.

Since 2005, by law, it is required that at least one of the workers in the ambulance have the certificate. The law also requires that all ambulances should be operated by at least two workers. In some areas, mostly rural, the ambulances previously were manned by only one worker, the driver. The law also set educational standards for the staff in ambulance planes, boats and helicopters. These reforms have increased the expenditure of the EMS in Norway (Norum and Elsbak, 2010; Norum and Elsbak, 2011). This thesis does not investigate the changes that occurred during the reforms in EMS, but investigate the current patterns of expenditures. This is important in order to predict the future expenditures for the EMS services.

5. Data

Access to registry data from the Norwegian Patient Registry (NPR) as well as to records of all ambulance transports in the South-Eastern Norway Regional Health Authority (Helse Sør-Øst), provided the basis for the analyses performed in this thesis. The record of ambulance transports is named Akutt medisinsk informasjonssytem (AMIS). Since 1997, NPR has recorded every hospital admission in Norway for somatic hospitals. Note that NPR only record diagnostic related groups (DRG) for outpatient care from 2008. In addition, papers 2–4 applied data from Statistics Norway on the number of inhabitants. In paper 1, data from the National Resident Registry (NRR) was applied. Furthermore, paper 4 applied Geodata for travel times between municipality centroids. Table 5.1 presents an overview of the data applied by paper.

Paper 1 linked 2010 NPR data with the NRR record that documented whether the patient died or not (d=1 if the patients dies, d=0 otherwise), and did not contain any information on the diagnosis of the patient. The data were on an individual level, i.e., it was possible to follow an individual between different hospital admissions. Apart from demographic information (e.g., age and gender) of the patients, the dataset also contained information on the cost of the treatment based on DRG for both inpatient and outpatient somatic hospital services.

Papers 2 and 3 applied NPR data for the time period of 1998–2009 for inpatient somatic hospital services where a total of 14.5 million admissions were observed. In this dataset it was not possible to track individuals between different hospitals admissions, which distinguishes this dataset from the dataset applied in paper 1. Papers 2 and 3 contain the following information from each hospital admission: the patients' home municipality (place of residence), age, gender, the year of hospital admission, and cost of treatment based on the DRG. As the variable of interest is on the per capita level, the data was aggregated to the smallest possible cell, defined by age, gender, year and municipality. This resulted in a data set with 1 093 920 cells (106 age groups × 2 genders × 12 years of observation (1998–2009) × 430 municipalities).

Finally, paper 4 applied data for road ambulance transports in the largest regional health authority, Health Southeast, in Norway from 2009 to 2010. Health Southeast covers the south-eastern part of Norway, with 2.7 million inhabitants, which is roughly 3/5 of the total population of Norway. There are 197 ambulances in Health Southeast and 498 in all of Norway. The health trust covers an area of 104 071 km^2, approximately two times the size of Denmark. The area is sparsely populated with the exception of areas along the coastline. The hospitals that are the most advanced in treating patients with multi-trauma and other severe illnesses are located in Oslo (the capital of Norway). Areas included in Health Southeast could require a traveling distance to Oslo of up to 379km (by road).

The data applied in paper 4, contained information on the age of the patient as well as the place of residence and travel time in the ambulance. It was not possible to distinguish between individuals, only ambulance trips. The structure of the data is, therefore, similar to the applied in papers 2 and 3. For each ambulance station, information on the total expenditures each year was available. By combining the travel time and total expenditures, the price per ambulance minute for each ambulance station was calculated. The data was further aggregated at the municipality level and averaged over the two years of observations, resulting in 140 observations, one for each municipality included in the study.

Furthermore, paper 4 applied the population predictions from Statistics Norway for the projection of future health care expenditures. Statistics Norway presents several different population projections; for example, high, low, and the main alternative (in Norwegian: Hovedalternativet eller “MMMM”). In the paper the main alternative was applied.

Section 6 (Methods) also presents regression analysis based on the same dataset as applied in papers 2 and 3. In section 8, the number of overnight stays by age and cost estimated by DRG for inpatient somatic hospitals for the time period 1998–2009 from NPR are presented.

Table 5.1: Overview of data applied by paper

Name of paper	Name of data set	Variables applied
Paper 1: Hospital expenses towards the end of life	NPR (in- and outpatients in somatic hospitals) / National Resident Registry Year: 2010	Age, gender, individual death record, time (year), estimated cost based on DRG, number of inhabitants
Paper 2: The association between age and mortality related hospital expenditures	NPR (inpatients in somatic hospitals) / Statistics Norway Year: 1998–2009	Age, gender, number of deaths, time (year), estimated cost based on DRG, place of residence (municipality), number of inhabitants
Paper 3: The impact of ageing on health care expenditures: A study of steepening		
Paper 4: Modeling and predicting the cost of providing ambulance services in Norway	AMIS / Statistics Norway / Geodata Year: 2009–2010 Statistics Norway population prediction Year: 2013–2040	Age, number of deaths, time (year), travel time in ambulances, total expenditures by ambulance station, number of inhabitants, travel times between municipality centroids Predicted future population, age, year
Thesis: Section 6 Section 8	The same data set as applied in papers 2 and 3 NPR / Statistic Norway Year: 1998-2009	Same variables as in papers 2 and 3 Age, year, length of stay, estimated cost based on DRG, number of inhabitants

6. Method

This section will, first, present "the simple model" that forms the foundation of the methods applied in this thesis. Second, it expands the discussion raised in paper 3 with regard to the concepts *steepening* and the *red herring hypothesis*. Finally, a brief summary of the empirical methods applied in each paper will be presented.

6.1 The simple model

This thesis investigates how health care expenditures (Y) for an individual (i) is influenced by demographic factors; age (a), gender (q)[4] and death (d), and other factors (x):

$$6.1 \quad Y_i \ (a, d, q, x)$$

With regard to the marginal effect of the explanatory variables in equation 6.1, the effect of ageing is discussed in section 2. To summarize section 2, the effect of both age and mortalities is suggested to be positive in many empirical studies (see, among others, Hogan et al. (2001) and Zweifel et al. (1999)), but the effect is not certain within the framework of Grossman (1972).

The share of total health care expenditures used by decedents (d=1):

$$6.2 \quad \sum_{i \in d=1} Y_i \Big/ \left(\sum_{i \in d=1} Y_i + \sum_{i \in d=0} Y_i \right)$$

Section 2; do not discuss the effect of gender. Several studies (Mustard et al., 1998; Lubitz et al., 2003; Stearns and Norton, 2004) report gender differences with regard to health care expenditures. Though Mustard et al. (1998) suggests, that the genders have similar expenditures patterns when controlling for "differences in reproductive biology and higher age-specific mortality rates" (page 1678).

With regard to the other factors driving health care expenditures (x), there are numerous variables that may be included. In section 2 mention several factors that influence health care expenditures apart from gender, age and death, e.g. income and health care reforms. In the

[4] 0 if male, 1 if female

analysis in paper 4, x is assumed to include jobs per capita, accessibility to hospital, and education. In papers 2-3 the effect of other variables (x) is assumed to be zero. The issue of potential omitted variables is further debated in section 8.1 (Limitations).

If the relationships between explanatory variables and health care expenditures are assumed to be linear, the health care expenditures may be presented as equation 6.3, where ε is the error term:

6.3 $Y_i = \alpha_0 + \alpha_1 a + \alpha_2 d + \alpha_3 q + \alpha_4 x_i \; + \varepsilon_i$

The per capita health care expenditures for a group (g) are denoted by Y_g. The mortality rate in group g is denoted by m.

6.4 $Y_g = \sum_{i \in g} Y_i \frac{1}{n_g} = \beta_0 + \beta_1 \frac{\sum_{i \in g} a_i}{n_g} + \beta_2 \frac{\sum_{i \in g} d_i}{n_g} + \beta_3 \frac{\sum_{i \in g} q_i}{n_g} + \beta_4 \frac{\sum_{i \in g} x}{n_g} + \frac{\sum_{i \in g} \varepsilon_i}{n_g}$

$\Leftrightarrow$

6.5 $Y_g = \beta_0 + \beta_1 a_g + \beta_2 m_g + \beta_3 q_g + \beta_4 x_g + \kappa_g$

g is in papers 2 and 3 defined by age, gender, municipality and year, while in paper 4 it is defined by municipality. In paper 4, a_g indicates the share of individuals with a given age, while in papers 2 and 3 it is a dummy variable indicating age group. Furthermore, in paper 4 m_g is the mortality rate in the municipality, while in papers 2 and 3 it is the mortality rate for a group characterized by age, gender, municipality and year.

6.2 Relation between concepts

In the debate over health care expenditures and ageing, two concepts are often mentioned in the literature, the *red herring hypothesis* and *steepening*. The rest of section 6.2 will briefly introduce these concepts, keeping the same notation as defined above ("The simple model").

Red herring hypothesis

The *red herring hypothesis* was introduced by Zweifel et al. (1999). They specified the hypothesis that health care expenditures for individual (i) are dependent on time to death (quarters to death (k)), but independent of age:

6.6 $$\frac{\partial Y_i(q,k,a)}{\partial k_i} \neq 0$$

6.7 $$\frac{\partial Y_i(q,k,a)}{\partial a} = 0$$

The connection between 6.5 and 6.6–7 is not straightforward. Felder and Werblow (2008) state that estimating $\widehat{\beta}_2 > 0$ "add[s] on to the finding of the red herring literature". Estimating $\widehat{\beta}_2$, however, only touches upon the first argument of the *red herring hypothesis*, i.e., equation 6.6. The second argument, that age may be ignored, is not tested. Furthermore, the hypothesis as formulated by Zweifel et al. (1999) uses quarters to death (k). In the simple model the variable (d) only indicates death within a calendar year, i.e., k≤4. In conclusion, estimating $\widehat{\beta}_2$ does not test the *red herring hypothesis* (paper 3).

Not discussed in the paper by Zweifel et al. (1999), but in papers 1 and 2, is that mortality-related health care expenditure may in and of itself be dependent on age ($\beta_5 \neq 0$ in equation 6.8). If that is the case, ignoring age when predicting health care expenditures will lead to biased results.

6.8 $$Y_g = \beta_0 + \beta_1 a_g + \beta_2 m_g + \beta_3 q_g + \beta_4 x_g + \beta_5 m_g a_g + \kappa_g$$

As discussed in section 2, one motive for demanding health is to increase the amount of an individual's healthy days. The expected number of potential healthy days declines with age, hence, the expected sign of β_5 is negative. On the contrary, one may argue the expected length of life when getting a serious illness is low regardless of age. This should in turn imply that the sign of β_5 is insignificant, i.e. the mortality-related costs are independent of age.

The section continues with a short presentation of some papers in the *red herring* debate in connection to 6.6 and 6.7. The aim of the presentation is to discuss how the studies define the *red herring hypothesis* and thereby give an overview of the applied definitions.

Karlsson and Klohn (2013) use aggregated data on long term care from Sweden. In their paper they use the probability of dying within the next two years as a proxy for time to death (k), and the share of individuals with a certain age as a proxy for age $(a_g,$ where g is municipality). They conclude that the effect of time to death is positive, but that "age remains the main driver" of long term care expenditures. They state on page 6 that "our results give evidence for the existence of the *red herring*, but age itself seems to have a strong impact on LTC (long term care) after controlling for mortality."

Colombier and Weber (2011) use data from Switzerland and include several other factors besides age and proximity to death in their regressions, among them income. They conclude that proximity to death is of marginal importance and argue that they have "further evidence against the *red herring hypothesis*".

Stearns and Norton (2004) use data from Medicare in the United States. They treat the "*red herring*" as an omitted variable problem by assuming the coefficient of time to death to be zero and then including it in the model. They find the interaction between age and time to death to be positive and significant. Furthermore, several of the coefficients are suggested to be significant in both models. They do not explicitly make conclusions with respect to the *red herring hypothesis*, but they state "it is time for time to death". The statement and paper in general have been interpreted in favor of the *red herring hypothesis* (Zweifel et al., 2004).

To summarize, some researchers refer to 6.6 (time to death) when referring to the *"red herring"*, while others refer to both 6.6 and 6.7. The primary hypothesis tested is, however, similar across studies; may time to death and/or age be ignored when estimating health care expenditures. In the rest of this thesis, I will refer to the *red herring hypothesis* as defined by Zweifel et al. (1999) (6.6 and 6.7).

There are several methodological problems raised in the *red herring* debate (Salas and Raftery, 2001; Seshamani and Gray, 2002; Felder et al., 2010). The two main problems addressed are (Häkkinen et al., 2008; paper 2): 1) that the point of death (time to death), i.e., also mortality, may be dependent on health care expenditures $(corr(\kappa_g, m) \neq 0)$, and 2) the probability of dying is strongly correlated to age, hence it might be a multicollinearity problem. In paper 2 both of these issues are discussed in detail.

With regard to the first methodological issued raised above, paper 2 argues that in Norway during the period of observation, it may be plausible that even though in an international context there is a causal relationship from health care expenditures to time to death, it may not be the case in the data applied. In the paper 2, we argue that due to decreasing marginal returns to scale, life expectancy may to a limited degree be influenced by health care expenditures for such high levels of health care expenditures as are observed in the data. In the background section of subsection 2.2 (wealth), refers to, Chapman and Hariharan (1996) and OECD (2013) who indicate that there might be a decreasing returns to scale from investments in health care expenditures measured in life expectancy.

Furthermore, paper 2 tests the hypothesis that mortality is independent of health care expenditures, based on the data set applied in the study with two stage least squares (2SLS). The mortality rate for the year (t-1) is applied as an instrument for the mortality rate in year t.

With regard to the second methodological issue mention above (i.e., multicollinearity), paper 2 suggests that the problem is negligible as the data set is large, with more than one million observations. Paper 4, in contrast, has a small sample with only 140 observations, and the problem of multicollinerity may therefore be larger for the analysis in paper 4 than in papers 2–3. This issue will be further discussed in section 8.

Steepening

The term *steepening* was introduced by Buchner and Wasem (2006) and states that health care expenditures for the elderly grow faster than for the rest of the population:

$$6.9 \quad Y_{a\in[65,79],t} / Y_{a\in[30,64],t} > Y_{a\in[65,79],t-1} / Y_{a\in[30,64],t-1},$$

where $Y_{a\in[65,79],t}$ is the per capita expenditures for the elderly (aged above 64 and below 80) in year t.

In paper 3, I generalized the definition to include all individuals and defined the younger group as those less than 65 (i.e., 0 to 64) and the elderly group as those older than 64 (i.e., 65+).

$$6.10 \quad Y_{a\in[65,106],t} / Y_{a\in[0,64],t} > Y_{a\in[65,106],t-1} / Y_{a\in[0,64],t-1}$$

Later, Felder and Werblow (2008) defined *steepening* as

$$6.11^{5} \quad \frac{\partial^2 \ln Y_g(a,t)}{\partial a \partial t} > 0$$

Their argument for introducing the new definition was that it was more flexible with respect to model specification. Note that Felder and Werblow (2008) also include mortality in the function of Y_g. However, as estimated in paper 3, the cross derivative of mortality over time and age $\left(\partial^2 m / \partial a \partial t\right)$ is small, and therefore for the sake of simplicity the rest of this section ignores the effect of mortalities when defining *steepening*. Furthermore, Buchner and Wasem (2006) defined *steepening* in three dimensions (age, time and per capita health care expenditures (6.10)), and ignoring mortalities will make the definitions (6.10 and 6.11) more comparable.

The argument for taking the natural logarithm was that they claimed that health care expenditures grow exponentially over time. Paper 3 argues that per capita health care expenditures are slightly better explained by a linear model than an exponential model in the data set applied in the study (NPR 1998–2009), hence:

[5] Note that Felder and Werblow (2008) and paper 3 also include gender and mortality in the regression when testing *steepening*.

6.12 $\frac{\partial^2 Y_g(a,t)}{\partial a \partial t} > 0$

where

6.13 $Y_g = \beta_0 + \beta_1 a_g + \beta_3 q_g + \beta_6 t + \beta_7 t a_g + \kappa_g$

Both paper 3 and Felder and Werblow (2008), however, do not discuss under what conditions definitions 6.10, 6.11 and 6.12 may give different results with regard to *steepening*. In general 6.12 presents the percentage increase in per capita health care expenditures as both age and time increase with one unit, while 6.12 presents the increase in absolute value. However, for testing the presence of *steepening* the sign β_7 is the matter of interest, and the magnitude is of secondary interest.

Furthermore, as mentioned in paper 3, 6.10 does not distinguish between differences within the young and old, while 6.11 and 6.12, as done in both paper 3 and Felder and Werblow (2008), allow for more variation within the two age groups.

To compare the results from 6.11 and 6.12, regressions on 6.13, both with and without applying the logarithmic transformation of the dependent variable, are performed, applying ordinary least squares (OLS) and the same data set as applied in paper 3 (NPR 1998–2009). Note that infants less than one year of age are excluded from the regression. The reason to exclude the zero-year-olds is that paper 3 supports *steepenin*g when excluding this group.[6] When applying the natural logarithms, β_7 is estimated to be 0.00271; when not applying logarithms it is 10.46. Both coefficients are significant, hence, the conclusion with respect to *steepening* is the same in both cases (does not reject). The magnitudes of the coefficients are, however, different in the two regressions.

With regard to the connection between *red herring hypothesis* (equations 6.6 and 6.7) and *steepening* (equations 6.10, 6.11 and 6.12), paper 3 concludes that the terms are independent.

[6] Note that paper 3 estimates the growth rate (β_7) for 20 age groups (0, 1-4, …,90+). The growth rate for the age group 0 is suggested to be the highest (paper 3).

6.3 Summary of methods applied by paper

In summary, papers 1 and 2 estimate the share of total health care expenditures used by decedents (6.2). Paper 1 has individual level data, while paper 2 has more aggregated data. Paper 1 uses descriptive statistics to estimate 6.2, while paper 2 uses regression analysis (6.8 assuming $\beta_4 = 0$ and including a dummy for each year). Furthermore, paper 2 tests the possible endogenity of mortality in equation 6.8. The analysis fails to reject that mortality is exogenous in the regression. Paper 3 tests *steepening* by 6.10 and 6.12. To estimate 6.12 regression analyses on 6.13 was applied. Paper 4 runs a regression analysis on 6.5, assuming $\beta_3 = 0$ (gender). In the analysis in paper 4, x is assumed to include jobs per capita, accessibility to hospital, and education. Furthermore, paper 4 projects future road ambulance expenditures by applying the estimates based on 6.5 and population predictions from Statistics Norway.

Note that in papers 2 and 3, g represents a cell defined by age, gender, time and municipality, while in paper 4 it represents municipality.

The thesis continues with empirical results (section 7) and then discussion (section 8).

7. Empirical results

This section will present the main empirical results in this thesis, while an overview of the sign of coefficients estimated for papers 2–4 may be found at the end of the section in Table 7.1. The reason not to include paper 1 in the table is that the paper is based on descriptive statistics and therefore does not estimate any coefficients, per se.

Papers 1 and 2 apply data from the hospital sector and estimate the per capita hospital expenditures to be high for newborns and the elderly as compared to the rest of the population. Paper 1 uses data from 2010, while paper 2 uses data for 1998–2009. Paper 1, based on descriptive statistics, estimates the share of the total inpatient and outpatient somatic hospital expenditures used by decedents (equation 6.2) to be 10.6 %, while paper 2, based on regression analysis on equation 6.8, estimates 6.2 to be 9.0 %.

Furthermore, both papers also find the mortality-related hospital expenditures to be declining by age. For the non-dead (survivors), the per capita health care expenditures are high for newborns and elderly. Note that paper 2 ignores non-demographic factors, i.e., β_4 is assumed to be zero. The possible impact of this simplification will be further discussed in section 8.

Papers 1-3 observe gender (q) differences with respect to health care expenditures. In the descriptive part of paper 2, the per capita health care expenditures for females are observed to be larger than those of males, for individuals less than approximately 50 years of age, with the exception of zero-year-olds. Conversely, the opposite is found for higher age groups. Paper 3, suggest that the coefficient (β_3) is negative (higher expenditures per capita for males than females) when excluding the effect of mortality (assuming $\beta_2 = 0$), positive otherwise.

Paper 3 focuses on *steepening* (6.10 and 6.12). Equation 6.10 is estimated to be negative and significant. [7] When, excluding the zero-year-olds, 6.10 is estimated to be positive and not significant. Furthermore, 6.12 is estimated to be greater than zero if excluding the zero-year-olds. The zero-year-olds have the highest growth in per capita health care expenditures. Apart

[7] Applying ordinary least squares (OLS) on: 7.1 $Y_{a\in[65,106],t} / Y_{a\in[0,64],t} = \psi_0 + \psi_1 * t$

from the newborns, the young have low growth in per capita expenditures compared to the elderly (50+). In conclusion, *steepening* is not rejected if the newborns are excluded based on 6.12.

Paper 4 applies data from the ambulance sector. The paper finds the expenditures for newborns and elderly to be high, as papers 1 and 2. Mortality (β_2) is found not to be significantly different from zero. In addition, β_4 is suggested to be positive for accessibility (short travel time to big hospital), negative for jobs per capita, and positive for low education.

With regard to the second part of paper 4, projecting future ambulance expenditures, the per capita expenditures are expected to decline towards 2040. There are two effects influencing the expenditures: 1) urbanization of the population, which decreases the costs per capita and 2) ageing, which increases the cost per capita.

Table 7.1: Sign of coefficients by paper

Coefficient	Paper 2*	Paper 3***	Paper 4*****
Age (β_1)	High for newborns and elderly	High for newborns and elderly	High for newborns and elderly
Mortalities (β_2)	+	+	Not significant
Gender (β_3) (0 if male; 1 if female)	**	- or + depending on regression****	
Other variables (β_4) Accessibility to hospital Jobs per capita Low education			 - + +
Age×mortalities (β_5)	-	-	
Time (β_6)		+	
Time×age (β_7)		+ (if excluding the newborns)	

* Dummy for each year (t) is included in the regression analysis
** Higher expenditures for males than females for newborns and elderly (50+)
*** The interaction between time and mortalities was also included, and estimated to be positive
**** If assuming the effects of mortalities to be zero the effect of gender is estimated to be negative, otherwise it is positive
***** Dummy for each ambulance district is included in the regression analysis

8. Conclusion and discussion

According to the Grossman model, the effect of ageing on health care expenditures is uncertain. Several empirical papers (Colombier and Weber, 2011; Felder and Werblow, 2008) suggest that ageing increases per capita health care expenditures. Papers 1–4 also suggest that ageing contributes to higher health care expenditures. Paper 3 suggests that health care expenditures among the elderly population are growing faster than those of the rest of the population. The paper does, however, mention that the literature on the underlying mechanisms that drive *steepening* is limited. Potential mechanisms will be further discussed in section 8.2 and 8.3.

The effect of mortality on per capita health care expenditures is suggested to be positive (papers 1–3); however, this is not supported in paper 4. The explanation for this rather unexpected result, in paper 4, may be the high correlation between age and mortality and the small data set applied in paper 4. The effect of age may then "mask" the effect of mortalities, i.e., the "multicollinerity problem" raised in the *red herring* debate (paper 2). Another explanation may be that mortality does not contribute to ambulance health care expenditures.

Furthermore, paper 2 suggests health care expenditures among females to be higher than those among males, apart from newborns and the elderly (aged 50 or above). In paper 3, when assuming the effect of mortalities to be zero $(\beta_2 = 0)$, females are suggested to have lower expenditures than males. For estimates not assuming the effect of mortalities to be zero, the effects of female gender are predicted to be positive. The explanation for the difference in results in paper 3 may be that women and men have different mortality-related expenditures, as suggested in papers 1 and 2.

With regard to the *red herring hypothesis,* papers 2 and 3 reject the hypothesis that age may be ignored when predicting health care expenditures. The papers support the hypothesis that mortalities influence health care expenditures.

The remainder of this section is divided into three parts: limitations, future research, and finally, political implications and concluding remarks.

8.1 Limitations

According to the Grossman model ageing is only one of several factors that influence health care expenditures. Christiansen et al. (2012) and Seshamani and Gray (2004) suggest that other factors such as income may rule out the effects of age and mortality. In addition, health care reforms may change health care expenditures, such as implementation of new payment schemes or patients' rights. Medeiros and Schwierz (2013) suggest that apart from income and demographic variables, other factors such as technological factors contribute to a substantial part of the observed growth in health care expenditures in European Union countries. This may require a model including more factors (x), to include potential omitted variables. In paper 2 we have addressed the issue of omitted variables by including dummies for each year, to control for unobservable time varying heterogeneity. However, it would add to the literature on drivers of health care expenditures to include more variables.

In paper 4, we only have observations over a 2-year period, and applied the average over the two years. The short time period may result in observations that are less sensitive to fluctuations in omitted variables over time. The small sample (140 observations) also limits the amount of explanatory variables that are reasonable to include in the analysis.

With regard to *steepening* (paper 3), it is defined in three dimensions (age, time and per capita health care expenditures) and inclusion of more variables will not, strictly speaking, test *steepening*. Applying more variables may, however, test the underlying mechanisms behind *steepening*.

With regard to the measurement of health care expenditures, papers 1–3 use DRG to estimate the cost. This proxy for expenditures does have limitations as discussed in papers 1–3. The papers mention three limitations: 1) The inflation adjustment performed to make the study costs comparable across years may fail to capture the rapid growth in wages in the health care sector in Norway; 2) the elderly in general have poorer health than the average patient with the same condition, hence DRG estimated costs that are equal for all age groups may underestimate the cost; and 3) DRG estimated costs are not the actual cost, but estimates based on averages.

With regard to 1), this would be in accordance with Baumol's cost disease theory (Baumol, 1993). The theory suggests that as health care expenditures increase, wages will increase more than productivity as the demand for health care workers increases.

The Euro-DRG project (http://www.eurodrg.eu/) debate DRG weights ability to predict costs. In the project they have compared DRG-estimated costs across Europe. They conclude that costs vary substantially between countries for the same diagnosis. Part of the difference in costs is driven by different treatment procedures and wages, but part of the variation is not explained (Busse and on behalf of the Euro, 2012). This may imply that DRG-estimated costs are not representative of the actual cost of treatment, yet may represent a proxy.

To overcome the problems mentioned with regard to DRG estimates as a proxy for costs, an alternative measure could be employed for resource use. Potential alternatives that are available from NPR are: Total number of days of stay in hospital or number of admissions.[8] Figure 8.1 presents the two different measures for resource use per capita by age; cost estimated by DRG (a)) and total length of stay (b)). Comparing the figures (8.1 a)-b)) the different measures seems to give similar distributions across the different age groups, i.e., high expenditures for newborns and elderly (50+). It is beyond the scope of this thesis to investigate this matter any further, but future research could aim at including alternative measures.

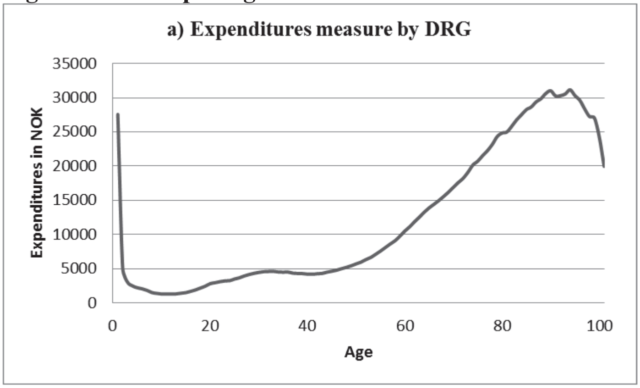
For the projections portion of paper 4, the paper does not discuss the uncertainty in the demographic predictions from Statistics Norway. This is a limitation of the study. To illustrate the uncertainty, the previous population predictions from 1996 as compared to the population in 2013 will be presented. The main alternative population forecast from Statistics Norway will be applied, as applied in paper 4.

The true population in 2013 is 5 051 275, while in 1996, SSB projected it to be 4 697 261. For the forecast in the following years (after 1996) presented by SSB, they systematically under-predict the population. Furthermore, the population prediction from SSB

[8] Length of stay was only available at an aggregated level (19 regions, year, age and gender), but data at the same aggregated level as applied in papers 2 and 3 are available upon request if the necessary permissions are granted.

is fairly accurate for the first 5 years ahead of time while the deviation between actual and predicted population increases over time.[9]

Figure 8.1: Comparing different measures for resource use per capita



An alternative could be to use a stochastic population forecast such as the one presented in Keilman et al. (2002), quantifying the uncertainty in the prediction. Here Keilman et al. (2002) present the population forecast with a confidence interval, indicating the historical variance in the variables applied in the prediction.

With regard to the analysis of the emergency services (paper 4), the paper only includes ambulances. Other forms of transport, such as helicopters, are substitutes for road ambulances. Especially for long distance transport, helicopters are used to reduce traveling time. Therefore, excluding other forms of transport from the analysis is a limitation of the

[9] The data was supplied upon request by Marianne Tønnesen of Statistics Norway.

study. However, as mentioned in paper 4, the helicopters comprise a small share of the total number of emergency missions as compared to road ambulances (1.6 %).

To summarize the limitations discussed, there may be omitted variables that potentially give biased results; for example, health care reforms. Furthermore, DRG-estimated costs are not a perfect measure of actual costs and future research should ideally include other measures. The uncertainty in population projections is not discussed in paper 4 when predicting future health care expenditures. Population projections have historically been not accurate.

8.2 Future research

This section summarizes and expands upon potential aims for future research within the topics presented in this thesis. Future research may, as previously mentioned, include: 1) the inclusion of additional variables (x) explaining the underlying mechanisms that induce *steepening* and health care expenditures, in general; 2) comparing different measures of health care expenditures; 3) including more forms of transport in the emergency services in order to control for the substitution effect between the different means of transport; 4) validating findings by using new and larger datasets to test whether mortality is still estimated not to have a significant effect on ambulance expenditures. A fifth target for future research, not previously mentioned, is to expand the discussion on the *red herring hypothesis*. The rest of this section will focus on 1) and 5).

As acknowledged in papers 2 and 3, the methods applied in the studies are not sufficient to test the *red herring hypothesis,* as defined by Zweifel et al. (1999) (i.e., equations 6.6 and 6.7). Karlsson and Klohn (2013) have, however, proposed techniques to test the hypothesis for similar data as was available and applied in papers 2 and 3. By using the probability of dying over a long period of time, as opposed to using only the mortality rate (the probability of dying within one year), they are able to estimate a proxy for time to death on aggregated data, subsequently enabling them to test the *red herring hypothesis*. They defined time to death as the probability of dying within the next two years. Expected time to death for age group *a* in year *t* is determined by: the probability of dying within the time period (t), the mortality rate for the age group in year t $(m_{a,t})$, and the mortality rate for the next time period for the same cohort $(m_{a+1,t+1})$.

Time to death (TTD) for age (a) and time (t) is then estimated to be:

8.1 $TTD_{a,t} = 1-(1-m_{a,t})\times(1-m_{a+1,t+1})$

By utilizing this approach, Karlsson and Klohn (2013), suggests that one may test the *red herring hypothesis* on similar data as applied in papers 2 and 3. This may be a potential target for future research.

Mechanisms inducing steepening

As mentioned in paper 3, the literature on mechanisms inducing *steepening* is limited. The paper states on page 3 that:

> "In summary, the literature on the causes of increased expenditures for the elderly indicates that there might be a technological bias and changes in biological factors (morbidity). With regard to the first, the technological bias is likely to be driven by some underlying mechanism that is poorly explained in Felder and Werblow (2008). One reason might be biological changes over time, but there could also be other mechanisms driving *steepening*."

The following section proposes that a major mechanism driving *steepening* is increased health care expenditures and rational behavior. To the best of my knowledge this hypothesis has not previously been presented. The model presented is limited, and a future research target should be to expand this model.

Health care expenditures and steepening; a simple theoretical model

To illustrate the hypothesis, I will build a simple model using only two individuals, old (O) and young (J) and two types of health care services, A and B.

The older consumer is assumed to have a wider range of healthcare needs (diseases or dysfunctions) than the younger, and hence uses a wider range of health care services. Further, it is assumed that category A services ($A_1,\ldots,A_m$) are relevant for both the old and young, while services in category B ($B_1,\ldots,B_n$) are only relevant for the old. Category A includes services like emergency care and simple procedures, while category B services include more complicated procedures. Another way of interpreting the assumption is that the older individual has multimorbidity conditions requiring advanced care, while the younger has "simpler" conditions, "monomorbidity".

a denotes the monetary investment in A services, while b is the monetary investment in B services. Furthermore, the amount of A services consumed by the young is denoted by a_J, equivalent for the old, a_O.

Utility for the old from health care expenditures is the sum of health care expenditures in A and B services:

$$8.2\ U_O = U_{A,O}(a_o) + U_{B,O}(b)$$

Utility for the young:

$$8.3\ U_J = U_{A,J}(a_J)$$

Furthermore, the social planner is assumed to maximize the sum of utility for the old and young. The old and young consumers are assumed to have strictly increasing utility from investments in A services, but decreasing marginal utility:

$$8.4\ \partial U_A / \partial a_i > 0,\ \partial^2 U_A / \partial a_i \partial a_i < 0 \quad i = \{J, O\}$$

Furthermore, it is assumed that the marginal utility for the old consumer from investments in B services is low. More specifically, it is assumed that below a certain threshold the marginal utility from investments in B services is lower than investments in A services. Above this threshold it is assumed that the marginal utility from investments in B services is higher than investment in A services:

$$8.5\ \frac{\partial U_{A,i}}{\partial a_i} > \frac{\partial U_{B,O}}{\partial b} \quad \text{for} \quad a_i < Y^T \qquad i = \{J, O\}$$

$$8.6\ \frac{\partial U_{A,i}}{\partial a_i} < \frac{\partial U_{B,O}}{\partial b} \quad \text{for} \quad a_i > Y^T \qquad i = \{J, O\}$$

$$8.7\ \frac{\partial U_{A,i}}{\partial a_i} = \frac{\partial U_{B,O}}{\partial b} \quad \text{for} \quad b = a_i = Y^T \quad i = \{J, O\}$$

The interpretation of equations 8.5–7 is that the society prefers to employ simple procedures before they deliver more complicated procedures, i.e., “triage” health care prioritization. For example, they first deliver vaccines and basic emergency care (type A services), before offering more complicated procedures such as complex cancer treatment (category B services). Another example of B services could be treatment at an intensive care unit in a hospital for multimorbidity.

Furthermore, total health care expenditures in the society are exogenously determined and denoted by Y^*. The budget constraint is then given by:

8.8 $Y^*=a_J+a_o+b$

The utility for the society is assumed to be the sum of utility for the old and young. The social planner will then maximize the sum of the utility for the old and young subjects against the budget constraint:

8.9 $Max_{a_J,a_O,b}\{ U_J + U_0 = U_{A,J}(a_J) + U_{A,O}(a_0) + U_{B,O}(b)\}$

subject to 8.7

The marginal utility for investments in A services for the young and old is higher than investments in B services below $a_i < Y^T$ (equations 8.5-7), hence the social planner will only invest in A services if the total health care expenditures are below $2Y^T$. For total expenditures above $2Y^T$, the social planner will invest Y^*-2Y^T in B services.

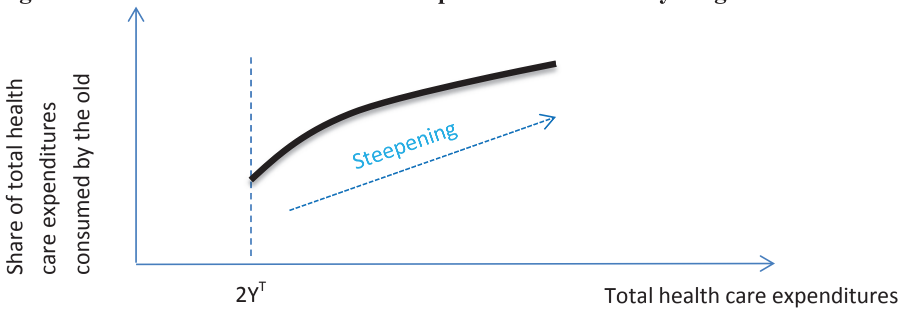
In conclusion, for total health care expenditures $Y^* < 2Y^T$, the share of total health care expenditures consumed by the old are not determined in the model, and above the share increases with increased expenditures.

Steepening is characterized by a situation where the share of total health care expenditures consumed by the elderly is increasing over time. According to the definition presented by Buchner and Wasem (2006) (6.11) *steepening* is defined by:

8.10 $\frac{a_{O,t}+b_t}{a_{J,t}} > \frac{a_{O,t-1}+b_{t-1}}{a_{J,t-1}}$, where t is time

In figure 8.1, the share of total health care expenditures consumed by the old is presented. In this figure the solid line indicates the share of total health care expenditures consumed by the old, above total health care expenditures of $2Y^T$. In conclusion, the model predicts that for countries with high health care expenditures, *steepening* will be present in periods of increased health care expenditures. For countries with low health care expenditures, the model is inconclusive with regard to *steepening*.

Figure 8.1 Distribution of health care expenditures between young and old



All the papers presented in the section 2.1 apart from Seshamani and Gray (2002) and Felder and Werblow (2008), find that an increasing share of the total health care expenditures is devoted to elderly. The papers, therefore, support *steepening*—hence our theoretical model—apart from Seshamani and Gray (2002) and Felder and Werblow (2008). With regard to the data that forms the empirical part of paper 3, we should observe *steepening* according to the hypothesis, as we observe strong growth in health care expenditures per capita in the observation period. Paper 3 therefore does not reject the hypothesis.

It is beyond the scope of this thesis to test the hypothesis any further, but the reduced per capita health care expenditures in Iceland for the past years may be compared to Norwegian data as a good case to test the hypothesis. Furthermore, future research should expand the discussion regarding the functional form of U_A and U_B.

8.3 Policy implications and concluding remarks

For hospital services, papers 1–3 suggest that the effect of both age and mortality have a positive impact on per capita hospital expenditures. This implies that solely including age when predicting future health care expenditures gives biased results. The simple method is also referred to as the naïve approach (Häkkinen et al., 2008). The naïve method may be illustrated by 8.11 and was applied in, among others, Waaler (1999). This method assumes that the total health care expenditures (Y) Δt years from year t are dependent on per capita expenditures for each age group today, multiplied by the number of inhabitants in different age groups in the future:

$$8.11 \quad Y_{t+\Delta t} = \sum_a \overline{Y}_{a,t} n_{a,t+\Delta t}$$

Papers 1–3 suggest that this approach will lead to biased results, as it does not distinguish between expenditures associated with end of life and non-end of life expenditures. As the papers propose, a substantial share of health care expenditures rise during the last year of life. A model that can be used to predict future health care expenditures that distinguish between these costs is therefore more appropriate. Equation 8.12 illustrates how this may be taken into account by drawing an explicit distinction between the health care expenditures for decedents (d) and survivors (s):

$$8.12 \quad Y_{t+\Delta t} = \sum_a \left(n^s_{a,t+\Delta t} \overline{Y}^s_{a,t} + n^d_{a,t+\Delta t} \overline{Y}^d_{a,t} \right)$$

Based on Melberg et al. (2012), which provided the inspiration for paper 3, the Norwegian Ministry of Finance altered the predictions of future health care expenditures from equation 8.11 to 8.12.

The empirical results in paper 3 suggest that the mortality-related expenditures are estimated to increase over time (the interaction between time and mortality is positive) even though life expectancy increases. With regard to the *shift* hypothesis presented in, among others, Melberg and Sørensen (2013), this result is interesting, as the result indicate movements in mortality related expenditures over time.

With regard to ambulances, we find the effect of mortalities to be non-significant, implying that 8.11 and 8.12 give equivalent results when predicting future expenditures. As mentioned earlier, one should, however, interpret the results with care due to the small dataset and high correlation between age and mortalities. Regardless of the sign of β_2 (mortalities), predictions of future ambulance expenditures are relevant for the ongoing debate surrounding the centralization of hospitals in Norway. The arguments which support centralization include better trained and specialized medical personnel and economic gains. Conversely, centralization of hospitals will increase the travel distance for some patients and subsequently increase the travel distance for ambulances. This thesis suggests that per capita expenditures for road ambulances will decrease due to urbanization and increase due to ageing towards 2040. In addition, the expenditures are suggested to be higher for newborns than for children and young adults (paper 4).

With regard to *steepening* in developed countries and assuming the hypothesis presented in the Future Research section holds, we can expect to observe *steepening* in periods of increased per capita health care expenditures, and bias towards younger age groups in periods of reduced per capita health care expenditures. Numerous empirical papers (see, among others, Getzen (2000)) suggest that when income increases, the investments in health care expenditures also increase. Therefore, in periods of economic growth, it is reasonable to predict that *steepening* will be present, assuming that the theoretical model is correct.

Key results

In Norway, between 9 and 10.6% of total hospital expenditures are allocated to decedents within one calendar year. Paper 1 uses data from 2010 and suggests the share to be 10.6% (in- and outpatient care), while paper 2 uses data from 1998–2009 and suggests the share to be 9.0% (inpatient care). Furthermore, our analysis suggests that mortality-related hospital expenditures are decreasing as a function of age (papers 1–3).

With regard to *steepening,* this thesis suggests that this phenomenon was present in Norway from 1998 to 2009 within the hospital sector (paper 3). Furthermore, the terms *red herring hypothesis* and *steepening* are found to be independent.

Based on the theoretical model presented, one should expect to observe *steepening* in countries with high health care expenditures per capita in periods of increased per capita health care expenditures, and biased towards younger age groups in periods of reduced expenditures per capita.

Furthermore, for ambulance services the expenditures are dependent on travel time to hospital and age (paper 4). Our predictions for 2040 suggest that the expenditures for ambulance services will decrease due to urbanization, but increase due to an increased share of elderly individuals—resulting in an overall decline in the expenditures per capita.

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Papers 1-4

I

Hospital expenses towards the end of life

BACKGROUND International research indicates that a considerable proportion of health expenditure is concentrated in the final phase of life, but to date, reliable Norwegian figures have not been available in this area. The purpose of this study is to investigate the proportion of Norwegian hospital expenditure for outpatient and hospital treatment which is devoted to persons who die in the course of the year.

MATERIAL AND METHOD To estimate the proportion of hospital resources devoted to treatment of patients who die in the course of the year, we use data from the Norwegian Patient Registry, which contains information on all individual treatment episodes of outpatient and hospital treatment in the period 2010, and information from the National Resident Registry on deaths that have occurred during the same year.

RESULTS In total, NOK 4.2 billion, or 10.6 % of all hospital expenses for outpatient and hospital treatment in 2010, was devoted to patients who died during the same year. The bulk of the expenses was incurred during the three months immediately prior to death. Hospital expenses towards the end of life declined with increasing age of the patient, and were more than halved for ninety-year-olds compared to seventy-year-olds. More than 50 % of the expenses incurred during the last year of life were spent during the three final months of life.

INTERPRETATION These results are relevant for estimating future hospital expenses in the health services. They are also relevant for decision-making related to priorities, but the figures for expenses cannot be used to determine whether too much or too little is spent on a given age group or disease.

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MAIN MESSAGE

More than 10 % of total hospital expenses for somatic outpatient and hospital treatment in 2010 were spent on patients who died within the same year.

Hospital expenses associated with patients in their final year of life increased considerably during the three months prior to their death.

The average expenses for hospital treatment of persons who died in 2010 declined with increasing age.

Several international studies show that a considerable proportion of health expenses are spent on treatment in the final phase of life, but the estimates vary greatly (1–6). Some of this variation occurs because the studies have different time frames, include different expenses and consider different groups of patients. A study by Polder and collaborators of expenses in the Netherlands shows that 11 % of all health expenses are devoted to patients in their final year of life (6), but do not include expenses for psychiatry. In their study from Finland, Häkkinen and collaborators include hospitals, psychiatry, drugs and other expenses, and conclude that 14 % of the expenses are devoted to patients in their final year of life, but they focus only on those aged over 65 (1). On the basis of data from Medicare, which largely include people aged 65 and above, studies from the USA show that 25–33 % of the expenses for this group are incurred by patients in their final year of life (7–10).

In Norway, we have a vibrant and important debate on treatment at the end of life (11–13), but we have little knowledge about the costs involved. The only Norwegian study available estimates these costs to be 18–26 % of the total (14), but the study is now more than 20 years old and based on estimates, since individual data were unavailable at the time. The literature is thus characterised by studies that are based on various components of expenditure for different periods of time in various sub-groups, and include results that are based on estimates. Using data from the Norwegian Patient Registry, many of these problems can be avoided. We can calculate hospital expenditure on the basis of individual data for the entire population, and we can estimate the real average hospital expenses for men and women who died in 2010 and for those who lived through the entire year.

Material and method

The results in this report are based on a data set in which information from the National Resident Registry identifying which persons died in 2010 and which survived, was linked to data from the Norwegian Patient Registry. The data set comprises 1 294 626 contacts with hospitals, distributed among 729 887 patients. For each of these individuals, we have information telling us whether he or she survived or died in 2010, and his or her use of hospital services in the form of outpatient or hospital treatment. The linkage of the registries was undertaken by the patient registry. Many individuals had more than one treatment episode, but with the aid of the personal identifier in the Norwegian Patient Registry we were able to total up costs at the individual level. The data set contained

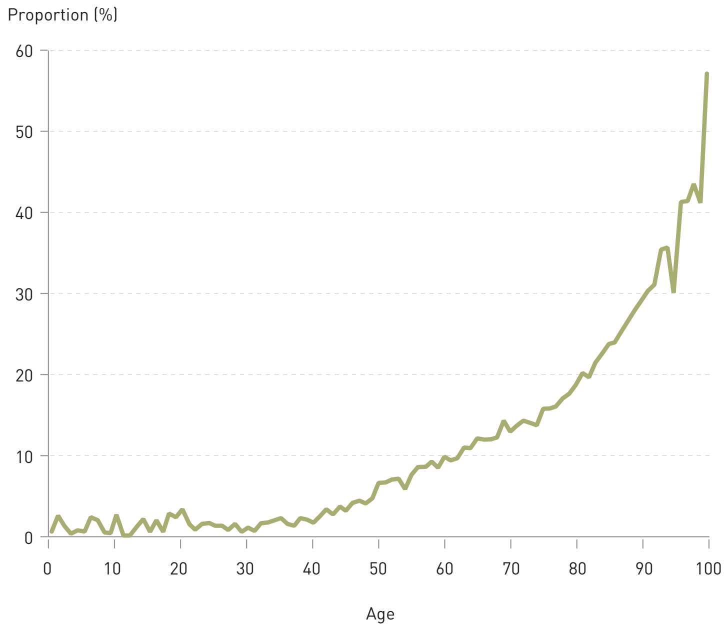

Figure 1 *Proportion of hospital expenses registered in the DRG system for outpatient and hospital treatment incurred at various age levels and devoted to patients who died during 2010*

27 341 patients who had died in 2010 and who had undergone outpatient or hospital treatment for which costs had been registered in the same year.

The average cost per person who died in each age group has been calculated by dividing the total hospital costs for persons who died in a given age group in 2010 by the total number of persons who died in Norway as a whole in the same age group. The average cost per person who survived 2010 has been calculated in the same manner. Our figures thus represent the average cost per person in the age group as a whole, not only the average cost for those who received treatment. Information on the number of deaths and survivors in various gender and age groups was retrieved from Statistics Norway. The calculation of costs was based on the assumption that a treatment sequence for various diagnostic groups has an average cost indicated by its DRG weight.

Results

Of those who died in 2010, altogether 27 341 (65 %) had visited a hospital for some form of cost-accounted outpatient or hospital treatment during the same year. The total costs for those who died amounted to NOK 4.2 billion, i.e. 10.6 % of the total hospital costs devoted to somatic outpatient or hospital treatment recorded by the DRG system. Figure 1 shows the proportion of hospital costs in various age groups that were devoted to persons who died in 2010. This proportion rises with age: Of all resources spent on people in their fifties in hospitals, 7 % were incurred by persons who died in the course of the year. For people in their seventies the corresponding proportion amounted to 13 %, for patients in their eighties it was 19 % and for those in their nineties it amounted to 29 %.

Figure 2 shows average hospital costs for outpatient and hospital treatment in various age groups over 50. For example, the diagram reveals that women aged 70 who died in 2010 on average received hospital treatment worth NOK 157 000 in that year, while the average for those who lived through the entire year amounted to NOK 16 000. The excess cost for those approaching the end of life thereby amounted to NOK 141 000, and the hospital expenses for women in their seventies who died in 2010 were close to ten times higher than for women who lived through all of 2010. The figure also shows that the costs for those who died decreased with age, while the costs for those who survived 2010 increased with age.

Figure 3 shows the monthly percentage distribution of the total hospital expenses for the last year for men and women in their eighties who died in December 2010. The data set contained 3 096 persons who died in December. Of these, altogether 102 persons were over 80 years of age, and for this group, a total of 868 cost-incurring hospital contacts had been recorded. Of all the expenses incurred during the last year before death, 30 % were incurred during the final month and more than 50 % during the final three months. This pattern could also be identified in other age groups (e-Table 1).

Discussion

The results show that the total expenses associated with hospital treatment of persons who died in 2010 amount to 10.6 % of total hospital expenditure, but that the average expenditure per person decreased with age (Figure 2). Hospital expenses for women in their eighties who died in 2010 were on average more than NOK 50 000 (33 %) lower than for seventy-year-olds who died in the same year. Corresponding figures for men were a decrease of NOK 40 000 (24 %). The figure also shows that more resources were spent on women than men who passed away at a relatively young age (under 60 years of age), while more was spent on men who passed away at an older age (over 80 years of age).

There are several reasons why expenses vary with gender and age. First, studies show that those who die at an early age often succumb to diseases or injuries that require more hospital resources than those who die in old age (15). For example, many die from cancer at a relatively young age, especially women, whereas people in older age groups more frequently die of a myocardial infarction (16).

International research in this area indicates that one cannot explain the entire difference between the age groups in terms of the prevalence of diseases or events; some of it may also be due to the fact that identical diseases are not treated as aggressively in older age groups (17–19). There may be sound medical reasons for this, since elderly patients are unable to sustain the same tough treatment as younger patients, although the literature indicates that elements of age discrimination may also be involved (16, 18). Further studies are required to clarify this.

The variations between consecutive age cohorts illustrate the impact of historical and institutional issues. For example, health and expenses may be influenced by retirement or by having been born into an age cohort that has experienced particular events or epidemics. In addition to random variations, such issues illustrate why the expenses do not follow a straight decline, but vary around a decreasing trend at different age levels.

A potential problem associated with investigating hospital expenses for those who died in a particular year as opposed to those who lived through the entire year is that one fails to capture all death-related hospital expenses: If the costs associated with the cause of death are spread over several years, the investigation will be biased if only hospital expenses in the current year are included. In the data set, this applied in particular to those who died early in 2010, where the hospital expenses most likely had increased from late 2009. A key issue is the extent to which the costs were incurred at the very end of life, or whether they were more evenly distributed over a short or long period prior to death. This is illustrated in Figure 3,

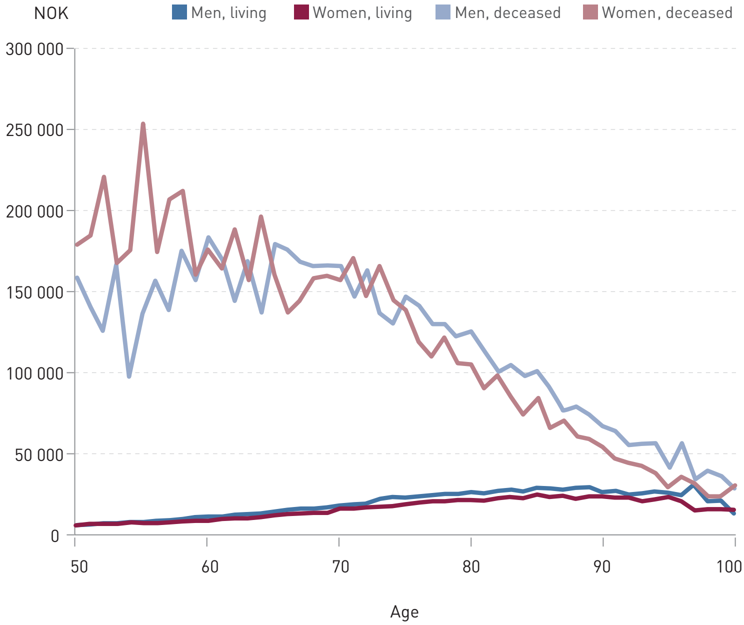

Figure 2 *Average cost registered in the DRG system for somatic hospital treatment of persons aged over 50. The costs are distributed on those who died in 2010 and those who survived, as well as by age and gender*

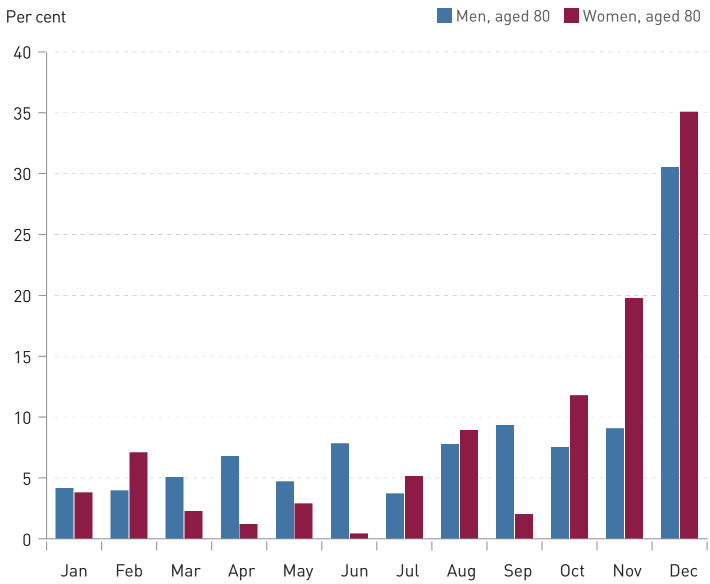

Figure 3 *Total registered costs for hospital treatment during the last year of life, percentage distribution by the last 12 months prior to death for all patients in their eighties who died in December 2010 and received hospital treatment in 2010 (n = 102)*

which shows two clear trends: First, expenses increased slowly towards the time of death. In analyses of data from the UK, a slight increase could be found as far back as 15 years before death (3). This could indicate that the definition of death-related expenses ought to be expanded. Second, the analysis of our material shows that even though the costs increased long before the time of death, this increase was minor compared to the increase in expenditure during the last few months. Hospital expenses accrued during the final month accounted for 30 % of all costs over the year for persons who died in December. Among patients in their eighties, the final three months prior to death accounted for 50 % of the total cost. We found a similar pattern for the other high-age groups. We may therefore assert that even though hospital expenses start increasing for some time prior to death, the bulk of the cost is incurred during a short period at the very end of life.

As a whole, this means that the figures probably capture a considerable proportion of the hospital expenses associated with the disease that caused death, but that the sum would have been greater if we could have obtained an overview of all death-related hospital expenses over several years. At the same time, by extending the time frame we would also run the risk of including treatment expenses that were unrelated to the end of life. For example, not all costs of treatment in January will necessarily be related to the cause of death if the patient dies in December. The correct interpretation of the figures is therefore «hospital expenses associated with persons who died in 2010», and that this represents a cautious, but not unrealistic, estimate of «hospital expenses towards the end of life».

The observation that large hospital costs are incurred by patients towards the end of their lives has major implications for the extrapolation of health expenditure. Assuming an increase in life expectancy, a traditional extrapolation of hospital expenses involves multiplication of the current average cost in various age groups with the number of people expected in these age groups in the future (20, 21). A problem associated with this method is that it fails to distinguish between expenses associated with the period prior to death, irrespective of age, and the expenses that follow from age alone. Today's average expenses for people in their seventies include the costs of the many who die at age 70. If life expectancy rises, the proportion of people who die at age 70 will decrease, and the age-related average expenses for people in their seventies will thus also decrease. A more correct extrapolation of expenditure levels should take this into account.

A possible limitation of the analyses can be found in the use of DRG weights as a measure of expenses. In reality, some patients will cost more and others less than the DRG rate. If it costs more to treat a patient in her final year of life than another patient with an identical diagnosis and DRG category, the use of DRG rates will underestimate the costs associated with the end of life. There is also the possibility of an opposite bias: That the treatment of patients with the same diagnosis costs less when the patient is in her final year of life and unable to sustain similarly aggressive treatment. In this case, the DRG rates will overestimate the costs.

The finding that approximately 10 % of all hospital expenses were devoted to patients who died in the course of the year should be treated with some caution in the context of prioritisation. This requires another approach, investigating the extent to which the quality and length of life increase for those patients who receive hospital treatment in what could potentially be their last year of life. While some of these patients will die, many others will have a longer and better life as a result of the treatment. Moreover, many of those who die will have an enhanced quality of life as a result of hospital treatment in the period preceding their death. We have only investigated one half of this assessment, the costs, and can conclude that the costs associated with patients who die in the course of a year account for approximately 10 % of all hospital costs and vary somewhat according to gender and a lot according to age.

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II

The association between age and mortality related hospital expenditures

Evidence from a complete national registry

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Abstract: The aim of this paper is to contribute to the debate on population aging and growth in health expenditures, by providing estimates on how mortality related expenditures are influenced by age. Using a register of inpatient hospital admissions to create gender-cohort specific panels for each of the 430 Norwegian municipalities, we are able to identify mortality related hospital expenditures by separating the impact of mortality on current hospital expenditures from the impact of patients' age and gender. We apply model estimates to quantify the mortality-related hospital expenditures for twenty age groups. Our results, which rely on the assumption that mortalities are exogenous in the empirical specification, suggest that mortality-related hospital expenditures are a decreasing function of age. Furthermore, the results imply that, both age and mortalities should be included when predicting future health care expenditures. The estimation results suggest that 9.0 % of all hospital expenditures are associated with treating individuals in their last year of life. Our results also suggest that the reduction in mortality rates in the period from 1998 to 2009 have, cet. par. contributed to an estimated reduction in total hospital expenditures of 0.6 billion NOK, a difference corresponding to 2 % of the expenditures in 2009.

JEL codes: I11, I12, I19, H51

Key words: mortality related expenditures, hospital expenditures, red herring hypothesis, ageing

1 Introduction and background

In early applications, a population's health care expenditures were commonly modeled as a function of basic demographic characteristics, such as age and gender. This approach applies the well-known fact that different age and gender groups have different health care needs. Using estimates of each group's per capita expenditures, so-called naïve predictions of the population's future health care expenditures can be computed based on future demographic characteristics.

This naïve approach was challenged by researchers who suggested that the expenditures are related to mortalities. In the seminal article by Zweifel et al. (1999) the

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authors hypothesized that time to death is more important than age in predicting future health care expenditure, and this hypothesis is frequently referred to as the *Red Herring Hypothesis*. Applying data on health care expenditures for inhabitants above 65 years of age in Switzerland, they found evidence supporting the *Red Herring Hypothesis*.

More than 30 papers (see among others Salas and Raftery (2001), Zweifel et al. (2001) and Felder et al. (2010)) have been published in the *Red Herring* debate and there appears to be strong evidence suggesting that both age and time to death are factors influencing health expenditures, even though the relative importance of age and time to death is strongly debated. In Colombier and Weber (2011) it is stated that "time to death is of marginal importance", while other studies, Werblow et al. (2007) and Zweifel et al. (2004), claim the opposite; age is of marginal importance. An aspect that has received less attention in the literature is that the costs that are incurred as a result of proximity to death may depend on the age of the individual. In a study of hospital expenditures for elderly decedents in the United States, Levinsky et al. (2001) found that expenditures decreased in age for elderly decedents, and similar findings were also reported by Häkkinen et al. (2008) and Melberg et al. (2013). If expenditures associated with the last year of life are substantially influenced by age, this implies that increasing longevity and postponing death until a higher and less costly age, will contribute to slower growth in health expenditures.[1] The aim of this paper is twofold. Firstly, we aim to quantify the impact of age on mortality related expenditures. Secondly, we aim to assess the influence of changing longevity on hospital expenditures that occur as death is postponed to higher ages where mortality related expenditures are lower.

By estimating the relationship between mortality related expenditures and age, we also contribute to the *Red Herring* debate. If there are large variations in the mortality related expenditures by age, including only time to death and not the interaction between age and mortalities, will yield upwardly biased results when predicting future health care expenditures.

There are several studies (see among others Häkkinen et al. (2008), Emanuel (1996) and Lubitz and Riley (1993)) that present the relationship between age and mortality related expenditures, but the studies only include the elderly part of the population. This paper includes all ages. This is important as the mortality related expenditures among younger individuals also contribute to the total health care expenditures.

Here, we apply data from the Norwegian Patient Registry (NPR) merged with demographic data from Statistics Norway (SSB). An advantage of this study, compared to previous studies is that there is no self-selection into our data. This makes the study unique. The data set follows Norway's population (5 million inhabitants) over a 12 year period from 1998-2009, and we are thus able to assess how the change in longevity over the 12-year period has influenced the expenditures.

The paper proceeds as follows: The study setting is described in the next section (Section 2). In Section 3 we describe the data. Our empirical specification and estimation results are presented in Section 4. Finally, in Section 5 we conclude and discuss the findings.

[1] In addition, length of life increases may, as suggested by Madsen (2004) and Breyer and Felder (2006), influence the morbidity patterns for different ages. It is beyond the scope of this paper to investigate this any further.

2 Study setting

The current organization of the health care system in Norway has many similarities to those in other Nordic countries and the United Kingdom (UK); hospital services are mainly provided by public health institutions, which are financed through general taxation. In Norway, hospitals are governed from the central government by the Ministry of Health, while the general practitioners (GP) and dentists practice privately and contract with the local level of government (municipality and county). At present, the hospital sector in Norway is divided into four Regional Health Enterprises (RHEs) which correspond to geographical areas. Each region receives funding based on per capita funding (60%) and activity based financing (ABF) (40%). ABF is based on the diagnosis related groups (DRG) system (Kalseth et al., 2010). ABF was introduced in June 1997. Note also that the share paid by per capita funding has varied from 1997 until today (Carlsen, 2008).

There is no out of pocket payment for public in-patient hospital services in Norway.[2] The GPs act as gatekeepers for hospitals with an exception of emergency cases, where the ambulance staff or other medical personnel may assign patients directly to the hospital (Johnsen and Bankauskaite, 2006). Patients may choose which hospital he/she would like to be treated at for elective care.

3 Data

3.1 Structure of the data

Two data sources are used in this study: Cost information for hospital admissions are extracted from the NPR and demographic data from SSB. The data from NPR provide a registry of all in-patient hospital admissions in Norway from January 1998 to December 2009. Registration in NPR is compulsory for all hospitals and each admission to the hospital is registered as one observation. It is not possible to track individuals across different hospitals, or different years. A total of 14.5 million admissions were recorded in the given time period, and the included patients are residents of all 430 different municipalities in Norway.

We apply five variables from the database; year of birth, gender, year of hospital stay and the number of DRG-points. Since we cannot identify individuals, we cannot link individual mortalities to hospital stays. We therefore aggregate the data to the smallest possible group where observed mortalities can be linked to observed hospital expenditures, and that is to groups formed by age-gender-specific groups in each Norwegian municipality. From SSB we received, for each year, data on the number of individuals belonging to each of these groups as well as the number of mortalities. Aggregation was performed by grouping the data, and each group was uniquely characterized by a realization of the set of categorical variables age (A_i), gender (G_i), year (T_i) and municipality catchment area (R_i). The variable A_i takes 101 discrete values in the range [0,100], the variable G_i takes two possible values, male or female. Since we have observations from 1998 to 2009 T_i takes 12 unique values. There are 430 municipalities, and hence, R takes 430 unique values. In total there are 101*2*12*430=1,042,320 unique groups formed by different combinations of A_i, G_i, T_i, R_i.

We index the groups by g and we let N_g denote the number of individuals belonging to group g. By computing the total cost of hospital services within the group

[2] There are a few exceptions, and on rare occasions individuals pay out of pocket for in-patient hospital care that is not covered by national insurance. Such payments amount to less than 0.4 % of total expenditures for secondary care (Samdata, The Norwegian Directorate of Health, 2012).

and dividing by the number of persons in each group, we get a per capita measure of hospital expenditures for each group. If we denote the expenditures associated with individual hospital admissions by Y_i , an expression for the per capita expenditures in group g, denoted by $\bar{Y}_g$ is given by:

$$\bar{Y}_g \equiv \frac{1}{N_g} \sum_{i \in g} Y_i$$

3.2 Descriptive statistics

We now provide an overview of the data. Throughout the rest of this paper we measure the expenditures in Norwegian Kroner (NOK) inflation adjusted to 2010 NOK.[3,4] In Table 1 we present the development of demographic characteristics in the period. We observe that although both the general population and the number of elderly older than 64 has increased during this period, the total number of mortalities has been reduced. We also see that the share of the population above 64 years of age has stayed stable at around 16 %.

Table 1: Demographic characteristics

Year	Number of inhabitants age >64	Total mortalities	Number of inhabitants	Share age >64
1998	718463	44119	4436605	16.2 %
1999	714455	44956	4465158	16.0 %
2000	709488	43930	4498328	15.8 %
2001	706532	43837	4520531	15.6 %
2002	705181	44268	4543897	15.5 %
2003	704553	42517	4573057	15.4 %
2004	706575	41280	4598770	15.4 %
2005	711357	41250	4628668	15.4 %
2006	716590	41416	4676098	15.3 %
2007	725038	42158	4716808	15.4 %
2008	739870	42139	4797661	15.4 %
2009	757259	41659	4861059	15.6 %
2010	777056	42025	4919639	15.8 %

In Table 2 we describe the characteristics of the group structure in the data. The average group includes 56 individuals. We observe that there is large variation in group size. The smallest group includes only one individual, whereas the largest group includes 6699 individuals. We also characterize the group level per capita expenditures and the group level mortality rate. We observe that the group level per capita expenditures range from zero to more than one million NOK whereas the group level mortality rate ranges from zero to one.

[3] 8 NOK=1 EURO and 6 NOK=1 USD (2010)
[4] The price level in the health care sector has grown faster than for the rest of the economy, therefore consumer price inflation adjustment may not be sufficient to isolate the changes in use of resources over time.

Table 2: Descriptive statistics of group level variables

Variable	Number of observations	Mean	Std. Dev.	Min	Max
Number of individuals in group N_g	995158	56	183	1	6699
Group level per capita expenditures [a] $\bar{Y}_g \equiv \frac{1}{N_g}\sum_{i\in g} Y_i.$	995158	10454.79	17153.82	0	1006657
Group level mortality rate $\bar{D}_g \equiv \frac{1}{N_g}\sum_{i\in g} D_i.$	995158	0.0341476	0.1229989	0	1

[a] The expenditure reported in the table is the expenditure related to activity (patient treatment) and not other costs such as pension costs in the health enterprises. The number is therefore lower than the cost reported in OECD and Norwegian Ministry of Health for inpatients in somatic care.

Furthermore, figure 1 describes per capita hospital expenditures for males and females. The expenditures are high for newborns and people above 60 years of age. The expenditures for women are clearly higher than males in the childbearing years (i.e. between the age of early twenties and late thirties), while males have higher expenditures for the ages above 50.

Figure 1: Hospital expenditures per capita measured in NOK by age, 1998-2009

4 Estimation and results

Our aim is to quantify the mortality related expenditures in a situation where mortalities are only observable at a group level. We aggregate our data to obtain data in a format including observable variables at group level which still enables us to identify the effect of mortalities on hospital expenditures at the individual level. To do this, we let Y_i refer to individual i's total hospital expenditures in a given year. We assume a linear regression function, relating these expenditures to observable characteristics:

$$1)\ Y_i = \gamma_0 + \gamma_1 X_i + \gamma_2 D_i + u_i,\ u_i \sim iid\left(0, \sigma^2\right)$$

where γ_1 and γ_2 are a vectors of unknown parameters to be estimated and γ_0 is an unknown scalar parameter to be estimated. The matrix X_i is a matrix of dummy variables capturing the effect of age and gender, including interaction terms. We distinguish between 20 different age groups in our regression model, infants and children aged 1-4, and we also categorize age in 5 year intervals until age 85-90. Individuals older than 90 are grouped together. The variable D_i is an indicator variable equal to one if the individual i died within the year. This variable is not observable due to the fact that we may not link current or future mortalities with hospital admissions; hence, estimating 1) is not feasible. However, the number of mortalities within each *group* each year, $\sum_{i \in g} D_i$, *is* observable and included in our data. Thus, we may estimate the impact of mortalities in each group on the group level hospital expenditures. If we index groups by g, and let N_g denote the number of observations in group g, we may express a regression equation where only observable variables are included, and where we may identify and estimate the unknown constants from 1): By summing over i on each side of 1) and dividing by N_g, equation 1) can be written based on the group means from each year:

$$2)\ \frac{1}{N_g}\sum_{i \in g}\left[Y_i\right] = \frac{1}{N_g}\sum_{i \in g}\left[\gamma_0 + \gamma_1 X_i + \gamma_2 D_i + u_i\right]$$

Applying the notation $\overline{Y}_g \equiv \frac{1}{N_g}\sum_{i \in g} Y_i$ we may write 2) as

$$3)\ \overline{Y}_g = \gamma_0 + \gamma_1 \overline{X}_g + \gamma_2 \overline{D}_g + \overline{u}_g$$

We note that the error terms in equation 3) are heteroscedastic, due to variation in the size of the groups, N_g.

One may argue that the mortality rate for each age group may be endogenous, and partly influenced by the health expenditures. However, one may argue that the potential simultaneity bias is likely to be small when analyzing Norwegian data, as Norway offers universal health insurance and full coverage for the whole population and the health care spending is high. The life expectancy at birth in Norway in 2011 was 79 years for males and 83.5 for females according to Statistics Norway. This is among the highest in the Organization for Economic Co-operation and Development (OECD), and one may argue that the marginal effect of hospital expenditures in terms of higher group level survival within the given year is likely to be very small for Norwegian patients.

However, we test the assumption that mortalities represent an exogenous variable in equation 3) by means of a Wu-Hausman and a Durbin test: We use the mortality rate in year *t-1*, as an instrument for the mortality rate in year *t*. The mortality rate in year *t-1* is likely to be correlated to the mortality rate in year *t*; however, it is clearly not a function of the health care expenditure in year *t*. We run two stage least squares (2SLS) and test the assumption that mortalities are exogenous. Based on the tests we cannot reject the null hypothesis that mortalities are exogenous (both tests with a p-value=0.9). The tests were performed on 3) with instruments; the 2SLS regression may be found in the appendix (Table A.1).

For the rest of the analysis, we will assume that we may treat mortalities as exogenous. Furthermore, we apply a Wooldridge test for serial correlation in panel data models, and the null hypothesis of no serial correlation is rejected in favor of a regression model with a first order autoregressive process (AR1) in the error terms (p=0.00). The test was performed on 3). The test results indicate that appropriate modeling and estimation should take both serial correlation and heteroscedasticity into account. We estimated 3) taking into account the AR1 process in the error terms, and the results from estimation is presented in Table 3. The resulting standard errors of the estimates were slightly larger compared to the results from a model estimated by means of weighted least squares (WLS) under the assumption of no serial correlation. The results for WLS regression assuming no serial correlation may be found in the appendix (Table A.2).

In Table 3a we observe that all the estimated coefficients for both age and mortalities are significant. The estimated coefficients are also statistically significant when excluding mortalities (Table 3b), a model referred to as *the naïve approach* in Häkkinen et al. (2008).

Based on the regressions presented in Table 3a, we may now describe how mortality related hospital expenditures (MRE), defined as the estimated marginal effect of mortalities on hospital expenditures, depend on age. In Figure 2, we present the relationship between age and MRE. We observe that MRE is highest for the age groups below 60 and declines sharply for the older age groups. We also observe that female decedents have a larger MRE than males until the age of 75, while after the age of 75 male decedents have the largest MRE. This is in accordance with the findings in Melberg et al. (2013).

Furthermore, Figure 3 presents estimated increase in per capita health care expenditures by age excluding the effect of mortalities, based on the regression results presented in Table 3a. The figure shows that the health care expenditures for newborns and elderly are high compared to the rest of the population. Furthermore, the expenditures for females are higher than for males for the ages 15 and 54. Above the age of 54 the expenditures for males are higher for males than for females.

In Tables 4a and 4b we present the estimated hospital expenditures for survivors and decedents separately for males and females. The table is based on the regression results presented in Table 3a combined with demographic information from Statistics Norway.

Table 3a: Results from weighted regression analysis of hospital expenditures assuming serial correlation in error terms

Dependent variable: Per capita expenditures

	Females				Males			
	Age		Mortality rate by age		Age		Mortality rate by age	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
0	23527.2***	(88.36)	119988.2***	(11426.8)	25429.8***	(87.78)	65412.4***	(9828.8)
1-4	1458.2***	(55.61)	215537.1***	(15404.9)	2255.0***	(55.06)	176742.4***	(15258.7)
5-9	171.4***	(50.59)	193107.8***	(23562.0)	585.5***	(51.61)	96843.6***	(17469.4)
10-14	Reference group		111588.5***	(22256.4)	112.9*	(51.61)	129338.8***	(19598.0)
15-19	966.9***	(51.40)	87140.5***	(15862.7)	611.1***	(52.49)	64229.1***	(9845.1)
20-24	2671.1***	(53.31)	60250.2***	(13546.0)	1023.1***	(53.24)	43107.9***	(7481.1)
25-29	4675.9***	(52.23)	68019.8***	(12891.9)	1113.7***	(52.33)	44369.7***	(7766.7)
30-34	5121.4***	(51.13)	80850.6***	(12473.2)	1431.9***	(51.09)	53933.5***	(7922.2)
35-39	4051.6***	(50.94)	103846.1***	(10135.8)	1860.0***	(50.86)	50064.8***	(7338.8)
40-44	3368.7***	(51.68)	118871.9***	(8539.3)	2443.2***	(51.46)	89489.5***	(6177.9)
45-49	3946.7***	(52.60)	132076.5***	(6305.6)	3441.8***	(52.60)	75365.7***	(4960.4)
50-54	5039.8***	(53.55)	140986.2***	(4841.1)	4975.2***	(53.98)	95812.3***	(3984.0)
55-59	6554.6***	(55.64)	138076.1***	(3977.4)	7250.8***	(56.34)	107490.7***	(3092.0)
60-64	8669.5***	(59.28)	121013.7***	(3155.1)	10227.9***	(61.15)	105001.6***	(2366.4)
65-69	11038.7***	(64.33)	109558.5***	(2532.2)	13890.7***	(68.90)	95870.9***	(1853.0)
70-74	13846.3***	(69.05)	99365.6***	(2007.7)	17779.9***	(76.86)	81194.3***	(1448.1)
75-79	17023.1***	(74.85)	61976.1***	(1457.7)	21308.7***	(86.99)	63649.4***	(1097.0)
80-84	18933.6***	(86.07)	39107.5***	(1054.5)	22987.3***	(105.9)	46879.7***	(863.3)
85-89	20119.3***	(108.9)	22423.0***	(793.4)	23969.9***	(140.8)	29566.5***	(713.3)
90+	19039.2***	(128.0)	5935.6***	(433.9)	22770.4***	(197.7)	15246.1***	(525.2)

Constant -363.4*** (41.49)

Year

1998	Reference group	
1999	542.0***	(24.59)
2000	349.6***	(27.28)
2001	945.7***	(27.86)
2002	1413.9***	(27.96)
2003	1869.4***	(27.96)
2004	1844.2***	(27.93)
2005	2184.7***	(27.89)
2006	2489.5***	(27.82)
2007	2733.4***	(27.77)
2008	2463.6***	(27.66)
2009	2744.9***	(27.68)

Note: * for p<0.05, ** for p<0.01, and *** for p<0.001. Number of observations: 991 930.

Table 3b: Results from weighted regression analysis of hospital expenditures assuming serial correlation in error terms – without controlling for mortality

Dependent variable: Per capita expenditures

	Females		Males	
	Coefficient	Standard error	Coefficient	Standard error
0	23796.5***	(84.27)	25596.7***	(82.60)
1-4	1503.5***	(56.64)	2297.7***	(56.02)
5-9	179.8***	(51.56)	586.0***	(52.70)
10-14	Reference group		116.8*	(52.70)
15-19	976.2***	(52.31)	629.9***	(53.39)
20-24	2673.8***	(54.29)	1045.8***	(53.90)
25-29	4679.2***	(53.15)	1140.0***	(52.87)
30-34	5133.9***	(51.95)	1468.0***	(51.56)
35-39	4103.1***	(51.66)	1906.7***	(51.15)
40-44	3475.1***	(52.12)	2575.8***	(51.58)
45-49	4148.6***	(52.75)	3619.0***	(52.26)
50-54	5399.6***	(53.14)	5351.6***	(52.65)
55-59	7103.2***	(54.42)	7925.2***	(54.01)
60-64	9425.0***	(57.06)	11330.6***	(57.11)
65-69	12111.3***	(60.66)	15590.3***	(61.89)
70-74	15465.2***	(62.10)	20182.8***	(65.18)
75-79	18854.4***	(62.43)	24524.3***	(68.36)
80-84	21043.6***	(65.33)	26977.9***	(77.06)
85-89	22333.2***	(75.23)	28074.7***	(100.3)
90+	20166.3***	(96.77)	26409.1***	(154.9)

Constant -290.1*** (42.33)

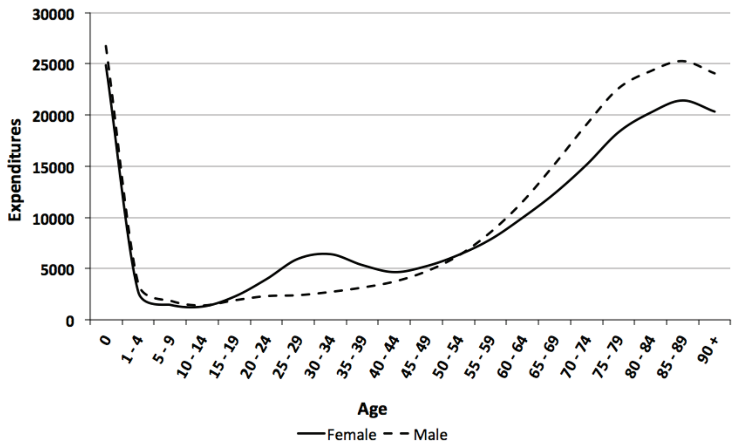
Year

1998	Reference group	
1999	545.1***	(24.90)
2000	335.5***	(27.72)
2001	923.0***	(28.34)
2002	1388.9***	(28.47)
2003	1819.3***	(28.46)
2004	1775.5***	(28.43)
2005	2104.8***	(28.39)
2006	2397.9***	(28.33)
2007	2640.3***	(28.27)
2008	2361.0***	(28.16)
2009	2628.1***	(28.18)

Note: * for p<0.05, ** for p<0.01, and *** for p<0.001.
Number of observations: 991 930.

Figure 2: Estimated increase in per capita hospital expenditures associated with the last year of life at different ages

Figure 3: Estimated per capita hospital expenditures by age excluding the effect of mortalities



As expected, the decedents have a higher per capita expenditure than survivors for all age groups. The number of decedents is small compared to the number of survivors, and the total expenditures are therefore higher for survivors than decedents. This holds for all age groups. In Tables 4a and b we see that even though the estimated MRE is falling with age, the total share of the hospital expenditures used by decedents increases with age. This is caused by the higher number of decedents in higher age groups. We also see that 10% of the total hospital expenditures for males are used by male decedents, whereas the corresponding figure for females is 8%. In total, for both genders, hospital expenditures among decedents comprise 9.0% of total hospital expenditures. In the international literature (Scitovsky, 1984; Polder et al., 2006; Hogan et al., 2001; Nord et al., 1989; Emanuel, 1996) the health care expenditures associated with the last year of life are estimated to be somewhere in between 10% and 30% of the total health care expenditures. The different studies include different components of total health expenditures, and/or selected segments of the population; hence, the results from different studies are not directly comparable.

In Tables 4a and b the demographic composition are the average over the period of observations (1998-2009). In the following sections, we will change this composition in order to observe how this may change the expenditure patterns. First, we hold the demographic composition equal to the one observed in 1998 and then 2009. Based on the composition in 1998, the share of total health care expenditures used by decedents is equal 9.8%. Based on the demographic composition in 2009, the corresponding number is 8.1% (see Table 5). The reason for the decline is two-fold. First, increased length of life increases the number of mortalities in higher ages with lower mortality related expenditures. Second, the share of decedents decreases in the time period.

Table 4a: Estimated expenditures in 1000 NOK for males per year

Age	MRE per capita	No. of Decedents	Expenditure per capita excluding MRE	No. of Survivors	Total expenditure for decedents	Total expenditure for survivors	Total*	Share used by decedents
0	65	100	27	29606	9191	791072	800263	1 %
1 - 4	177	41	4	119896	7445	425048	432492	2 %
5 - 9	97	20	2	154720	1943	290200	292143	1 %
10 - 14	129	18	1	155041	2383	217522	219906	1 %
15 - 19	64	76	2	146764	5016	279031	284047	2 %
20 - 24	43	136	2	140607	6185	325262	331447	2 %
25 - 29	44	156	2	151930	7279	365213	372492	2 %
30 - 34	54	172	3	169348	9720	460968	470688	2 %
35 - 39	50	216	3	175738	11505	553592	565097	2 %
40 - 44	89	273	4	169022	25481	631021	656502	4 %
45 - 49	75	397	5	159694	31829	755667	787496	4 %
50 - 54	96	626	6	154606	63855	968651	1032505	6 %
55 - 59	107	887	9	140076	102943	1196386	1299329	8 %
60 - 64	105	1192	12	113146	138882	1303220	1442103	10 %
65 - 69	96	1529	15	85009	169782	1290503	1460285	12 %
70 - 74	81	2171	19	71603	217638	1365470	1583108	14 %
75 - 79	64	3243	23	61155	279690	1382030	1661720	17 %
80 - 84	47	3990	24	42454	283901	1030663	1314565	22 %
85 - 89	30	3397	25	20720	186226	523382	709608	26 %
90 +	15	2235	24	7244	87853	174284	262137	34 %
Total all age groups					1648747	14329185	15977933	10 %

Total expenditures = Total expenditures for survivors + Total expenditures for decedents =[(Constant term weighted by the number of observations each year+ marginal increase in health care expenditures excluding MRE) # survivors] + [Constant term weighted by the number of observations each year + marginal increase in health care expenditure excluding MRE + MRE)* # decedents].

Table 4b: Estimated expenditures in 1000 NOK for females per year

Age	MRE per capita	No. of Decedents	Expenditure per capita excluding MRE	No. of Survivors	Total expenditure for decedents	Total expenditure for survivors	Total*	Share used by decedents
0	120	74	25	28124	10698	697961	708658	2 %
1 - 4	216	32	3	114266	7092	314041	321134	2 %
5 - 9	193	15	1	147036	3012	214900	217912	1 %
10 - 14	112	16	1	146941	1772	189574	191346	1 %
15 - 19	87	34	2	139204	3073	314194	317267	1 %
20 - 24	60	44	4	135637	2801	537286	540088	1 %
25 - 29	68	57	6	148745	4181	887420	891601	0 %
30 - 34	81	72	6	164195	6279	1052742	1059020	1 %
35 - 39	104	106	5	168451	11563	899825	911387	1 %
40 - 44	119	158	5	161787	19546	753742	773288	3 %
45 - 49	132	247	5	153788	33960	805356	839317	4 %
50 - 54	141	393	6	149090	57894	943724	1001618	6 %
55 - 59	138	555	8	136208	80966	1068518	1149484	7 %
60 - 64	121	723	10	113929	94740	1134689	1229429	8 %
65 - 69	110	902	12	91409	109911	1126963	1236874	9 %
70 - 74	99	1398	15	84252	160062	1275279	1435340	11 %
75 - 79	62	2490	18	82019	199913	1502025	1701938	12 %
80 - 84	39	4018	20	69732	238396	1410252	1648648	14 %
85 - 89	22	4987	21	44446	218587	951558	1170145	19 %
90 +	6	5470	20	22153	143658	450348	594007	24 %
Total all age groups					1408104	16530397	17938501	8 %

Total expenditures = Total expenditures for survivors + Total expenditures for decedents =[(Constant term weighted by the number of observations each year+ marginal increase in health care expenditures excluding MRE) # survivors] + [Constant term weighted by the number of observations each year + marginal increase in health care expenditure excluding MRE + MRE)* # decedents].

In order to further investigate the influence of changes in demographic composition on health care expenditures we hold the number of inhabitants equal to that in 2009, but hold the mortality rates equal to 1998. By this approach the share used by decedents increase to 10.0 % in 2009 (see Table 5). The reason for the increase is increased mortality rates for almost all age groups apart from the 90+ age group. Hence, an increased length of life reduces the mortality related hospital expenditures. Furthermore, the increased length of life leads to a reduction in the total expenditures with 2% (0.6 billion NOK) (see Table 5).

In summary, our results supports the claim that mortalities are, *ceteris paribus*, associated with higher hospital expenditures. We show that when life expectancy increases the naïve models will produce biased projections of future hospital expenditures. The results also show that even though the decedents incur high expenditures on hospital services, the decedent’s expenditures comprise a relatively small share of the total hospital expenditures (9 %).

Table 5: The effect of increasing longevity on total hospital expenditures in Norway

- Assuming the same per capita expenditures as in the regression presented in Table 3, but changed demographic composition[5]

	Demographic composition as in 2009				**Demographic composition as in 1998**				**Demographic composition as in 2009, but mortality rates as in 1998**			
	Male		**Female**		**Males**		**Female**		**Males**		**Female**	
Age	# D	# S	# D	# S	# D	# S	# D	# S	# D	# S	# D	# S
0	96	31737	58	29916	129	29497	85	28192	139	31694	90	29884
1-4	33	122577	30	116642	49	123554	43	116730	49	122561	43	116629
5-9	17	151276	13	145132	22	155843	11	147574	21	151272	11	145134
10-14	14	160836	13	152417	21	138363	19	131782	24	160826	22	152408
15 - 19	73	163948	37	155177	70	133768	35	127232	86	163935	43	155171
20 - 24	105	153315	46	146643	164	141842	44	137927	177	153243	47	146642
25 - 29	145	151494	52	146855	177	169082	58	164089	159	151480	52	146855
30 - 34	139	159013	59	153778	202	175598	92	166903	183	158969	85	153752
35 - 39	185	181973	98	173849	250	163026	114	155779	279	181879	127	173820
40 - 44	274	186904	133	176770	325	158962	183	153781	382	186796	210	176693
45 - 49	341	171124	230	162081	436	152679	253	145844	488	170977	281	162030
50 - 54	576	161823	398	155927	729	154386	474	147707	763	161636	500	155825
55 - 59	869	149491	494	145311	783	107923	462	107431	1083	149277	624	145181
60 - 64	1370	146777	843	144273	1163	85527	592	89905	1987	146160	949	144167
65 - 69	1576	104472	976	107548	1701	81305	924	89531	2173	103875	1109	107415
70 - 74	1846	73750	1250	83800	2788	75778	1676	92348	2683	72913	1516	83534
75 - 79	2608	58670	1916	74087	4019	64204	3116	91629	3610	57668	2500	73503
80 - 84	3524	43704	3469	65401	4079	38114	4246	67322	4566	42662	4086	64784
85 - 89	3695	25000	5220	50212	3081	17652	4793	39129	4264	24431	6049	49383
90 +	2609	8907	6238	26781	1446	5906	4262	18078	2265	9251	6299	26720
Expenditures	Share of total health care expenditures used on decedents 8.1% Total expenditures in billion NOK 35.8				Share of total health care expenditures used on decedents 9.8% Total expenditures in billion NOK 32.8				Share of total health care expenditures used on decedents 10.0% Total expenditures in billion NOK 36.4			

5 Policy implications and conclusion

In our analysis we find that 9% of all hospital expenditures from 1998 to 2009 were spent on individuals in their last calendar year of life. Our analysis also suggests that mortality related expenditures are a decreasing function of age.

Our analysis supports the inclusion of both mortalities and age in predictions of future hospital expenditures. We provide an estimate of how increasing longevity over a twelve year period has influenced total hospital expenditures in Norway, and find that it had an impact of 2 percentage points in the period 1998-2009. Thus we conclude that the naïve approach is insufficient to predict future health care expenditures.

[5] #D : Number of decedents , #S : Number of survivors

The *Red Herring Hypothesis* as it was formulated by Zweifel et al. (1999) states that; 1) time to death do influence health care expenditures, 2) age do not influence health care expenditures. We use the mortality rate in the last calendar year of life, and not time to death. Hence, our assumptions and empirical specification is not tailored to test the Red Herring Hypothesis. Given the assumption that our regression equation is correctly specified, we clearly reject the hypothesis that hospital expenditures is unaffected by age.

The main implication of our results is that increasing longevity may bring about reductions in mortality related expenditures as death is postponed until higher ages, and these reductions in mortality related health expenditures should be taken into account when predicting future health expenditures. Furthermore, as mortality related expenditures are dependent on age, our study suggest that only including time to death without the interaction with age, will give misleading results when predicting future health care expenditures.

Finally, it is important to emphasize that several other factors such as technological progress and general growth in gross domestic product influence the health care spending, and not demographic factors alone (Häkkinen et al., 2008).

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III

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ORIGINAL PAPER

The impact of ageing on health care expenditures: a study of steepening

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Abstract Some researchers claim that health care expenditures for older people are growing faster than for the rest of the population. This process is referred to as *steepening*. The aim of this paper is to test *steepening*, applying new data and revised methods. Furthermore, we explain the connection between the terms *red herring hypothesis*, i.e., that time to death and not age per se drives the health care expenditures, and *steepening*. We also present the mechanisms that may induce *steepening*, as presented in the literature. When testing *steepening*, we apply data from all inpatient stays in somatic hospitals in Norway in the period 1998–2009, i.e., the data has no self-selection and covers the entire population of Norway (5 million). Our analysis does not reject *steepening*, with the exception of the 0-year-olds. The results also hold when controlling for mortality-related expenditures. Furthermore, we observe an increase in expenditures for the 0-year-olds. Finally, we find increasing mortality-related expenditures over time. We find the link between *steepening* and the *red herring hypothesis* to be vague, and we find *steepening* and the *red herring hypothesis* to be independent.

Keywords *Red herring hypothesis* · Hospital expenditure · Trends in health care expenditures · *Steepening* · Ageing

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Introduction

The proportion of the elderly population in the countries of the Organization for Economic Co-operation and Development (OECD) will increase substantially in the coming years. Knowledge regarding the distribution of per capita health care costs between different age groups is essential in order to forecast future health care expenditures. In this study, we discuss the long-term development of health care expenditures. Even though the long-term developments for the entire population are discussed in detail in several papers [1, 2], the specific increase for different age groups is poorly covered. This is vital in order to understand the long-term developments in health care expenditures. In this paper, we will investigate the specific growth for different age groups.

When discussing trends in health care expenditures, two concepts are often brought up in the literature: *red herring hypothesis* and *steepening*. The *red herring hypothesis* states that health care expenditures are driven by time to death, not age per se [3]. *Steepening* states that the growth in per capita health care expenditures for older people is higher than for the rest of the population [4]. In this paper, we will focus on the latter, but clarify the relation between the terms. The aim of the clarification is threefold. First, in the literature [4, 5], the connection between *steepening* and the *red herring* is vaguely described, so a clarification will therefore contribute to the *steepening* literature. Second, a discussion of the link between the terms will contribute to further understanding of the concept of *steepening*. Third, several methodological issues discussed in the *red herring* debate also apply in the *steepening* debate, and hence bringing in the *red herring* literature will improve the *steepening* debate.

The aim of this paper is threefold. First, we measure changes in health care expenditures over time, in order to test if *steepening* may be rejected. Second, we present mechanisms that may induce *steepening*, as presented in the literature. Third, we attempt explain the connection between *red herring* and *steepening*.

When testing *steepening*, we apply a complete data set for inpatient hospital expenditures in Norway from 1998 to 2009. We use diagnostic related groups (DRG) weights to measure the hospital expenditures. Norway has a National Health Service similar to the one we find in other Scandinavian countries and the United Kingdom (UK). The hospitals are public and financed through general taxation [6].

The contribution of this paper is that we elaborate on the link between *red herring* and *steepening* more than has previously been done in the literature [4, 5]. We also summarize the literature on mechanisms that may induce *steepening*. Furthermore, the estimation techniques previously presented in the literature are improved and the previous methods are replicated. The data set applied to test *steepening* is of high quality, with no self-selection over a long period of time.

The paper proceeds as follows: first, we present the terms *steepening* and *red herring* with the present literature, and discuss in detail what may induce *steepening*. Secondly, we explain the link between the two concepts. Thirdly, we test *steepening*. In the third part, we first present the data, then the methods and the results. Fourth, we present the conclusion and discussion.

Background

"If steepening [occurs]…, the future increase of health care costs will even be larger than in the predictions which keep expenditure profiles constant"[4] p 582.

From the quote above, *steepening* may be seen as a contradiction to the more optimistic future scenarios described in the *red herring* debate [2], which claim that future health care expenditures will be lower than previously expected, due to an increased length of life. However, as we will return to in the end of this section, both hypotheses may in fact hold at the same time. Before the link between the terms is explained in more detail, we will summarize the literature on the *steepening* and briefly mention the *red herring* literature.

Steepening

In 2006, a new term regarding health care expenditures and older people was introduced by Buchner and Wasem [4] that suggested per capita health care expenditures would grow faster for the elderly than for younger people, i.e., a situation characterized by *steepening*. *Steepening* was defined as the increase in the ratio of per capita expenditures for older people (65+) divided by the younger (below 65), over time:

$$\overline{Y}_{a\in[65,106],t}/\overline{Y}_{a\in[0,64],t} > \overline{Y}_{a\in[65,106],t-1}/\overline{Y}_{a\in[0,64],t-1} \quad (1)$$

where $\overline{Y}_{a\in[65,106],t}$ is the per capita expenditures for the elderly (aged above 65+) in year t.

Note that in their regression analysis they defined the young to be between 30 and 64, while the old were between 65 and 79 [4]. To make the age limits more comparable with the other definition (2) of *steepening* presented in this paper, we will use the age limits as presented in definition (1) throughout this paper. Also note that Buchner and Wasem [4] include other definitions of *steepening* that we will return to in the "Methods" section.

Based on the same definition, but without using the term *steepening*, health data from OECD between 1984 and 1998 indicates *steepening* in several countries, among them the United States (US), Finland and Japan. However, this pattern is not found in the UK [7], where a decline in the expenditures for the elderly compared to the rest of the population is observed. There are also other studies that suggest health care expenditures grow faster for the elderly than the rest of the population [8–11]. There are, however, methodological issues connected to the simple method (definition) used in these papers, which we will discuss in more detail later. Some of the methodological issues are solved by Felder and Werblow [5], who defined *steepening* as a positive cross derivative of per capita health care expenditures with respect to age and time:

$$\frac{\partial^2 \overline{Y}_g(a,t)}{\partial a \partial t} > 0. \quad (2)$$

Note that Felder and Werblow [5] included mortality rates in the function of per capita expenditures, in contradiction with the definition by Bucher and Wasem [4], as they defined *steepening* in three dimensions (age, per capita expenditures and time). Therefore, in the rest of this section we will ignore the impact of mortalities.

Definition (2) forms the basis of this paper, but results based on both definitions (1) and (2) will be presented later. The reason for focusing on the latter definition is that the definition is more flexible with respect to model specification, and in our view it captures the concept as it was originally formulated by Bucher and Wasem [4]. A wider discussion on the different definitions of *steepening* will be presented in the methods section.

Felder and Werblow [5] mention several factors that may lead to *steepening* or reduce the effect of *steepening*. We will give a short summary in the following section.

They suggest that *steepening* may arise due to increased "maintenance" costs as length of life increases, or simply as a bias in the technological frontier (more innovations in medical treatments for older people). They also mentioned that, to the contrary, per capita mortality-related expenditures for hospitals are decreasing with age; hence, increased length of life might reduce mortality-related expenditures. This is supported in several studies [12–14]. Felder and Werblow [5] also suggest that, due to compression of morbidity, the period of illness will be compressed over time, which will in turn reduce the per capita health care expenditures related to older people [15].

Another paper discussing the reasons for growth in health care expenditures for the elderly is written by Barer et al. [11]. They discuss the implications of changes in morbidity and mortality and how that might change utilization for health care. Their study is formed around rectangularization of survival curves over time, compression of mortality [16], and compression of morbidity [15]. They argue that based on the preferences of society to either accept "natural death" or use all resources possible to reduce morbidity, the compression of mortality and morbidity will influence health care expenditures in different ways. If society accepted "natural death", health care expenditures for the elderly will drop over time, while if society minimizes morbidity it will increase expenditures for elderly.

In summary, the literature on the causes of increased expenditures for the elderly indicates that there might be a technological bias and changes in biological factors (morbidity). With regard to the first, the technological bias is likely to be driven by some underlying mechanisms that are poorly explained by Felder and Werblow [5]. One reason might be biological changes over time, but there could also be other mechanisms driving *steepening*.

Red herring

The *red herring hypothesis* was formulated by Zweifel et al. [3], and states that health care expenditures are driven by time to death and not age per se. A similar idea had previously been presented by Fuchs [17]. Zweifel et al. [3] formulated precisely as:

The health care expenditures for an individual (i) independent of age:

$$\frac{\partial Y_i(a,k)}{\partial a} = 0 \tag{3}$$

where a is age and k is quarters to death.

The health care expenditures are dependent on quarters to death:

$$\frac{\partial Y_i(a,k)}{\partial k} \neq 0. \tag{4}$$

Several studies have tested the *red herring hypothesis* (see, among others, [2, 18, 19]); i.e., the studies have tested how time to death and age for a sample of the population may explain the observed health care expenditures. Some of the studies reject, while other support, the *red herring hypothesis*.

In the *red herring* debate, several methodological problems have been raised (see. among others. [20, 21]). The debate is summarized in Häkkinen et al. [22] by pointing at two econometrical issues: first, multicollinearity between the explanatory variables (age and time to death), and second, endogeneity between health care expenditure and time to death (mortalities). Both these issues will be relevant in the "Methods" section in Eqs. 10, 11, 14 and 16. Gregersen and Godager [13] apply the same data set as we do in this study, and discuss both these issues in detail. In summary, first, the multicollinearity is of minor importance, as the data set is large; second, the assumption that mortalities are exogenous is not rejected.

The link between steepening and red herring

By definition, *steepening* is defined in three dimensions (age, time, and per capita health care expenditures) as is the *red herring* (age, time to death and individual health care expenditures). As the dimensions in the terms differ with respect to time and time to death, the link between the terms is not obvious, and both hypotheses may hold at once. Furthermore, when comparing (2) (*steepening*) with (3) and (4) (*red herring*), the definitions of the terms do not contradict or support each other. In summary, we therefore conclude that the terms are independent.

Data

For this study, we have repeated cross-sectional data (pseudo-panel) for all hospital admissions in Norway from 1998 until 2009. The data comes from the Norwegian Patient Registry (NPR). The data was merged with demographic characteristics from Statistics Norway (SSB). The data from NPR provides a complete registry of all hospital admissions in Norway from January 1998 to December 2009. The dataset contains data on somatic in patient care. Registration in NPR is compulsory for all hospitals, and therefore there is no self-selection in the dataset. Each admission to the hospital (hospital stay) is registered as an observation, and it is not possible to track individuals between admissions. The dataset contains five variables; year of birth, gender, year of hospital stay, DRG-points (diagnostic related group) and place of residence of the patient (municipality). Data on the number of inhabitants (N) are given by SSB (Table 1).

In order to get per capita measures, we aggregated the data by grouping the data so the smallest possible cell is defined by a given age (a_i), gender (q_i), year (t_i) and municipality (m_i). The 430 municipalities, 106 ages, 2 genders and years of observation (1998–2009) gave 1,093,920 unique cells that form the dataset our analysis is based on. We index the cells with the index g ($g = 1, 2\ldots,1{,}093{,}920$).

The per capita expenditure in one cell is:

$$\overline{Y}_g = \frac{1}{N_g}\sum_{i\in g} Y_i \qquad (5)$$

The per capita hospital expenditures in year (t) are defined by:

$$\overline{Y}_t = \frac{1}{N_t}\sum_{i\in t} Y_i \qquad (6)$$

For the rest of this paper, the expenditure will be measured in Norwegian kroner (NOK), inflation adjusted to 2010 NOK {8 NOK = 1 € [Norwegian Bank (2010)]}. In Fig. 1 we present per capita expenditures as a function of age. To explore how expenditures have developed over time for different age groups, we compared the per capita expenditures for the first 6 years with the last 6 years in the dataset. We aggregate the total health care expenditures for each age (a) and divide by the number of inhabitants with age (a), for each of the two time periods (1998–2003 and 2004–2009). If we denote the start of a period by t_1 and the end by t_2 (for example $t_1 = 1998$ and $t_2 = 2003$) the health care expenditures for age (a) in Fig. 1 is defined by:

$$\overline{Y}_{a,t\in[t_1,t_2]} = \frac{1}{N_{a,t\in[t_1,t_2]}}\sum_{i\in\{a,t\in[t_1,t_2]\}} Y_i. \qquad (7)$$

The figure clearly shows that the per capita health care expenditures for the older people and newborns (0 years of age) have increased substantially over time during the period of observation. Except for newborns, the expenditures for older people increased more than for the rest of the population. If newborns are excluded, the figure shows that the expenditures for older people have grown faster than for the rest of the population, consistent with *steepening*.

One reason for the increase in expenditures for newborns may be increased expenditures for premature infants. Both Bratlid and Nordermoen [23] and Nordermoen and Bratlid [24] discusses the increases in treatment expenditures for treatment of premature infants in Norway. In summary, they highlight that more premature infants with low birth weight are treated, and advances in technology not only increase the cost of treatment, but also improve the quality of the treatment.

Table 2 compares demographic characteristics for the first 6 years (1998–2003) in the data set with the last 6 years (2004–2009). Comparing the two periods, the average annual number of inhabitants has increased from 4.5 million in the first period to 4.7 million in the last period. The total number of decedents does decline over time, comparing the same two periods from 263,627 to 249,902. The mortality rate (number of decedents divided by the total population) for most age groups is falling over time, apart from the age groups containing the individuals aged between 5 and 14.

Methods; identifying steeping

In Buchner and Wasem [4], three methods are presented with which to identify *steepening*. The first is based on definition (1); using this approach, they find clear evidence of *steepening*. As they state, the clear advantage of this simple method is that it is transparent and easy to replicate. On the other hand it does not investigate changes within the two age groups—the younger and older people. This is closely related to:

$$\overline{Y}_{a\in[65,106],t}/\overline{Y}_{a\in[0,64],t} = \psi_0 + \psi_1 * t. \qquad (8)$$

Second, they suggest a slightly modified method, using a benchmark age group, and compare the growth of the other age groups relative to the benchmark age group:

$$\frac{\overline{Y}_{a,t}}{\overline{Y}_{\text{benchmark},t}} = \lambda_{0,a} + \lambda_{1,a} * t. \qquad (9)$$

Finally, they suggested a model with health care expenditures as an exponential function of age. Buchner and Wasem [4] only had 20 age groups and two genders, each year for 18 years ($20 \times 18 \times 2 = 720$ observations). The data limitations put strong limitations on their regression methods. The methods were later significantly improved by Felder and Werblow [5]. They had more variation in the data (a larger data set) with 26 regions, both genders, 10 years and 20 age groups, i.e., 10,400 observations. This allowed for a more complex model. They assumed that the health care expenditures are a function of time (t) and demographics [age (a), gender (q) and mortality rate (ϕ)]:

$$\begin{aligned}&\text{Per capita health care expenditure}\\&\quad = \text{Constant} + \beta * \text{gender} + \gamma * \text{age} + \theta * \text{time}\\&\quad + \kappa * \text{mortality rate} + \mu * \text{age} * \text{time} + \text{error term} \leftrightarrow\end{aligned} \qquad (10)$$

$$\overline{Y}_g = \alpha + \beta * q + \gamma * a + \theta * t + \kappa * \phi_g + \mu * a * t + \varepsilon_g. \qquad (11)$$

Table 1 Descriptive statistics: expenditures

Variable	Number of observations	Mean	Std. dev.	Min	Max
Per capita expenditures by year: $\overline{Y}_t = \frac{1}{N_t}\sum_{i \in t} Y_i$	12	7,340.71	947.5119	5,786.21	8,595.46
Per capita expenditures by group: $\overline{Y}_g = \frac{1}{N_g}\sum_{i \in g} Y_i$	995,158	10,453.61	17,145.92	0	1,006,657

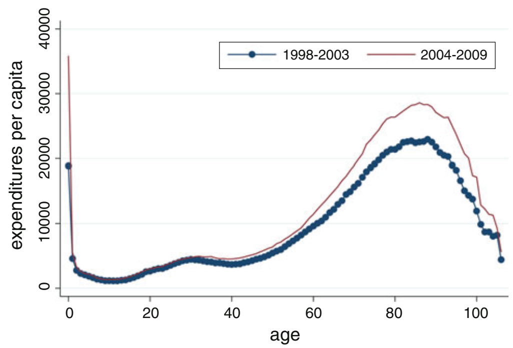

Fig. 1 Hospital expenditures per capita measured in NOK over age

In Eqs. 10 and 11,[1] β indicates the marginal increase in cost for females compared to males, and θ captures yearly growth in per capita expenditures, while μ measures the age specific growth rate as deviation from the yearly growth rate (θ), κ is the increase in per capita hospital expenditures due to mortality rate, and γ is the impact of age on per capita expenditures. Finally, ε is the error term. In this setting, *steepening* was defined by (2).

Note that Felder and Werblow [5] argue that hospital expenditures grow exponentially over time. To test if an exponential or linear model applies to our data set, we ran two regressions: first, keeping the dependent variable as a linear function of time, and second, keeping the dependent variable as an exponential function of time:

$$\overline{Y}_g = \theta_0 + \theta_1 * t \tag{12}$$

with $R^2 = 0.0095$ and $\ln \overline{Y}_g = \theta_0 + \theta_1 * t$ with $R^2 = 0.0019$.

From Eq. 12 we see that the R^2 is low in both the exponential and linear model, but slightly higher in the linear model. Based on the result, the difference between the two models is small and both models may apply. However, we choose to apply a linear model due to the slightly higher R^2.

Felder and Werblow [5], argue that $\frac{\partial^2 \overline{Y}}{\partial a \partial t}$ is a function not only of μ_a, but also of the mortality rate ϕ. They assume that $\frac{\partial^2 \phi}{\partial a \partial t} < 0$ due to increased length of life. Therefore, we tested the magnitude of changes in mortality rate from changes in age and time:

$$\phi_g = \alpha_0 + \alpha_1 * t * a + \alpha_2 * a + \alpha_3 * t + \varepsilon_g. \tag{13}$$

In the rest of the methods section, we will ignore the impact of changes in mortalities on *steepening*, but we will come back to this issue in the results section.

Further, as stated earlier, Felder and Werblow [5] only had 20 age groups (d_z) in their data set, limiting their analysis to 14. As we have more variation in the age variable, we are not forced to keep the same grouping of the regression parameter. However, per capita expenditure is not a linear function of age (see Fig. 1); therefore, we also treat age as a categorical variable, with 21 groups, respectively. The reasons for keeping age to 21 groups only are twofold. First, it will make the results easier to compare to the methods presented by Felder and Werblow [5]. Second, if age is treated with one-year age-groups, the number of observations in each group declines, and therefore the precision of each estimate will drop. In summary, as the estimate of interest here is the differences in growth between the young and old, and not the specific growth rate for each age per se, we therefore find the grouping similar to the one found in Felder and Werblow [5] to be sensible in this analysis:

$$\overline{Y}_g = \alpha + \beta * q + \sum_{z=0}^{20} \gamma_z * d_z + \theta * t + \sum_{x=1}^{4} \kappa_x * (\phi_g)^x + \sum_{z=11}^{20} \mu_z d_z * t + \varepsilon_g \tag{14}$$

d_z is a dummy for indicating age group (0, 1–4, 5–9, …, 90+), $\varepsilon_{m,a,t,q}$ represents the error term, and μ_z measures the deviation in growth rate for age group z compared to the young [below 50 ($z < 11$)]. As $\mu_{z \in \{1,10\}}$ is the benchmark age group, *steepening* is for age group z as defined by:

$\mu_z - \mu_{z \in \{1,10\}} > 0$ for z > 10, indicating that the growth rate for the elderly is higher than for the young.

Steepening within the 50+ age group is defined by $\mu_{z+1} - \mu_z > 0$ for $z > 10$.

The reasoning for choosing the specific functional form to capture the mortality-related expenditures in

[1] Note that g denotes a cell in the data set applied in this study, characterized by age, gender, time and municipality.

Table 2 Descriptive statistics: demographic characteristics

Age	2004–2009			1998–2003			Mortality rate 1–mortality rate 2
	#Decedents	Inhabitants	Mortality rate 1	#Decedents	Inhabitants	Mortality rate 2	
0	943	351,791	0.002681	1,146	342,773	0.003343	−0.0007
1–4	359	1,390,934	0.000258	531	1,420,461	0.000374	−0.0001
5–9	192	1,795,174	0.000107	231	1,827,422	0.000126	0.0000
10–14	186	1,868,604	0.0001	222	1,752,313	0.000127	0.0000
15–19	607	1,834,645	0.000331	718	1,591,994	0.000451	−0.0001
20–24	995	1,681,558	0.000592	1,168	1,634,271	0.000715	−0.0001
25–29	1,173	1,728,377	0.000679	1,378	1,886,462	0.00073	−0.0001
30–34	1,252	1,932,635	0.000648	1,681	2,077,068	0.000809	−0.0002
35–39	1,791	2,130,113	0.000841	2,084	2,000,640	0.001042	−0.0002
40–44	2,416	2,066,621	0.001169	2773	1,903,477	0.001457	−0.0003
45–49	3,699	1,931,564	0.001915	4,049	1,835,113	0.002206	−0.0003
50–54	5,741	1,847,509	0.003107	6,505	1,807,816	0.003598	−0.0005
55–59	8,617	1,776,023	0.004852	8,690	1,550,439	0.005605	−0.0008
60–64	12,527	1,586,827	0.007894	10395	1,148,655	0.00905	−0.0012
65–69	14,342	1,137,507	0.012608	14,833	1,004,696	0.014764	−0.0022
70–74	18,734	925,269	0.020247	24,233	989,335	0.024494	−0.0042
75–79	29,838	848,292	0.035174	39,216	941232	0.041,665	−0.0065
80–84	45,382	725,662	0.062539	50,893	716,681	0.071012	−0.0085
85–89	51,417	475,017	0.10824	49,216	405,885	0.12126	−0.0130
90+	49,691	244,942	0.20287	43,665	200,843	0.21741	−0.0145
Sum	249,902	28,279,064		263,627	27,037,576		−0.053386
Average sum by year (sum/6)	41,650	4,713,177		43,938	4,506,263		

Eq. 14 is poorly described by Felder and Werblow [5]. From several papers [12–14], it is known that mortality-related health care expenditures are a decreasing function of age. We therefore include the interaction between age and mortalities (age $*\,\phi$) in our analysis. Furthermore, we cannot find any studies supporting the inclusion of mortalities to the power of two, three and four ($x = 2, 3, 4$). We therefore choose to only include mortality rate to the power of one ($x = 1$). The number of mortalities, due to compression of morbidity, increases for the highest age groups (see Table 2). We would therefore expect, as mortality related expenditures decrease with age, to observe a reduction in the mortality related expenditures over time. To capture the latter effect, we include the interaction between mortalities and time, which we expect to be negative:

$$\frac{\partial^2 \overline{Y}_g}{\partial\phi\partial t} = \lambda < 0. \tag{15}$$

Finally, we also include the yearly growth rate for all age groups (μ_z, $z = 0, 1, \ldots, 20$), to identify differences within the young. We are now left with the equation that forms the basis of our analysis:

$$\overline{Y}_g = \alpha + \beta * q + \sum_{z=0}^{20} \gamma_z * d_z + \theta * t + \kappa * \phi_g + \eta * \phi_g * a + \sum_{z=0}^{20} \mu_z * d_z * t + \lambda * \phi_g * t + \varepsilon_g \tag{16}$$

We note that the error terms in Eqs. 10–16 are heteroscedastic, due to variation in the size of the cells, N_g. We therefore weight the regressions by the number of inhabitants in each cell.

Results

This section will present estimations based on the methods presented in methods section. The share of the per capita health care expenditures used by the elderly (65+) does not increase over time (1998–2009) (Table 3). This holds even though we exclude the newborns. On the contrary, the share used by the younger group is highest in 1998. The estimation based on Eq. 1, therefore, does not support *steepening*. When running a regression on Table 3, equivalent to (8), we find a negative and significant effect

Table 3 The share of total health care expenditures spent on the elderly compared to the rest of the population

Year	Including all ages $\overline{Y}_{a\in[65,106],t}/\overline{Y}_{a\in[0,64],t}$	Excluding age zero $\overline{Y}_{a\in[65,106],t}/\overline{Y}_{a\in[1,64],t}$
1998	4.524	4.760
1999	4.204	4.346
2000	4.290	4.442
2001	4.334	4.483
2002	4.117	4.452
2003	4.113	4.431
2004	4.143	4.496
2005	4.164	4.510
2006	4.098	4.447
2007	4.159	4.567
2008	4.107	4.490
2009	4.239	4.648

when including all ages $\psi_1 = -0.021$. Furthermore, when excluding individuals <1 year of age, we find a positive, not significant effect $\psi_1 = 0.003$. Overall, the estimation effect based on (1) and (8) rejects *steepening*.

To identify *steepening* in Eqs. 10, 11, 14 and 16, the magnitude of the changes in mortality over time has to be identified. As discussed in the methods section, mortality rates are decreasing over time, i.e., there is a compression of mortalities (see Table 2). From the regression on (13), we find the effect to be small, significant, and negative ($\alpha_1 = -0.0000085$) (see Table 4). To also estimate the effect of changes in mortality rates over time in (14), i.e., mortality rate to the power of 1, 2, 3 and 4, we also included regressions with the mortalities to the power of 2, 3, and 4 as the dependent variable in Table 4.

Table 5 presents four regressions. The first is based on Eq. 14 in the "Methods" section. As expected, the age coefficient for the younger age group is low (below 25), apart from the 0-year-olds. The age coefficient peaks for the 70–75-year-olds. For the highest age groups, there is a decline compared with the age group 70–75. We may not reject *steepening* in this model based on the analysis:

$$\begin{aligned}\frac{\partial^2\overline{Y}}{\partial a\partial t} &= \mu + \frac{\partial^2\sum_{x=1}^{4}\kappa_x(\phi)^x}{\partial a\partial t} = \mu_z - \mu_{z\in\{1,10\}}\\ &+ \frac{\partial^2\sum_{x=1}^{4}\kappa_x(\phi)^x}{\partial a\partial t} = \mu_z - \mu_{z\in\{1,10\}} + 131415.8\\ &* (-0.0000085) + (-446127.2) * (-0.00000147)\\ &+ 640520.0 * (0.000000546) + (-310920.1)\\ &* (-0.000000336) > 0\end{aligned} \quad (17)$$

Within the group of older people (above 50), we find *steepening* for all age groups ($\mu_{z+1} - \mu_z > 0$) apart from

Table 4 Results from regression analysis based on Eq. 13

Dependent variable	Mortality rate (ϕ)		(ϕ^2)		(ϕ^3)		(ϕ^4)	
Independent variable	Coefficient	Std. er.	Coefficient	Std. er.	Coefficient	Std. er.	Coefficient	Std. er.
Age	0.000708***	(−0.00000256)	0.000126***	(−0.00000139)	0.0000502***	(−0.00000121)	0.0000327***	(−0.00000116)
Time	0.000129***	(−0.0000176)	0.0000274**	(−0.00000957)	0.0000106	(−0.0000083)	0.00000661	(−0.00000798)
Age × time	−0.00000850***	(−0.00000039)	−0.00000149***	(−0.000000212)	−0.000000546**	(−0.000000184)	−0.000000336	(0.00000017)
Constant	−0.0169***	(−0.000115)	−0.00339***	(−0.0000626)	−0.00140***	(−0.0000543)	−0.000922***	(−0.0000522)
N	995,158		995,158		995,158		995,158	
R^2	0.194		0.025		0.005		0.003	

the highest age group, above 90 ($\mu_{20} - \mu_{19} < 0$). Furthermore, the effect of mortalities[2] $\left(\frac{\partial \overline{Y}_g}{\partial \phi} > 0\right)$ is positive, and females have higher expenditures than males on average.

Second, the regression output based on Eq. 16 excludes mortalities. In this regression, the 0-year-olds have the highest yearly growth, of 2,700 NOK ($\mu_0 = 2700.4$). The second-highest yearly growth is found for the 80–85-year-olds, with 939.4. In comparison, the 5–9-year-olds have a yearly growth rate of 38.12. The annual growth for young individuals (i.e., below age 50) is lower than for those individuals age 50 or greater, that is, apart from the newborns. This does not reject *steepening* if newborns are excluded.

Third, the regression output based on Eq. 16 is presented, but now including the effect of mortalities, while excluding the interaction between time and mortalities. As expected, the effect of mortalities is positive, and as expected the mortality related cost is a decreasing function of age. Also, the age effect is slightly reduced here for each age group, implying that part of the expenditures for each age group is generated by mortalities. Especially for the highest age groups, there is a decline from a model excluding mortalities. The yearly growth rate for the different age groups are similar to the previous (second) results presented, and the same interpretation regarding *steepening* applies.

Finally, the results from running a regression on Eq. 16 both including the effect of the interaction of mortalities and time are presented. When the interaction of time and mortalities are included, the yearly growth rate is declining for all age groups, apart from the 1–4 group. The yearly growth for the 90+ was 976.4; after the inclusion of the interaction term it became 548.5, implying that part of the growth for the highest age groups is caused by increased mortality related costs over time ($\lambda = 2045.9$).

To summarize the results in Table 5, the first regression does not reject *steepening* (based on Eq. 14). In the following three regressions presented (based on Eq. 16), we can also not reject *steepening* if excluding individuals below age 1.

Conclusion and discussion

The first part of this paper clarified the connection between *steepening* and the *red herring hypothesis*. We concluded that the terms are independent. Furthermore, the data applied in this study is insufficient to test the *red herring hypothesis*. The reason for the data "insufficiency" is that the data do not contain information on time-to-death at the individual level. Therefore, the data may not reject the hypothesis as formulated by Zweifel et al. [3], i.e. (3) and (4).

The first part of this paper continued with summarizing causes mentioned in the literature that may induce *steepening*. In summary, the literature is limited and points at biological and technological factors.

The second part of this paper was to test *steepening*. *Steepening* was defined by Buchner and Wasem [4] in three dimensions: time, age and per capita health care expenditures. In these dimensions, the term states that health care expenditures should grow faster for older people than the rest of the population. In these dimensions, we find evidence of *steepening* with the exception of the 0-year-olds, i.e., Eq. 16, excluding mortalities. The method is similar to the method found in Felder and Werblow [5]. When using definitions (1) and (8), similar to the methods suggested by Buchner and Wasem [4], we find no evidence of *steepening*, including all ages. However, when excluding the individuals aged zero, we find a non-significant effect in (8) in favour of *steepening*. Our results are not directly comparable to Buchner and Wasem [4], as they only included individuals between 30 and 70 years of age in their study. Regardless of the age limits used, the latter model has little flexibility within the age groups (young and older), as there is only one dummy for each group. From Fig. 1, it is clear that per capita health care expenditures is not a linear function of age, and a model allowing for more variation is more appropriate. Overall, we therefore find the results based on Eq. 16, excluding mortalities, to be more reliable.

The second step in our empirical estimations was then to estimate what factors may drive the *steepening* effect. From several studies, among them Zweifel et al. [3] and Seshamani and Gray [25], mortalities are an important driver of health care expenditures. We would therefore expect the effect of *steepening* to be reduced in Eq. 16, including mortalities. In Table 5, it is shown that such a decrease does not occur. However, when including the interaction between mortalities and time, the *steepening* effect strongly declines, i.e., part of the *steepening* effect is driven by increased mortality-related expenditures over time.

Several implications follow from the results. First, as shown in several other studies (see, among others, [12, 26]) both mortality and age contribute to health care expenditures. Second, per capita health care expenditures are biased towards older individuals over time. Per capita health care expenditures for infants are increasing more than for the rest of the younger population. Third, if the observed trend continues, expenditures for older individuals are likely to increase substantially in the future (both

[2] $\frac{\partial \overline{Y}_g}{\partial \phi_g} = \kappa_1 + 2\kappa_2\phi_g + 3\kappa_3\phi_g^2 + 4\kappa_4\phi_g^3 = 131416 - 2 * 446127 * \phi_g + 3 * 640520 * \phi_g^2 - 4 * 310920 * \phi_g^3 > 0 \forall \phi_g.$

Table 5 Results from regression analysis based on Eqs. 14 and 16

Dependent variable per capita expenditures ($\overline{Y}_g$)

Equation	(14)		(16) Excluding mortalities		(16) Excluding the interaction between time and mortalities		(16) Including the interaction between time and mortalities	
Independent variable	Coefficient	Standard er.	Coefficient	Standard er.	Coefficient	Standard er.	Coefficient	Standard er.
Year (t) $t = 0$ if year = 1998 $t = 1$ if year = 1999 … $t = 11$ if year = 2009 (θ)	142.1***	(2.024)						
$t \times$ age (μ)								
$t \times$ age 0			2,700.4***	(14.75)	2,731.0***	(14.39)	2,725.1***	(14.38)
$t \times$ age 1–4			76.86***	(7.365)	82.03***	(7.184)	81.43***	(7.181)
$t \times$ age 5–9			38.12***	(6.545)	38.74***	(6.384)	38.52***	(6.381)
$t \times$ age 10–14			44.18***	(6.598)	45.24***	(6.436)	45.02***	(6.433)
$t \times$ age 15–19			58.88***	(6.699)	62.99***	(6.534)	62.24***	(6.531)
$t \times$ age 20–24			53.80***	(6.751)	58.96***	(6.584)	57.71***	(6.581)
$t \times$ age 25–29			56.33***	(6.454)	58.06***	(6.295)	56.65***	(6.292)
$t \times$ age 30–34			97.25***	(6.250)	101.9***	(6.096)	100.4***	(6.093)
$t \times$ age 35–39			130.4***	(6.152)	136.8***	(6.001)	135.0***	(5.999)
$t \times$ age 40–44			147.7***	(6.202)	155.7***	(6.049)	153.1***	(6.047)
$t \times$ age 45–49			164.5***	(6.401)	173.0***	(6.243)	168.9***	(6.242)
$t \times$ age 50–54	51.53***	(6.710)	183.3***	(6.454)	195.5***	(6.295)	188.6***	(6.296)
$t \times$ age 55–59	115.2***	(7.236)	243.0***	(7.008)	259.7***	(6.836)	249.3***	(6.842)
$t \times$ age 60–64	247.9***	(7.741)	371.8***	(7.537)	393.0***	(7.352)	375.7***	(7.372)
$t \times$ age 65–69	368.6***	(8.509)	476.6***	(8.336)	509.2***	(8.132)	481.4***	(8.182)
$t \times$ age 70–74	552.0***	(9.058)	625.7***	(8.901)	682.4***	(8.685)	636.8***	(8.816)
$t \times$ age 75–79	741.8***	(9.417)	790.2***	(9.268)	862.5***	(9.045)	783.7***	(9.421)
$t \times$ age 80–84	819.3***	(10.61)	867.9***	(10.49)	948.9***	(10.24)	811.9***	(11.23)
$t \times$ age 85–89	866.5***	(13.28)	939.4***	(13.22)	1,021.8***	(12.90)	787.4***	(15.12)
$t \times$ age 90+	778.4***	(18.61)	913.5***	(18.64)	976.4***	(18.19)	548.5***	(23.19)
Gender (q)	197.4***	(11.55)	−92.59***	(11.58)	222.7***	(11.38)	222.7***	(11.37)
Age (γ)								
0	23,927.5***	(57.03)	9,705.0***	(107.8)	8,761.0***	(105.3)	8,783.9***	(105.3)
1–4	Reference		Reference		Reference		Reference	
5–9	−1,554.6***	(33.81)	−1,368.4***	(63.77)	−1,283.1***	(62.20)	−1,285.0***	(62.18)
10–14	−1,847.8***	(33.81)	−1,678.6***	(64.59)	−1,592.9***	(63.00)	−1,594.7***	(62.97)
15–19	−1,093.4***	(34.23)	−962.8***	(65.62)	−960.5***	(64.00)	−959.7***	(63.97)
20–24	−80.42*	(34.49)	96.26	(65.16)	35.33	(63.55)	38.47	(63.52)
25–29	956.1***	(33.83)	1,108.1***	(63.06)	1,063.5***	(61.51)	1,067.2***	(61.48)
30–34	1,368.6***	(33.09)	1,306.3***	(62.16)	1,252.2***	(60.63)	1,256.5***	(60.61)
35–39	1,011.4***	(32.89)	799.1***	(62.62)	706.4***	(61.08)	713.0***	(61.05)
40–44	985.8***	(33.17)	722.4***	(63.06)	569.6***	(61.51)	580.1***	(61.48)
45–49	1,760.5***	(33.55)	1,496.4***	(63.69)	1,240.6***	(62.13)	1,258.7***	(62.10)
50–54	2,807.8***	(50.25)	2,885.2***	(63.74)	2,453.2***	(62.20)	2,486.0***	(62.19)
55–59	4,405.1***	(54.24)	4,731.7***	(66.91)	4,076.6***	(65.34)	4,127.6***	(65.33)
60–64	6,089.4***	(59.61)	6,813.5***	(71.24)	5,831.2***	(69.64)	5,919.5***	(69.68)
65–69	8,264.0***	(62.92)	9,649.5***	(73.68)	8,200.5***	(72.18)	8,347.5***	(72.31)

Table 5 continued

Dependent variable per capita expenditures ($\overline{Y}_g$)								
Equation	(14)		(16) Excluding mortalities		(16) Excluding the interaction between time and mortalities		(16) Including the interaction between time and mortalities	
Independent variable	Coefficient	Standard er.	Coefficient	Standard er.	Coefficient	Standard er.	Coefficient	Standard er.
70–74	10,326.0***	(64.89)	12,811.1***	(74.42)	10,679.8***	(73.21)	10,929.5***	(73.66)
75–79	11,538.5***	(68.44)	15,688.1***	(75.63)	12,646.0***	(74.99)	13,081.9***	(76.37)
80–84	10,803.2***	(79.57)	17,176.7***	(83.18)	13,006.6***	(83.41)	13,767.3***	(87.20)
85–89	8,676.3***	(101.8)	17,490.2***	(101.3)	12,186.2***	(103.3)	13,499.3***	(112.3)
90+	4,508.2***	(141.9)	14,703.5***	(136.1)	9,302.3***	(145.1)	11,712.1***	(166.1)
Mortality rate (κ)	131,415.8***	(871.7)			297,704.7***	(1,759.7)	289,556.8***	(1,780.1)
Mortality rate^2	−446,127.2***	(7,069.6)						
Mortality rate^3	640,520.0***	(16,487.0)						
Mortality rate^4	−310,920.1***	(10,454.6)						
Age × mortality rate (η)					−2,932.4***	(19.91)	−2,966.2***	(19.93)
Mortality rate × t (λ)							2,045.9***	(68.79)
Constant (α)	2,053.2***	(32.60)	2,881.3***	(50.74)	2,291.4***	(49.57)	2,294.2***	(49.55)
N	995,158		995,158		995,158		995,158	
R^2	0.605		0.598		0.618		0.618	
Adjusted R^2	0.605		0.598		0.618		0.618	

due to increased expenditures towards elderly in general and increased expenditures for decedents [based on Table 5, last regression]). However, the implication of the results with regard to predictions of future health care expenditures should be interpreted with care until to the mechanisms that drive *steepening* are detected.

The only health care service included in this study is inpatient in somatic hospitals; this is a limitation to this study. If there is a substitution effect between different health care services, excluding other services could potentially lead to biased results. It may be plausible that *steepening* is observed for inpatients, but the opposite effect is observed in other health care services. Additional research should therefore take place in other parts of the health care sector in order to confirm *steepening* outside inpatient care.

The use of DRG-cost weights to measure expenditure enables the study to investigate costs for different age and gender groups over time. There are, however, some limitations associated with using DRGs as a proxy for costs. DRG-cost weights are the expected cost of a treatment for the average patient and not the actual cost. As mentioned by Melberg et al. [12], elderly individuals have poorer health than the average patient, and the cost for this group might therefore be underestimated. Conversely, for other healthier groups, the use of DRG-weights may have overestimated actual costs.

In summary, our results clearly do not reject *steepening* in per capita health care expenditures over time for the 50+ age group, with the exception of 0-year-olds. Mortality-related expenditures also increase over time, and the effect of *steepening* is reduced when this effect is taken into account.

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IV