

DSI Institut for Sundhedsvæsen

DSI rapport 2006.01

The lifetime costs of smoking and smoking cessation

PhD thesis

Susanne Reindahl Rasmussen



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2005

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Januar 2006



DSI Danish Institute for Health Services Research

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ISBN 87-7488-407-7 (printed version)
ISBN 87-7488-409-3 (electronic version)
ISSN 0904-1737
DSI Rapport 2006.01

Graphics production: Frederiksberg Bogtrykkeri A/S

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Abbreviations

ATC	Anatomical Therapeutical Chemical Classification System
CEA	Cost effectiveness analysis
CHD	Coronary heart disease
COI	Cost-of-illness approach
COPD	Chronic obstructive pulmonary disease
CPS-I Study	Cancer Prevention Study I
CPS-II Study	Cancer Prevention Study II
CVD	Cardiovascular diseases
DIKE	Danish Institute for Clinical Epidemiology
GPs	General practitioners
HCFA	Health Care Financing Administration
ICD-10	International classification of diseases - version 10
ICPC	Wonica's International Classification of Primary Care
LPR	The Natinal Register of Patients
NordDRG	Nordic diagnosis-related groups
PAR%	Population attributable risk per cent
RR	Relative risk estimates
WTP	Willingness-to-pay approach

Preface

For snart 10 år siden viste en hollandsk undersøgelse, at rygere hvert år de levede kostede op til 40 procent mere i sundhedsudgifter end ikke-rygere. Men fordi ikke-rygerne lever længere, så var ikke-rygerne over hele livet ca. 15 procent dyrere i sundhedsudgifter end rygerne. På trods af at undersøgelsen var publiceret i *New England Journal of Medicine*, troede vi simpelthen ikke på resultaterne. Derimod syntes vi, at det var et fremskridt at se og opgøre rygeomkostninger i et livsperspektiv i forhold til den mere statiske opgørelse af rygeomkostninger, som ikke tager højde for forskellen i levetid mellem rygere og ikke-rygere.

Susanne Reindahl Rasmussen har som den første i Danmark brugt den dynamiske livstidsmetode til at estimere sundhedsrelaterede omkostninger ved en bestemt livsstilsfaktor – her rygning. Metoden er både data- og arbejdskrævende, og nærværende arbejde har nok haft et rigere datagrundlag end det oprindelige hollandske. Susanne Reindahl Rasmussens resultater tilbageviser klart det hollandske resultat: Rygning er dyrt for sundhedsvæsenet som følge af større behandlingsbehov og for samfundet som følge af mere sygefravær og sygdomsbetinget arbejdsophør. Afvigelsen i forhold til det hollandske arbejde forklares ikke af forskelle mellem de to lande men af et bedre og bredere datagrundlag i Danmark, og ikke mindst af meget omfattende og detaljerede risikoestimer fra Eva Prescotts disputats.

Vi tror ikke, at dette sundhedsøkonomiske arbejde vil revolutionere sundhedsfremmeindsatsen på tobaksområdet. Det er trods alt sundhedseffekten, der er vigtigst. Men netop derfor er det vigtigt at få fastslået, at sundhedsøkonomi og sundhedseffekt også her trækker i samme retning. Derfor har Susanne Reindahl Rasmussen fortjent ph.d.-graden ikke kun af akademiske grunde men også af sundhedspolitiske grunde.

Så tak og tillykke til Susanne Reindahl Rasmussen for det flotte arbejde og for ph.d.-graden. Først og fremmest en tak til vores vejlederkollega dr.med. Eva Prescott, som har ydet en stor vejlederindsats og derudover stillet sit store datamateriale til rådighed. Tak også til økonomisk konsulent Per Lunde-Jensen for udlån af arbejds papirer til beregning af sygedage og til medicinsk skribent Niels Neymark for hjælp med oversættelse af dele af teksten til engelsk og sproglig tilretning af resten. Tak til bibliotekar Trine Okholm for en utrolig hjælpsomhed med at fremskaffe de store mængder af litteratur. Også tak til de mange andre, der har støttet arbejdet på forskellig vis både i og uden for de to involverede institutter.

Statens Sundhedsvidenskabelige Forskningsråd (nr. 9901111 kg/mg) og DSI Institut for Sundhedsvæsen har finansieret arbejdet med ph.d.-afhandlingen.

Til sidst vil vi udtrykke et håb om, at afhandlingen vil kunne bruges både i debatten og i det videre analysearbejde af tobakspolitik i Danmark.

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Summary

In Western societies, where smoking has been common for decades, it has become clear that this has serious health damaging consequences. Epidemiological studies have documented that cigarette smoking is positively associated with many types of cancers, cardiovascular diseases, and respiratory diseases. To this should be added that several studies have shown that smoking cessation has substantial positive effects, immediate as well as long-term, on the health of both men and women of all ages. Although smoking cessation and non-smoking is desirable from a public health policy perspective, the consequent impact on societal costs is controversial. Several studies have shown that smoking leads to considerable societal costs each year, but the existing economic findings are not clear, when costs are determined over a lifetime and the shorter expected lifetime of smokers is taken into account. The objectives of this thesis are therefore:

1. To determine the societal costs of smoking in Denmark on the basis of comparative estimates of the lifetime direct health care costs of never-smokers and smokers (current smokers and ex-smokers) and estimates of the productivity costs due to the excess morbidity and premature mortality.
2. To determine the potential reduction of these societal costs that would result from smoking cessation based on comparative estimates of the lifetime direct health care costs of ex-smokers and those continuing to smoke and estimates of the reduction of productivity costs due to smoking cessation.

The thesis builds on three fundamental components: 1) population attributable risk percentages, estimated based on Danish data for the prevalence of smoking (PLS Consult (1999)) and Danish data on the relative risks of smoking (Prescott et al. (1998)), 2) the cost-of-illness, and 3) Danish survival probabilities (Statistics Denmark (1998/1999)).

The studies include present and future smoking-related medical health care costs and present and future unrelated medical health care costs determined on the basis of data from public registries, plus productivity costs due to morbidity, disability and mortality. The annual frequencies and the determination of the costs of different health care services are based on the following Danish registers and sources; hospital stays and ambulatory treatment and costs of this (The Danish Ministry of Health and National Board of Health; DRG-tariffs (1999)); consultations with and costs of general practitioners and physiotherapists (a multi-centre study from the county of Århus

(1997) and The National Health Security System (1999)); and the consumption of pharmaceuticals and the cost of this (The Danish Medicines Agency (1999)). The productivity costs are estimated based on data regarding: mortality (The National Register of Causes of Deaths (1999)), early retirement benefits (The Social Appeals Board (1999)), and sickness absences (The Danish Working Environment Authority (1995) and Statistics Denmark (1999)). The determination of the value of the lost production includes data on annual incomes, frequencies of employment and rates of participation in the labour force (Statistics Denmark (1997 and 1999)).

Study 1: Based on a determination of the annual costs for 1999, the average direct health care costs and productivity costs for ever-smokers (ex-smokers and those continuing to smoke) exceed those of never-smokers, regardless of gender and age-group. When the differences in expected lifetimes between smokers and never-smokers are taken into account and a discount rate of 5% is applied, the lifetime direct health care costs and lifetime productivity costs, respectively, of 35-years old ever-smoking men are 66% and 83%, respectively, higher than those of never-smoking men. For women, the corresponding excess costs of smokers are 74% and 79%, respectively. These results are not sensitive to a rather wide range of values of relative risks and discount rates (0%, 3% and 8% per year) examined in sensitivity analyses. However, the excess costs of smokers vanish under the extreme assumption that smoking attributable diseases are limited to cancers, cardiovascular diseases and respiratory diseases, provided that no discounting of future costs is performed.

Study 2: The total reduction of lifetime health costs following from smoking cessation is biggest for the youngest age groups. The reduction of costs vary by the person's age at the time of quitting smoking, daily consumption, and gender, but for all ex-smokers, who quit smoking between the age 35 and 55, smoking cessation engenders a substantial reduction of health care costs estimated over the lifetime and discounted at 5%. In moderate smokers who quit smoking at the age of 35, the estimated reductions of lifetime total health care costs, lifetime direct health care costs and lifetime productivity costs, respectively, are 184,500 DKK, 56,700 DKK, and 127,800 DKK in men. The corresponding cost reductions for women are 253,600 DKK, 90,900 DKK, and 162,700 DKK, respectively. Applying alternatively a discount rate of 8%, the reduction of lifetime healthcare costs following smoking cessation becomes considerably smaller, but the reduction of direct health care costs is still sizable for ex-smokers who quit between 35 and 50 years of age. But, when a discount rate of 8% is applied, the reduction of productivity costs becomes minimal for smokers who quit at age 45 or older.

It should be noted for both studies that the estimated direct related and unrelated medical health care costs of smoking should be considered con-

servative, because the estimations do not include all smoking-related costs. This implies that not only the lifetime direct medical health care costs for never-smokers, but also for ex-smokers and those continuing to smoke are underestimated. The relative difference between the lifetime direct health care costs for ever-smokers and never-smokers is considered a good estimate of the order of magnitude of the real difference. The relative difference between the lifetime direct health care costs for ever-smokers and ex-smokers must, however, be considered slightly overestimated, while the lifetime productivity costs, if accepted estimated by the human capital method most likely are underestimated for all groups; ever-smokers, ex-smokers, and never-smokers. This is primarily because this approach does not include unpaid work and activities.

1. Introduction

1.1 Background

In Western societies, where cigarette smoking has been common for decades, smoking is the major preventable cause of disease and accounts for a substantial proportion of premature deaths (1;2). Epidemiological studies have demonstrated that cigarette smoking is positively associated with the occurrence of a wide range of diseases, including several types of cancers and cardiovascular and respiratory diseases. Even though smoking may conceivably provide a certain protection against various diseases, this effect is minuscule compared to smoking-related morbidity and mortality (3;4). In Denmark smoking-related deaths constituted in 1995 about 30% of all deaths of both men and women between 35 and 69 years of age (5). Worldwide, smoking-related yearly mortality is predicted to rise, if current smoking-patterns persist, from about four million deaths in 1998 to ten million deaths by 2030 (2).

However, several studies have shown that smoking cessation has major, both immediate and long-term, health benefits in men and women of all ages (6). Although non-smoking is desirable from a public health perspective,¹ the likely impacts on health care costs are controversial. Several studies have shown that, estimated on an annual basis, smoking imposes substantial health-related economic costs on society (8;9). In my dissertation for the masters degree, I estimated in a cost-of-illness (COI) analysis that the annual costs of smoking in Denmark amounted to 7,400 million DKK in 1995. This estimate included 3,800 million DKK in productivity costs, estimated by the human capital approach. In the COI analysis, population attributable risk per cents (PAR%) based on, respectively, English and Danish mortality risk estimates (RR), were used. Contrary to this, a public cash flow analysis showed a public net revenue of about 3,900 – 5,600 million DKK (10).

When the costs of smoking are estimated by means of a dynamic life cycle approach, the economic findings become less clear, however. Two studies show that smokers incur higher health care costs than non-smokers over a lifetime horizon (11;12), while three other studies show the opposite result (13-15). Only few studies have attempted an estimate of the economic impact of smoking cessation in a lifetime perspective, and the results are ambiguous and uncertain. An American study by Oster, Colditz and Kelly reports that average lifetime costs, estimated as the combination of direct health care costs and productivity costs, among smokers who quit smoking are substantially reduced compared to those of continuing smokers for all

¹ In this connection it is important to remark that stimulating smoking cessation is a part of the Danish Government Programme on Public Health and Health Promotion (7).

groups of smokers, but they do not take differences in life expectancy into account (16). A Dutch study conducted by Barendregt et al. did include life expectancy and reported 15% higher lifetime direct health care costs in non-smokers (never-smokers and ex-smokers) than in smokers, and indicate that interventions to reduce or prevent smoking are unattractive in a narrow economic sense (13). The estimations by Barendregt et al. included only direct health care costs, limited the smoking-related diseases to five groups and assumed that the costs of all other diagnoses were independent of smoking status. I believe, and this is my major contention, that these assumptions effectively imply that Barendregt et al. underestimate the lifetime direct health care costs of smoking.

1.2 Aims

On this background, the aim of the present PhD thesis is to determine the socioeconomic consequences of the health effects of smoking in Denmark from a societal perspective by applying a dynamic life cycle approach to estimation. The calculations are based on national data from the health care authorities and comprise the direct cost of medical health care and the value of productive output lost due to morbidity, disability and premature mortality. I have performed two studies taking life expectancy into account. In the first study, I compare the direct health care costs and productivity costs of ever-smokers (ex-smokers and those continuing to smoke) and never-smokers over their lifetime horizon. In the second study, I examine the effect of smoking cessation by comparing the lifetime direct health care costs and productivity costs of ex-smokers and of smokers that continue to smoke. A broader array of smoking related diseases than in previous studies is included (13;16), and I perform sensitivity analyses to examine whether the results are robust under a range of assumptions.

Excluded costs

In this thesis, the intangible costs of smoking (e.g. insecurity, fear and pain due to smoking related morbidity and mortality) have not been estimated in pecuniary terms, as there are not sufficient valid data available in Denmark for these cost items. Just as the benefits to smokers of tobacco consumption have not been included. Even though some smokers probably enjoy smoking, an attempt at quantifying such benefits that to some extent would offset costs would be purely speculative and I have therefore refrained from this.

The thesis is based on two studies:

1. The total lifetime costs of smoking.
2. The total lifetime health costs saving to society of smoking cessation.

The first study (Study I, Appendix R) is published in the *European Journal of Public Health* in 2004 (17) and the second study (Study II, Appendix S) is published in the *European Journal of Public Health* in 2005 (18).

2. Review of the literature

2.1 Health effects of smoking

The application of population attributable risk per cents (PAR%), based on the relative risks of smoking (RR) (cf. the methods section), is a principal element of the calculations performed for this thesis. It is therefore considered appropriate to perform a survey of the literature on the health effects of smoking.

In 1989, a report from the US Surgeon General summarized the findings on the health consequences of smoking, and it was found that smoking causes both cancer as well as cardiovascular and respiratory diseases (19). In addition, it was concluded that involuntary exposure to tobacco smoke is a cause of disease, in unborn children and in healthy non-smokers, and that children, whose parents smoke, have an increased frequency of respiratory infections and symptoms (19). The medical evidence on the substantial health-related damages attributable to smoking continues to accumulate (2), and cigarette smoking has now been found to have a positive association with some 40 diseases or causes of death (20), reduced life expectancy (21-23) and increases in the expected part of life spent in poor health (24). In the following review, the evidence obtained from epidemiological studies is described with emphasis on smoking-related overall mortality and on mortality and morbidity in the principal groups of diseases associated with active smoking: cancers, cardiovascular diseases, and respiratory diseases.

2.1.1 Life expectancy and overall mortality

In general, never-smokers have a longer expected lifetime than current smokers (21-23;25;26). Data from high income countries suggest that about half of current smokers with a long history of smoking will die of tobacco related diseases and about half of these die as middle-aged, thus losing some 20 to 25 years of expected lifetime as compared with non-smokers (27). In a British study, it has been estimated that continuing to smoke reduces the life expectancy of 20-years old smokers by 4.25 years (28). Similarly, a Danish study found that the expected lifetime of 35 years old female heavy smokers (≥ 15 cigarettes / day and inhaling the smoke) is reduced by 9.4 years compared to the life expectancy of never-smokers, while for female light smokers (< 15 cigarettes / day, inhaling) the estimated reduction is 7.4 years. The corresponding estimated reductions for Danish men are 9.2 and 6.0 years, respectively (22).

Some prospective epidemiological studies have shown that the overall mortality rates for smokers continuing to smoke were approximately twice those for never-smokers (26;29-31). An American study compares the mortality

rates among cigarette smokers over a 20 years period from the mid-1960s through the early 1980s. From this, it appears that the overall mortality rate among middle-aged men in the Cancer Prevention Study II (CPS-II Study) was about three times higher for smokers than for never-smokers, while the increase in the mortality rate for smokers observed in the Cancer Prevention Study I (CPS-I Study) was a doubling (32;33). Similar results have been shown in a 40-year follow-up study carried out in male British doctors over two 20-year periods, 1951-1971 and 1971-1991 (21). This may be an indication of a true increase in relative risks, but both these studies found that the increase over time in the relative risk of smoking was primarily caused by a substantial decrease in age-specific mortality of non-smokers.

Danish age-specific mortality rates reported for male smokers continuing to smoke (26) were close to those observed among the British doctors (21) and a little higher than those observed in the CPS-II Study (34). In women, the Danish age-specific mortality rates (26) were higher than those found in the CPS-II Study (34). However, data from the study by Prescott et al. (35) do not indicate that such a mortality decrease occurred for Danish never-smokers over this period, neither with regard to all-cause mortality nor with respect to the major disease groups (cancers, cardiovascular diseases, and respiratory diseases), whether for men or women (personal communication from Prescott). And consequently, there has not been found an increase over time in the all-cause mortality RR-estimates for Danish men, among whom the prevalence of smoking remained uniformly high throughout the study period from 1964 to 1994 (35). As a reservation it should be noted, though, that these data are only adjusted for age, inhalation, study population, and cohort effect. According to Prescott et al., a possible explanation for this lack of change in the RR-estimates for Danish male smokers could be that the smoking epidemic had already 'matured' among Danish males, reflecting the fact that the average male smoker's exposure to tobacco did not change over this period. Another possible explanation is that, as a large number of subjects quit smoking during the study period both in the American and, perhaps particularly, in the British study population, the population of remaining smokers might be particularly unhealthy (35).

From the CPS-II data, it has been shown that for male former smokers of one pack per day or less, the mortality risk was reduced to that for never-smokers about 16 years after they quit smoking, while it remained elevated for former smokers of more than one pack per day. For female former smokers, mortality was similar to that of never-smokers after 16 years of abstinence for both smoking categories (6). These results from the CPS-II Study are in broad agreement with those of the British Doctors Study (21) and the US Veterans study (31). In both, it was found that the overall mortality risk for former smokers remained elevated compared to that of never-smokers up to 15 years after quitting, while it was substantially smaller than the over-

all mortality risk for those continuing to smoke. Subjects, who quit smoking before the age of 35, had a survival pattern that did not differ significantly from that of never-smokers (21).

2.1.2 Cancers

Cigarette smoking is associated with an increased risk of cancers, including cancer of the mouth, pharynx, oesophagus, pancreas, larynx, lung, bladder (4;19;21;36-39), and stomach (19;21;40;41). A review of cancers weakly related to smoking indicates that cigarette smoking also is a cause of some cancers of the kidney, liver and nose, and also of some myeloid leukaemias (42). It has been estimated that in the developed countries in 1995, 46% and 14% of male and female cancer deaths, respectively, were attributable to tobacco smoking (34). In 1999, 26% of all death in Denmark were caused by cancer; and lung cancer made up 22% of all cancer deaths (43). The mortality risk of lung cancer of smokers has been estimated to be 3-25 fold the risk of non-smokers, and it has been shown that risk increases with the duration (44;45) and amount of smoking (19;21;26;36;38;46). A Danish study estimated the mortality risk of lung cancer of smokers to be 9-25 fold that of never-smokers (26). From CPS-I Study to CPS-II Study, there was among cigarette smokers nearly a doubling of the lung cancer death rate of males and almost a sixfold increase of that of women (33), whereas the lung cancer death rate for male smokers increased by 20% from the first to the second period of the British Doctors Study (21). In both the American and the British study, the lung cancer death rates for non-smokers (never smoked regularly) remained essentially constant (21;33).

People, who quit smoking, even well into middle age, avoid most of their subsequent risk of lung cancer, and those quitting earlier than middle age avoid more than 90% of the risk attributable to tobacco smoking (47). Former smokers show, 10 to 20 years after quitting, varying extents of risk reduction compared to never-smokers. Results from the British Doctors Study, the US Veterans Study, and the CPS-II Study show that 15 years or more after quitting, former smokers have a risk reduction of 80-90% compared to those continuing to smoke (6). The percentage risk reduction was slightly lower in a Japanese cohort study and higher in CPS-I Study (6). The report from the US Surgeon General concludes that compared to continuing to smoke, smoking cessation halves the risk of bladder cancer in only a few years and that of cancers of the oral cavity and the oesophagus in about 5 years. For pancreatic cancer, the rate of risk reduction after smoking cessation is slower and may only be measurable 10 years after or later (6).

2.1.3 Cardiovascular diseases

Despite decreases in mortality of cardiovascular diseases (CVD), in Denmark as well as in several other Western countries (21;43;48), CVD is one of the most common causes of death for both men and women in the OECD

countries (48). In Denmark, 25% of all deaths in 1999 were caused by CVD (43).

It is well established that cigarette smoking increases the risks of cardiovascular diseases, including the main form coronary heart disease (CHD) (21;26;36;38;49), cerebrovascular disease (4;19;21;26;36;50), atherosclerosis (4;21), and aortic aneurisms (4;19;21;38).

The relative risk of CHD associated with smoking increases with the number of cigarettes smoked per day (21;26;36;38) and with the duration of smoking (51;52). In the Danish study it was shown that the age-adjusted relative risk of cardiovascular disease increased significantly (at the 0.1% level) for both men and women, when testing for a linear trend according to quantity consumed. With the risk for never-smokers set equal to 1, the estimates for light smokers (<15 gram tobacco / day) become RR = 1.6 for men and RR = 1.8 for women, while those for people smoking more than this become RR = 1.7 for men and RR = 2.0 for women. However, it also appears that the age-adjusted relative risk of cardiovascular disease was equal for men smoking 15-24 gram tobacco per day and for men smoking 25 gram tobacco or more per day, with almost entirely overlapping 95% confidence intervals (26). This finding is probably due to the relatively limited size of the study. From the CPS-II Study, it appears that over the period 1982-86 the age-adjusted relative risks of CHD were 2.81 and 3.00 for men and women, respectively, in the age group from 35 to 64 years old, while from age 65 and up the risks were 1.62 and 1.60 for men and women, respectively (19). Between the CPS-I and CPS-II Study, current smokers' relative risk of death from CHD compared to never-smokers' increased from 1.7 to 1.9 in men and from 1.4 to 1.8 in women (33). Similar findings appear in the British Doctors Study (21). The increase in the relative risk of CHD for current smokers compared to never-smokers observed between the CPS-I and CPS-II Study occurred despite a general fall in the CHD risk over the period. Although the CHD death rates of current smokers in the CPS-II Study were generally lower than those of never-smokers in the CPS-I Study, the CHD death rates for never-smokers in proportionate terms fell more rapidly over the period than those of current smokers (33).

In a meta-analysis of relation between cigarette smoking and stroke, the relative risk of stroke for smokers compared to never-smokers was found to be 1.43 in men and 1.72 in women (53). Just as was the case for CHD, the fall in the death-rate of stroke for non-smokers between the CPS-I and CPS-II Study was proportionately larger than the fall for current smokers, and consequently an increase in the relative risk for smokers compared to never-smokers was observed, from 1.3 to 1.9 and from 1.2 to 1.8, respectively, in men and women, respectively (32). In the CPS-II Study, the age-specific relative risk of death of stroke of current smokers compared to never-smokers

followed a non-monotonic pattern in men, decreasing from age 54, while for women it fluctuated somewhat before decreasing consistently after age 74 (54). The meta-analysis mentioned above showed considerable differences in relative risks, for instance: cerebral infarction 1.9, cerebral haemorrhage 0.7, and subarachnoid haemorrhage 2.9 (53).

Within one to two years after smoking cessation, the excess risk of CHD for former smokers is reduced by 25-50% compared to those continuing to smoke. After this time, the decline is more gradual and the risk level of never-smokers is attained 10-15 years after smoking cessation. Estimates of the time period of smoking abstinence required for the excess risk of stroke in former smokers to be attenuated and reach the risk level of never-smokers vary between less than five years and more than 15 years (6;55). Even for persons with already diagnosed CHD, quitting smoking reduces the risks of re-infarction and cardiovascular death by some 50% or even more (6;56).

2.1.4 Respiratory diseases

Smoking markedly increases the risk of developing and dying of respiratory diseases, principally chronic obstructive pulmonary disease (COPD) (19;21;57), pneumonia (21), chronic bronchitis and emphysema (19;31;38). In Denmark, 10% of all deaths in 1999 were caused by respiratory diseases (43).

In the Danish Study, the age-adjusted relative risk of respiratory disease was 4.2 for light smoking men (<15 gram tobacco / day) compared to never-smoking men and 4.8 for heavily smoking men (\geq 15 gram tobacco / day). The corresponding relative risk estimates for women were higher, 7.5 in light and 12.5 in heavy smokers, respectively, but a statistical test of the difference in the RR-estimates for men and women did not find them significantly different at the 5%-level ($p = 0.09$) (26). Both in the British doctors Study and in the CPS-II Study, there was a resemblance between COPD and lung cancer, because for both there was a very wide divergence between the death rates of smokers and non-smokers (21;54). In the CPS-II Study, the age-specific relative risk of COPD fluctuated somewhat erratically between 8.1 and 18.9 and between 9.5 and 14.7, respectively, for currently smoking men and women, respectively, compared to non-smokers in each case (54). Analogous to the pattern observed for lung cancer, there was an increase between the CPS-I and CPS-II Study in the age-specific death rates of smokers compared to non-smokers, in almost every age group for women and for men from age 65 and up (54).

Former smokers have lower risks of emphysema and bronchitis (6;31) and of dying of COPD (6;21;58) than those continuing to smoke. In a report from the US Surgeon General, it was shown that, despite an initial rise in COPD mortality right after smoking cessation, the COPD mortality rates drop with

increasing time since cessation, but even 20 years after quitting smoking former smokers still have a higher risk of dying from COPD than non-smokers (6).

2.1.5 'Other diseases'

Smokers are also at higher risk for a variety of other diseases than cancers, cardiovascular diseases, and respiratory diseases. The US Surgeon General report from 1979 stated that the relationship between the occurrence of peptic ulcer disease and cigarette smoking is sufficiently clear to suggest a causal relation (59). Furthermore, it has consistently been demonstrated by epidemiological studies that current smokers are at increased risk compared to non-smokers of dying from duodenal and gastric ulcers. For these causes of death, it is generally found that the risks of former smokers are intermediate between those of non-smokers and of those continuing to smoke (59). The CPS-II Study found that the relative risk of dying from peptic ulcer was 4.0 and 4.6 for current smoking men and women, respectively, compared to never-smoking men and women (20). In the US Veterans Study, the mortality ratio from duodenal ulcer for current smokers were 3.6 compared to non-smokers (31).

In recent years, it has been shown that smoking also increases the risks of several other diseases. For instance does it appear from a recent review that prospectively, the increased risk for diabetes in smoking men and women is around 50%. Furthermore, cigarette smoking increases the risk for diabetic nephropathy, retinopathy, and neuropathy in many patients with type 1 and type 2 diabetes mellitus (60). In another review of the literature on smoking and diabetes it was concluded that smoking increases the risk of death from macrovascular complications in individuals with diabetes (61).

Several studies have examined the possible effect of tobacco smoking on bone mineral density and the risk of hip fracture in women. A meta-analysis of studies reporting the difference in bone density concluded that post-menopausal bone density loss is greater in smokers than in non-smokers and that tobacco smoking increases the lifetime risk of hip fracture in women by about 50%. This analysis showed that smoking has no effect on risk at age 50, but that smokers compared to non-smokers have an increase in the risk of hip fracture of 17% at the age of 60, 41% at age 70, 71% at age 80, and 108% at age 90 (62). Furthermore, two studies that recorded the number of fractures in older men as well as those in women suggest that the effect of smoking on the risk of hip fracture is increased for both men and women (63;64). A similar result appears from a Danish Study (65) published later.

Smoking mothers imposes major risks on their children, not only in terms of pre-term births low birth weight (66-69) and peri-natal and neo-natal deaths

(66;68-72), but also with regard to certain malformations (cleft lip / cleft palate, limb defects etc.) (73).

The risk of a number of other conditions is increased among smokers compared to non-smokers. These conditions include, but are not limited to: periodontitis (74), about 50% of periodontal disease in young adults is attributable to cigarette smoking and postoperative results in smokers with periodontal disease are considerably poorer than those achieved in non-smokers (75), cataracts; heavy smokers have a risk of up to three times the risk of non-smokers of nuclear, posterior subcapsular, and mixed opacities as non-smokers (76-80), and facial wrinkling (81;82). While not necessarily life-threatening, these conditions can have considerably socioeconomic impacts.

Finally, smokers also have higher utilization rates and expenditures for coexisting diseases not related to smoking, i.e. smoking is considered to be a risk factor for patients undergoing surgery and anesthesia. Smoking is a risk factor for intra-operative pulmonary and cardiovascular complications (83;84) and a wide range of postoperative pulmonary, cardiovascular (85-88), infection and wound-related complications (86;89-91). Furthermore, smoking increases admission to the intensive care unit (92;93) and apparently also the in-hospital mortality (93).

2.2 Economic consequences of smoking

In most cases, statements to the effect that smoking imposes a large cost burden on society are based on estimates of the economic costs over a period of time. The World Bank (94) suggests that in high-income countries, smoking causes an estimated 6-15% of total health care costs per year. The general economic impact of tobacco smoking is, however, a controversial issue and widely divergent results are reported. This is partly because of the heterogeneous approaches to estimation used, partly because the data of the studies depend both on the context of time and place and on the specific delimitation of cost categories and smoking related diseases applied.

In the present thesis, the socioeconomic consequences for society of the health effects of smoking are determined by applying cost-of-illness methods using a lifetime perspective. Cost-of-illness methods differ in aim from economic evaluation methods such as cost-benefit analysis (95) and cost-effectiveness analysis (96). These economic evaluation methods are used to assess the economic value of a specific intervention compared to an alternative, e.g. different policies aimed at inducing smoking cessation, whereas a cost-of-illness analysis aims at estimating the economic burden to society of an activity, such as smoking. If combined with evidence on the health effects of specific interventions, cost-of-illness results may be useful inputs to economic evaluations.

In the following sections, the main points of the cost-of-illness methods applied in this analysis are described and the types of resources and costs included in the assessment are delimited.

2.2.1 Prevalence and incidence based costs

Cost-of-illness studies estimate the economic burden of specific diseases or lifestyle habits. They can be understood as an economic extension of epidemiological studies of prevalence or incidence of diseases, and if lifestyle habits are the object also of assessments of possible health risks of those habits. Cost-of-illness studies may accordingly also differ in their epidemiological basis.

The earliest studies of the economic impacts of tobacco smoking were prevalence based, and this approach has so far been used by the majority of the published studies (97). With this approach, one estimates the economic burden over a period of time (usually one year) as a result of the prevalence of diseases and mortality attributable to smoking. The advantage of the prevalence-based approach is its simplicity and that readily available data can be used. Unfortunately, serious limitations are involved in studies applying the prevalence-based approach. One of these is that the costs for a given year are estimated on the basis of smoking behaviours that may date many years back in time and regardless of the time of onset of the diseases. Many smoking-related diseases are chronic, and the latency period between the initiation of smoking and the onset of illness may be long. Another limitation is that it does not take into account that, although smokers on average have higher annual health care costs than non-smokers, their expected lifetime is shorter than that of non-smokers, implying that they incur less of the relatively high medical costs of the old and very old (13:98).

More recent studies have adopted an incidence-based approach, using a dynamic life-cycle method, which takes differences in expected survival between particular groups into account. The incidence-based method estimates the present value of present and future costs, the lifetime costs, resulting from a given disease or a lifestyle. If, for example, estimation of the lifetime costs of smoking is the objective, the incidence-based method takes smokers' and non-smokers' different life span into account, when costs are summed over an entire life. Incidence-based analyses may be more useful for analysis of interventions that may impede the development of smoking-related diseases, because they determine the expected current and future costs for a group of smokers or the costs due to smoking-related diseases that will be incurred over a smoker's expected lifetime.

Regardless of the underlying epidemiological basis, all cost-of-illness studies are in principle subject to criticism of the choices made concerning the

cost categories included. If the study object is a lifestyle habit such as smoking the specification of health risks, i.e. in practice the choice of diseases to attribute to the habit, is also critical. A societal perspective is extremely ambitious, and in practice one must always refrain from including certain costs and accept criticism for this. Similarly, with specification of health risks. It is obvious to include diseases directly related to smoking such as certain cancers, cardiovascular diseases, and respiratory diseases. It is also well accepted, albeit inadequately quantified, that smokers generally have higher health care utilization rates and costs for coexisting diseases not related to smoking (99). How to include such costs in practice is, however, another question.

2.2.2 Types of resources and costs

When economists seek to determine the social costs of smoking, they usually distinguish between three categories of costs: direct costs, productivity costs, and intangible costs. Direct costs refer to resource utilisation directly attributable to the disease or the lifestyle concerned. Productivity costs refer to the loss of potential production because of absence from work or premature mortality. Previously the term 'indirect costs' was used. The US Panel on Cost-Effectiveness in Health and Medicine recommended the term 'productivity costs' to refer to 'the costs associated with lost or impaired ability to work or to engage in leisure activities due to morbidity and lost economic productivity due to death (100), and this is the term used in the present thesis. However, in Study I the term 'indirect costs' was used. Intangible costs are the costs of pain and suffering (101). As a preliminary to the assessment of the costs of smoking, it is important to acknowledge that smokers incur costs not only for themselves but also for their families as well as for the society as a whole.

Direct costs

The direct costs of smoking are usually determined as the value of the resources used in the health care sector, and possibly also in the wider social sector, on the prevention, diagnosis and treatment of smoking related diseases, including the costs of hospital admissions, ambulatory care, visits in emergency units, consultations with general practitioners (GPs) and pharmaceuticals (97). If the results of such studies are to be made comparable, there is, however, an urgent need to apply a more uniform methodology, because the existing studies are highly divergent in the extent to which they include other categories of smoking related health care. Sometimes, the costs of stays in nursing homes, assistance in the patient's home as well as other types of treatment or care are included in the calculation (11;12). In certain cases, also transport to and from treatment, material damages of fires caused by smoking (102), the environmental costs of smoking (103), among these the costs of the health impact on unborn children and infants of (future) mothers' smoking, are included (9). However, direct costs like

those for education of personnel and research, the additional laundering of clothes necessitated by smoking plus the putting away and cleaning after smokers, usually fail to be taken into account. To this should be added costs related to the time spent by patients and their relatives on consulting physicians or other health care professionals, and the time spent visiting hospitalized patients,² but such costs are usually absent from the calculations.

Productivity costs

The productivity costs of smoking are determined as the value of the production that is lost because of the temporary or permanent discontinuation of work activity due to smoking related diseases and deaths. Sometimes, also the external productivity costs of smoking are included, in terms of the loss of production due to the higher incidence of premature deaths among passive smokers (103). Productivity costs may be determined by two different methods, the human capital method (104), the willingness-to-pay (WTP) approach (105), and the friction cost method (106;107).

As applied in economic assessments of health care, the human capital approach is used to value changes in the amount of time individuals are able to allocate to paid work activities as a result of illness or programmes to alleviate ill-health (108). Applying the human capital approach, the loss of potential production caused by illness and premature death is determined from the point in time, where the individual discontinues his/her work activity until the average age of retirement from the labour market. In case of temporary, whether short or long term, discontinuation of the work activity because of illness, the loss of effective working time is determined for the period of temporary absence. The value of the production lost due to smoking related mortality is usually determined as the present value of the foregone future stream of income over the (average) working lifetime of the individual (101;104). This present value is referred to as the human capital costs. Application of the human capital method presumes that the labour market is in a state of full employment equilibrium. There are, however, certain disadvantages involved in applying this method, and these will be discussed in the discussion section.

The aim of the friction cost method is to obtain estimates of the value of the loss of production due to morbidity and mortality that are economically more realistic than those obtained by the human capital method (109). Contrary to the human capital approach, the friction cost method, takes into account that there usually is a certain pool of unemployed persons in the labour force, some of whom can be drawn into production fairly quickly, thereby allowing production to be normalized after a relatively brief friction period following the occurrence of illness or premature deaths. Accordingly, the fric-

² The US Panel on Cost-effectiveness in Health and Medicine has suggested that these time cost should be included under the direct costs of care, previously the time costs have been included under 'indirect costs' (100).

tion cost method is intended to estimate the value of the production lost during the friction period until the productive activity has become normalized after the interruption caused by the incidence of these events. Among the criticisms that have been made of the friction cost method are: if the existence of involuntary unemployment effectively reduces the opportunity costs of labour to zero after the friction period, this has major implications for the appropriate valuation in economic evaluations of direct labour inputs in health care (such as clinicians' time) (110;111).

Intangible costs

Intangible costs related to anguish, pain, uncertainty, and discomfort due to the different consequences of smoking for smokers, non-smokers and the relatives of smokers alike are difficult to quantify and include in economic assessments. However, by the willingness-to-pay (WTP) approach, the value of a human life is determined on the basis of the amount of money individuals concerned are willing to pay in order to reduce the statistical probability of a particular illness or death. Willingness-to-pay estimates of intangible costs are rarely used in studies of the costs of smoking, although it has been tried in some cost analyses, one American, another a Swiss study (12;105). The American study applying this approach estimated the value of innocent lives lost because of fires caused by smoking and because of passive smoking at US\$ 1.6 million per life (1986-prices) (12). By way of comparison it may be mentioned that a Danish study has estimated the WTP for a statistically avoided traffic death in Denmark to be 13.6 million DKK (in 1993) at a 20-30% risk reduction (112). This amount is, depending on age and gender, five to 20 times higher than the estimates of the value of life generated by the human capital approach. The approach can in particular be criticized for the potential hypothetical bias (i.e. that the responders may have difficulties in comprehending the hypothetical character of the question and that they are unfamiliar with the stated choice situation). This probably contributes to the unrealistically high willingness-to-pay estimates frequently observed or, at the other extreme, to statements of zero values of willingness-to-pay. Another essential point of criticism of the WTP approach is that it allows irrational valuations, in that the value obtained for a minor part of a good may be higher than the value obtained for the good in its entirety.

The cost categories on which attention should be focused depend on the perspective chosen for the assessment and on the methods of measurement selected. However, the cost components actually included in an assessment depend critically on the measurability and accessibility of the necessary data. In the following sections, I first discuss briefly transfer payments in relation to cost studies. Subsequently, I discuss appropriate cost delimitations related to the chosen perspective. Thirdly, I discuss whether to include future costs in the cost accounting. Finally, I summarize the cost components that actually have been included.

2.2.3 Transfer payments

In the general economics literature, it is standard to leave out transfer payments like welfare benefits or taxes from determinations of the costs to society of a particular activity. This is because such transfers do not influence the amount of real resources available to the society, their function is simply to redistribute money between the individuals of the society. On the other hand, in the extent that prices should be an expression of the value of resources in alternative applications, one may argue that the value of productivity is the price inclusive VAT. Furthermore, it may be argued theoretically that there are costs related to transfer payments and that such costs should be added to the real costs (direct costs and productivity costs) assessed in the traditional way. The justification for inclusion of such costs may be that increased transfer payments may be assumed, *ceteris paribus*, to engender higher administrative costs. Further, it is generally agreed by public finance economists that public transfer payments or other publicly provided goods or services financed by income taxes engender a deadweight loss. When the citizens have to pay income taxes, their remuneration from work activity is less, than if there were no taxes to pay. Presumably this will reduce their incentive to work and people will prefer taking more leisure time. For society this means a loss of the value of the work that could have been, but was not, performed. This type of reasoning is applied by the Danish Ministry of Finance for the assessment of the costs of public projects partly or entirely financed by taxes. The Ministry assumes that the deadweight loss on average approximates 20%³ of the monetary net cash-flow to the state, and this amount is added to the estimated costs of each such project (113).

The inclusion of a tax deadweight loss in the present study has been considered but has not been pursued for the following two reasons:

1. The inclusion of such costs is not recommended in the Danish guidelines for economic evaluations of health care interventions (114).
2. A precise estimate of the size of the deadweight loss due to taxes in Denmark is not available, so including such costs in this study would increase the uncertainty of the results.
3. None of the other studies of the costs of smoking retrieved from the literature include an estimate of the possible deadweight loss of taxes, so omitting them from the present study as well facilitates comparisons.

2.2.4 Examples of delimitations of the costs of smoking

Choi et al. have in detail reviewed the cost categories related to drug abuse (including the excessive use of alcohol, tobacco and illicit drugs) according to the study perspective (97). The categorisations are based on published

³ This estimate is based on an assessment of the marginal efficiency costs of VAT and tax on labour in Denmark plus the results of a number of similar international investigations (113).

review articles by Rice et al. (115), Collins and Lapsley (116) and by Manning et al. (28), and on a theoretical paper by French et al. (117). Table 1 is based on Table 2 from Choi et al. with some restructuring and additions,⁴ as the table is also later used for a schematic description and delimitation of the cost components included in the present cost assessment (column "COI"). The inclusion (indicated with an "x") or the omission of each cost category provides a rough idea of its relative importance within the methodology used by each of the reviews.

As shown in Table 1, Collins and Lapsley (116) and French et al. (117) used the societal point of view. According to this, the total costs of smoking should be determined as all costs attributable to smoking, no matter who pays or benefits (the state, regional and local governments, insurance, or the smokers and possibly their surroundings). The total costs are found as the sum of the internal costs (private costs) and the external costs (social costs).⁵ In consequence, pensions and social benefit payments are not included, as this would be double counting. On the other hand, the administrative costs of transfer payments attributable to smoking are included, as these costs would not have existed in the absence of smoking.

Some studies attempt to estimate the economic burden of illness attributable to smoking. In these cases the costs have typically been limited to the medical costs attributable to smoking related diseases, e.g. lung cancer, coronary heart diseases, and chronic obstructive lung disease (11;118).

In contrast, the review by Manning et al. (Table 1) included only costs that are external to the smokers and their families (28). Consequently, transfers from non-smokers to smokers via collectively financed programs (taxes and group life insurance to finance pensions) are included, while loss of wages due to premature mortality is excluded, as such losses are considered as internal costs. Studies like this have typically been designed to assess the distributional issue whether smokers 'pay their way' in terms of the balance between their internal costs and the external costs they generate through their habit (12;14;119). For the policymakers, one of the purposes of estimating the costs of smoking can be to determine an economically efficient level of the excise taxes on cigarettes and other tobacco products. In this case the public revenue is compared with the external costs of smoking (11;12;118;119). Further discussion of how to define the external costs is found in the discussion section 5.4.

⁴ The review form Rice et al. devised a list of economic costs for alcohol and drug abuse and mental illnesses in the US (this review is not included in Table 1).

⁵ Although no universally accepted definitions are available, it is generally agreed that private costs are the same as internal costs, i.e. costs borne by the smokers themselves, e.g. their share of medical expenses, their lost earnings, and the cost of purchasing the cigarettes. But some authors define social costs as being different from external costs (the costs smokers impose on non-smokers). As an example, Manning et al. define the total social costs of smoking as the sum of internal costs and external costs (28).

Table 1A. Cost categories according to reviews and the present thesis assessing the costs of smoking.*Direct costs*

Cost categories	C	M	F	COI
1 Hospitalisation	x	x	x	x
2 Physician visits	x	x	x	x
3 ^a Institutions for delivery of specialized care	x		x	+
4 ^b Professional services (other than physicians)	x		x	x
5 Extra neonatal care (neonatal complications caused by mothers' smoking)		x		(x)
6 Prescription drugs for treatment	x		x	x
7 Counselling, re-training and re-education			x	+
8 Care in the patient's home by health care professionals			x	+
9 Household caretakers			x	++
10 Nursing home stays	x	x	x	+
11 ^c Ambulance costs	x		x	+
12 Special equipment for rehabilitation (e.g. wheelchairs)			x	++
13* Cost of patients' time receiving treatment				++
14* Cost of patients' time spent waiting and travelling to receive treatment				++
15* Cost of relatives and friends' time in relation to hospital visits and visits in other specialized institutions				++
16* Cost of time spent by informal caregivers				++
17* Cost of time spent following prevention programs				++
18 ^d Smoking prevention programs	x		x	+
19 ^e Program administration		x		+
20 Medical and health services research	x			+
21 Training costs for physicians and nurses (as an example)				+
22 Administrative costs of private insurance for treatment of (tobacco) disorders		x		+
23* Administrative costs of social payments				+
24 Costs of products (cigarettes)	x	x		++
25 ^f Property and forest fires	x	x		++
26 ^g Motor vehicle crashes	x	x	x	++
27 Employee assistance programs provided by employers for smoking employees			x	++
28 employees				
29* Laundering of clothes necessitated by smoking				++
30* Putting away and cleaning after smoking				++
31 ^h Payroll taxes on earnings that finance medical, sick leave, disability, group life insurance and retirement benefits		x		#

Source: Based on Choi et al. (97).

C: Collins and Lapsley (115).

M: Manning et al. (28).

F: French et al. (116).

COI: The present thesis.

x: Included in the analysis.

(x): Partly included in the present analysis.

+: Should, if possible, be included in a determination of the direct health care costs (comprising unrelated as well as related medical health care costs) financed by the public sector and estimates of the lifetime productivity costs due to smoking-related morbidity and mortality.

++: Should be included in a cost determination from the societal perspective, comprising, unrelated as well as related medical health care costs, productivity costs, and intangible costs.

#: Cost categories that may be considered for inclusion depending on the perspective chosen for the assessment.

-: Should not be included in a determination of costs.

Table 1A. Continued.

- *: Cost categories added to the original Table 2 (97).
- a: Includes treatment centres other than hospitals and smoking correctional facilities.
- b: Includes psychologists, social workers, nurses, physical and occupational therapists, pharmacists, technicians, etc.
- c: Includes other transportation to health care providers.
- d: Screening, education programs and mass media campaigns to inform the public about the hazards of smoking.
- e: Tobacco-related program and social welfare programs.
- f: Includes repair and cleaning of damaged goods.
- g: Includes legal and court proceedings, insurance administration, accident investigation, vehicle damage, traffic delay.
- h: Paid as taxes, premiums, payroll deductions and employer contributions.

Table 1B. Cost categories according to reviews and the present thesis assessing the costs of smoking.*Productivity costs*

Cost categories	C	M	F	COI
1 ⁱ Morbidity costs: income loss due to smoking	x	x	x	++
2 ^j Related productivity losses	x	x	x	++
3 ^k Mortality costs: present value of lifetime earnings			x	++
4 [*] The production and employment of the tobacco industry (friction costs)				++
5 ^l Foregone consumption	x		x	#

i: Value of goods and services lost by individuals unable to perform their usual activities or to perform them at a level of full effectiveness due to disability, absenteeism, etc.

j: Loss of innocent lives and work time caused by passive smoking and time spent caring for family members, because of their tobacco abuse.

k: Current monetary value of future output lost due to premature death.

l: Reduction in consumption resulting from smoking-induced deaths, which is net resource benefit to society, considered as a negative cost.

Table 1C. Cost categories according to reviews and the present thesis assessing the costs of smoking.*Intangible costs and benefits*

Cost categories	C	M	F	COI
1 ^m Pain and suffering			x	++
2 Pain and suffering of victims and the rest of the community	x	x		++
3 Value of lost life to the deceased (estimated by WTP to avoid death)	x			++
4 Loss of consumption by prematurely deceased	x			#
5 [*] The benefits of tobacco consumption				++

m: Depression, isolation, heightened anxiety, loss of companionship, loss of job, physical disability, reduced self-esteem, and resentment.

Table 1D. Other categories according to reviews and the present thesis assessing the costs of smoking.

Other categories, expenditures and revenues

Cost categories	C	M	F	COI
1 ⁿ Group life insurance		x		-
2 ^o Widow's bonus from husband dying at age 60-79		x		-
3 ^p Extra disability pension due to retirement for health reason		x		-
4 * Social security benefits paid out to smokers during periods of smoking-related illness: sickness benefits, early retirement pension, rehabilitation payments				-
5 Taxation of tobacco products, e.g. excise taxes, VAT				-

n: Death benefits provided by employers, usually not adjusted for habits and reduced to zero at retirement.
o: When wife outlives male pensioner and her social security pension increases if she never worked.
p: Non-smokers receive less in disability pension than do smokers since smoking is causally related to disability retirement.

If, however, the objective of the study is to determine on which part of society (the households, the public sector, or the business community) the costs fall, an estimation of public revenues and expenditures should be performed. In this case, transfer payments such as public expenditures on sickness or revalidation benefits and old age pensions should be determined and included just as transfer incomes such as taxes, duty payments and excise taxes on tobacco.

2.2.5 Future costs

A controversial question is how to handle future costs that occur because of a successful, life-extending intervention. Such costs can be divided into three categories: (1) health care costs for the disease or diseases affected by the intervention (or behaviour modification), (2) health care costs for other diseases, and (3) other (nonhealth care) costs such as for food, shelter and clothing (120).

It is non-controversial that costs in category (1) ought to be included when estimating lifetime costs in cost-of-illness analyses as well as in cost-effectiveness analyses. In relation to the latter type of studies, however, it remains controversial whether to include the future unrelated health care costs (category 2) and future non-health care costs (category 3), respectively, and whether or not such an inclusion will affect the incremental cost-effectiveness ratio (121-125) in a significant way. This literature relates to CEA. The the cost-of-illness (smoking) studies mainly focus cost delimitation on which diseases and health care costs to include (8;126). However, the issue of present and future unrelated health care costs is obviously relevant also in the cost-of-illness context.

One can argue, as Russell did, that the future unrelated health care costs should not be included in the estimations as they are irrelevant for the question whether the intervention under study is worthwhile (127). In contrast, Weinstein and Fineberg stated that they should be included, as future unrelated costs appear due to the intervention (128). Others, such as Garber and Phelps (125), and Meltzer (124), have taken a more analytical approach and applied models of expected utility maximation from which they have tried to answer the question whether to include the future unrelated health care costs. From their analysis Garber and Phelps adduce that when unrelated future costs can be identified, there may be no compelling reason to select inclusion or not of future unrelated health care costs. However, they call attention to the fact that it frequently is not possible to determine that all changes in future health care costs are due to “unrelated” expenditures, for which reason it is reasonable to include future costs as the default option. They conclude that the inclusion or not of unrelated future costs is without consequence for the rank ordering of programs according to their cost-effectiveness ratio, provided the practice is consistent between studies (125). As noted by Garber et al., this theoretical result is only valid for comparisons made between persons of the same age, because otherwise the unrelated future costs will not be a constant (120). Meltzer demonstrates in his model that cost-effectiveness analysis criteria are consistent with lifetime utility maximation only if all future medical and non-medical expenditures are included (124). Weinstein et al. state that the conclusion of Garber and Phelps is correct in theory, but will be problematic in practice (129), and this is also pointed out in a book chapter by Garber et al. (120) on the theoretical foundations of cost-effectiveness analysis:

“This means that if we choose to exclude the costs of “unrelated” diseases, we would also have to exclude the “unrelated” components of the costs of “related” diseases ... There are practical and conceptual problems in disentangling the “related” and “unrelated” components of costs for “related” diseases, both of which are included in the category (1). The comprehensive exclusion of future “unrelated” costs would therefore be difficult, if not impossible, in practice.”

In guidelines by public authorities on how to conduct economic evaluations of health care interventions, the choice whether or not to include the future unrelated costs is generally left to the analyst (130). A Canadian guideline concludes that future health care costs not directly related to the intervention should be excluded (131), while the Danish approach to standards for medical economic evaluations abstains from taking a position on this issue (114).

Although the analysis by Meltzer indicates that the future non-health care costs should be included in the analysis, as these costs are relevant for the

total welfare (124), there seems to be reluctance to include this type of costs. Brouwer et al. (132) declare:

“The analyst may decide to present this cost-category when considered relevant for the final decisions, but for reasons of feasibility a prescription to include these costs is not considered useful. Furthermore, discussion on where to draw the line in costs to consider in the analysis is encouraged here.”

Garber et al. (120) propose that future non-health care costs can be omitted from the analysis, if they are small compared to the magnitude of the cost-effectiveness ratio and therefore won't affect the conclusion. In addition, Brouwer and Koopmanschap point out that it is important to acknowledge that, next to welfare theoretical approaches to the problem, the societal decision-maker's view should also be considered (133).

2.2.6 Costs included in the present study

In Table 1 (column “COI”) those costs, which have in fact been included in the present PhD thesis are marked with an “x”. The cost components marked with a “++” are those that also ought to be included in a cost-of-illness analysis performed from the societal perspective comprising direct health care costs, productivity costs, and intangible costs. While the cost components marked with an “#” are those costs about which controversies about inclusion exist. The “-” indicates that this category should not be included in a determination of costs. This list is probably still incomplete and debatable, because any cost determination unavoidably will continue to be constrained by the available knowledge, the perspective chosen for the assessment, the actual availability of the necessary data and the conditions for performing the assessment that the analyst has obtained from the assignment giver. Thus, traditional COI analyses only rarely take into account the fact that the resources used for the production of the disease-causing tobacco products alternatively might have been used for other utility creating activities, and this is most likely why the production and employment of the tobacco industry have not been included in the original Table 1. However, friction costs related to conversion to non-tobacco production might be relevant to include. In relation to the discussion about inclusion of all future unrelated health care costs and future nonhealth costs, the reasoning leads ultimately to the conclusion that no cost component can be excluded when comparing the lifetime health care costs of smokers and non-smokers from the societal perspective. This would, however, become a very demanding task, and such a comprehensive assessment would probably have little relevance for health policy decisions.

2.2.7 Other studies estimating lifetime health care costs

Relatively few studies have estimated the lifetime health care costs of smokers and non-smokers, and they reach widely divergent results. Some studies report that the costs of non-smokers are higher than those of smokers (13-15;103;134), while other studies report that costs of ever-smokers are higher than those of never-smokers (11;12;119) or that costs of current smokers are higher than those of former smokers (16). The results of the lifetime cost studies will be presented in the following sections, while the discussion of these studies and their results is in the discussion section. The studies are outlined in Table 2.

Table 2. Studies with estimations of lifetime health costs of smoking (except for the latter one) as (part of) the outcome measure. Definition of smoking status and study results are not directly comparable due to differences in goals, methodology etc. The studies are arranged by date of publication.

Author and year of publication	Year of estimate	Location of study	Discount rate (%)	Included populations	Ratio Men (women)	Delimitation of diseases attributable to smoking	Included cost categories	Comments
Leu and Schaub (14) 1983	1976	Switzerland	0	Current smokers vs. non-smokers	0.93 (-)	Cancers ^a , coronary heart disease, aortic aneurism, peripheral vascular disease, and bronchitis and/or emphysema	Physician visits and hospital stays	Probably underestimates the annual number of physician visits and days in hospital of smokers
Oster et al. (16) 1984	1980	US.	3	Current smokers ^b vs. former smokers	2.41; 2.81; 2.99 (2.25; 2.71; 2.81)	Lung cancer, coronary heart disease, and emphysema	Included productivity costs, but either the direct or the productivity costs are described	The study did not take current and former smokers' different life expectancy into account
Leu and Schaub (134) 1985	1976	Switzerland	5	Current smokers vs. non-smokers	0.90 (-)	Cancers ^a , coronary heart disease, aortic aneurism, peripheral vascular disease, and bronchitis	Physician visits and hospital stays	
Manning et al. (12;28) 1989	1986	US.	5	Ever-smokers vs. non-smoking Smokers and ever-smokers vs. never-smokers	- (-)	-	All medical services except maternity (no complications) and dental care. Nursing home	Each pack of cigarettes increases external medical costs by, respectively, \$0.26 (comparing ever-smokers and non-smoking smokers) and \$0.30 (comparing ever-smokers and never-smokers), and total external ^c costs by, respectively, \$0.15 and \$0.28. Discounted at 0% non-smoking smokers costs exceed ever-smokers costs
Lippitt (15) 1990	1986	US.	3	Current smokers ^b vs. former smokers and current smokers vs. non-smokers	- (-)	Lung cancer, coronary heart disease, and emphysema	Direct costs, but not described	The author concluded that for each year of life gained by not smoking, health care costs increase by \$280 in 1986-prices. But probably the lifetime costs of current smokers are underestimated
Hodgson (11) 1992	1990	US.	3	Ever-smokers ^c vs. never-smokers	1.32; 1.21; 1.47 (1.24; 1.14; 1.41)	-	Hospital care, physicians' services, and nursing home care	

Table 2. Continued.

Author and year of publication	Year of estimate	Location of study	Discount rate (%)	Included populations	Ratio Men (women)	Delimitation of diseases attributable to smoking	Included cost categories	Comments
Viscusi (103) 1995	1993	US.	5	Ever-smokers vs. non-smoking smokers	- (-)	-	Nursing home, all medical services except maternity, well, and dental care. Environmental costs from death of lung cancer and heart disease	Each pack of cigarettes increases medical costs by \$0.45, and total external ^a costs by \$0.27. Discounted at 0% and 3% non-smoking smokers costs exceed ever-smokers costs
Barendregt et al. (13) 1997	1988	Netherlands	0	Current smokers vs. non-smokers	0.87 (0.85)	Heart disease, stroke, lung and other cancers, and chronic obstructive pulmonary disease	Health care service (hospital nursing homes, psychiatric care, care for mentally retarded and physically handicapped, GPs, physical therapy and dental care. Drugs, district nursing, home help, maternity services, and eyeglasses. Patient transport and administration)	Discounted at 4.5% for men and 5.5% for women smokers costs exceed non-smokers costs
Roberts and Lindgren (119) 2001	1988/ 1989	Sweden		Current smokers vs. never-smokers Former smokers vs. never-smokers	1.67 (1.53) 1.32 (1.35)		Health care (hospitalisations and outpatient services), sickness, early retirement pension, and care for the elderly	
Kliskinen et al. (135) 2002	1991	Finland		Current smokers vs. never-smokers Current smokers vs. former smokers	1.86 (1.85) 1.42 (1.31)		Hospitalisation and major drugs. Productivity costs: morbidity and mortality	The estimations are not lifetime costs, but costs during a 19-year follow-up period

a: Including oral cavity, esophagus, pancreas, larynx, lung, and bladder cancer.

b: Estimated for light smokers (1-19 cigarettes per day), moderate smokers (20-39 cigarettes per day), and heavy smokers (40+ cigarettes per day). The ratios are based on costs for current smokers and benefits of quitting (current smokers' costs – former smokers' costs) according to quantity of daily tobacco consumption.

c: Estimated for all smokers, moderate smokers (fewer than 25 cigarettes per day), heavy smokers (25 or more cigarettes per day).

d: The estimations included medical care, sick leave, group life insurance, nursing home, retirement pension, fires, and taxes on earnings to finance the programs.

One of the first studies using the life cycle method was performed in Switzerland by Leu and Schaub. In their first study, the authors estimated disease specific aetiological fractions on the basis of mortality data and applied them to morbidity. In this study they found that in 1976, smokers had on average 8% more physician consultations and 10% more hospital days per year than non-smokers. On this basis, they estimated that the direct, undiscounted lifetime health care costs (including physician consultations and hospital admission) for non-smoking 35 years old men are higher than for current smokers of the same age (14).

Oster et al. (16) have for 1980 calculated the American lifetime health care costs by using age- and gender-specific estimates of incidence based costs for three diseases (lung cancer, coronary heart disease and pulmonary emphysema) and estimates of the risks of contracting these diseases over the remaining lifetime. Discounted (3%), but unspecified direct and indirect costs have been estimated for men and women between the ages of 35 and 79, distributed according to the quantity of daily tobacco consumption for current smokers. The study finds that costs are increasing with the quantity of tobacco consumed and that costs are higher for men than for women, but the different survival probability of smokers and nonsmokers has not been taken into account in this study.

Lippiat (15) finds, on the basis of the cost data of Oster et al. (16) that smoking lowers lifetime medical costs in 1986. To take into account the different survival probabilities of smokers and non-smokers, Lippiat adjusted Oster's cost figures for smokers by deducting the average annual medical costs for non-smokers over 65 years old for each year of life lost based on the estimates of Leu and Schaub (14).

Hodgson (11) has for 1990 estimated the discounted lifetime medical expenditures for 17 years old never-smoking and smoking (moderate smokers, heavy smokers and former smokers) men and women. The estimates included the costs of hospital care, physician services and home care and are based on different sources. For hospital and physician services the National Health Interview Survey was used, for nursing care the National Nursing Home Survey and the Nutrition Examination Survey Epidemiologic Followup Study, survival probabilities were taken from the CPS II study and the costs of medical care were based on the National Medical Care Utilization and Expenditure Survey and Medicare data files. Using a discount rate of 3%, Hodgson finds that total lifetime health care costs are 1.32 and 1.24 times higher for smoking than for never smoking men and women, respectively.

Contrary to the results of Hodgson (11), Barendregt et al. (13) report that for 40 years old Dutch men and women in 1988, the undiscounted direct life-

time cost ratio between current smokers and non-smokers is 0.87 and 0.85 for men and women, respectively. Barendregt et al. used three life tables to examine the effect of smoking on health care costs. They limited the health care costs due to smoking to heart disease, lung cancer, stroke, other cancers and chronic obstructive pulmonary disease and assumed the costs for all other diagnoses to be independent of smoking status.

Econometric models

During the last decades, some researchers have developed econometric models of smoking related health care costs.⁶ In a revised version of their first study (14) Leu and Schaub used an econometric model. This time they found that smokers every year have somewhat less physician visits, but slightly more hospital and medical care days than non-smokers. Again, Leu and Schaub concluded that, irrespective of the discount rate used (0%, 5% or 10%), smoking does not increase lifetime medical costs (134).

Manning et al. (12;28) have estimated the discounted lifetime external costs in 1986 for 20 year old men and women. The estimate includes expenditures (medical care, sick leave, group life insurance, nursing home care, retirement pension and fires) and revenues from taxes on earnings to finance the above programs. The estimates are based on two cross section studies, the Rand Corporation Health Insurance Experiment and the National Health Interview Survey (1983). To define a value for innocent lives lost because of fires and passive smoking, they used a method based on WTP. The authors estimate that the discounted difference in total net lifetime external costs between smokers and 'non-smoking smokers' (i.e. non-smokers with a behavior otherwise identical to that of smokers i.e. in age, sex, education, drinking habits, except that they never have smoked) is \$1,000 and \$900 at discount rates of 5% and 10% respectively.

Viscusi (103) has estimated the external costs of smoking in 1993 on the basis of an update of the estimates by Manning et al. (28) but including the costs of environmental smoke (mortality costs from lung cancer and heart disease) based on adjustments of estimates reported by the US Occupational Safety and Health Administration and the US Environmental Protection Agency. After comparing expenditures and revenues, Viscusi concludes, using a discount rate of 3% that on balance smokers do not cost society resources because of their smoking activity; rather there is a net cost saving to society even excluding consideration of the current cigarette taxes paid by smokers.

⁶ Most recently, studies referred to as econometric models (12;28;119;134) have been used to determine the smoking related lifetime costs. They are based on direct survey methods and apply regression analysis techniques to control for possible confounders such as sociodemographic and economic variables and other risk factors.

Roberts and Lindgren (119) have in an econometric study estimated lifetime costs on the basis of a cross section study from 1988-89. The calculation comprises expenditures for Swedes between 16 and 84 years old for hospital care, outpatient services, care for the elderly (homehelp service, transportation services, and special housing), early retirement benefits, and sickness benefits. Possible confounding variables controlled for comprise life style factors (over-weight, exercise and drinking habits) and a number of socioeconomic factors. Taking into consideration expected lifetime and taxation to finance the abovementioned services, the authors conclude that smoking imposes net expenditures. Even though smokers have a shorter life expectancy and therefore do not have the possibility of receiving collectively financed benefits and services for as long time as non-smokers, they use health services and sickness and early retirement benefits to such a large extent that the mortality effect is offset.

The Finnish study by Kiiskinen et al. (135) differs from the other studies in that the estimates of smoking-related costs for 25 to 59 years old men are based on a 19-year individual follow-up study from 1972 to 1991, and thus it is not a lifetime study. The estimates include direct costs (hospital care and pharmaceuticals) and indirect costs of morbidity (sickness related absence and early retirement benefits) and mortality costs for current, former and never-smokers, but apparently there is no control for confounders (i.e. drinking habits and socioeconomic factors). The study estimates that the mean direct and indirect costs for current smokers exceed those for never-smokers by 46% (€9,800 vs. 6,700) and 90% (€139,900 vs. 73,500), respectively.

2.2.8 Comparison of studies

Based on three reviews including prevalence and incidence based studies (136-138), Max (8) has summarized the available knowledge on the economic impact of smoking on health-related costs concluding that the overwhelming body of evidence in the literature asserts that smoking imposes costs on an annual basis and that it leads to increased medical costs over the lifespan. Choi et al. point out that, in most cases, statements that smoking imposes large costs on society are based on prevalence-based cost-of-illness studies, but the studies are difficult to compare because of differences in methodology and treatment of data (97).

This point has also been made by Wagner et al. (138). Equivalent results should not be expected across countries, because the costs of smoking will depend on: 1) the extent of smoking related diseases, including a) the use of tobacco (smoking vs. chewing, habits with regard to inhalation of smoke, age at start of smoking, the size of daily consumption), b) the age structure of the country's population, c) competing causes of disease, d) the prevalence of diseases that interact with the smoking related diseases; 2) how

aggressively different diseases are treated, and 3) the level of treatment costs and the effectiveness of treatments (138). Furthermore, the social costs of smoking must be expected to increase in the future, particularly in the developed countries. This will happen, partly as a consequence of a long-standing, large consumption of tobacco and the high costs associated with this, partly because of an increasing level of costs for treatment of chronic diseases, as there is a growing popular acceptance of the treatment of these. The same development may be expected to take place in the countries under development, but with a time-lag of perhaps 15-25 years (139).

However, in a historical review of American prevalence based studies of the economic costs of smoking from 1971 to 1993, Rice (137) concludes that despite the fact that studies of the costs of smoking have been carried out by different researchers over a period of 30 years and applied varying methods and data bases, the estimates of the direct costs of smoking are relatively consistent in terms of the percentage of personal health care expenditures they account for. Except for two studies that yielded a lower per cent of around 3% (140;141) and another (142) that found a higher share, 9%, most studies find that smoking-related direct costs account for 5-6% of personal health care expenditures. In their review of six American studies of the annual costs of smoking and of Hodgsons lifetime study (11), Warner et al. (138) contend that it is likely that at least 6-8% of the personal health care expenditures in the United States can be attributed to smoking. In addition, Warner et al. consider it likely that the estimate by Hodgson et al. (11) of 14% of the personal health care expenditures is the upper limit for the share of smoking related costs as a part of overall health care costs. This assessment of the share of overall health care expenditures of high-income countries attributable to smoking is supported by two more recent American studies (9;143) and a German study (144). This way of expressing the results, i.e. as the proportion of personal health care costs that can be attributed to smoking, may be a pragmatic approach to make comparisons over time, provided that it is ensured that all the types of costs included in the denominator are also included in the numerator.

3. Methods

As mentioned in the introduction, the aim of the present PhD thesis is to determine the socioeconomic consequences in Denmark of the health effects of smoking assessed over a lifetime horizon. The estimations are based on national data from the health care authorities using the cost-of-illness analytical approach. The study includes present and future smoking-related medical health care costs and present and future unrelated medical health care costs. Further included are productivity costs due to morbidity, disability and premature mortality.

The thesis is based on data from two studies estimating the economic consequences of smoking seen in a lifetime perspective. In Study I (17), ever-smokers' and never-smokers' lifetime direct health care costs and productivity costs have been compared by age, gender and disease groups. In Study II (18), the economic impact of smoking cessation has been determined by comparing the lifetime direct health care costs and productivity costs of people who quit smoking and of continuing smokers' by quantity of their daily tobacco consumption, age, gender and disease group. The calculations are based on Danish data for health care costs, smoking prevalence (145), relative risks (26), and life tables (146). Both studies have been described in detail in the articles reporting them, which are reprinted in the appendices of the thesis (Study I (17) in Appendix R and Study II (18) in Appendix S). In what follows, the three basic components, on which the studies included in the thesis are based, are described in further detail: the population attributable risk percentages, the cost-of-illness approach (101), and life expectancy for a given smoking status. In addition, the sensitivity analyses performed are described in a separate section.

3.1 Smoking attributable fraction

Corresponding to what has been done in a number of studies on the costs of smoking (e.g. (9;118;147-149)), the estimated population attributable risk percentages have been used for determining the excess costs of smokers compared to never-smokers and former smokers, respectively. This approach has been taken, because it was considered that the development and use of an econometric model for the determination of the smoking-related health costs would be more time consuming and costly than what is practically possible within the context of a PhD thesis.

With the population attributable risk percent (PAR%) derived from the work of Lewin (150), I estimated the percentage of mortality in the population that can be attributed to tobacco consumption by combining relative mortality

risk-estimates (RR) related to smoking with the prevalence of persons with a particular smoking status.

In both studies, the PAR%'s were used as indicators for parts of outcome (150) as well as parts of costs attributable to smoking and were applied to both mortality- and morbidity-related data, as no data for relative morbidity risks were available.

Based on Danish smoking proportions and Danish RR-estimates, I estimated age-, gender-, and disease-specific PAR%'s in the first study, and quantity-, age-, gender-, and disease specific PAR%'s in the second study. The algorithms used for this are shown in Appendix A.

3.1.1 Smoking proportion

Despite decreases of around 40% between 1970 and 1999 in the proportion of everyday smokers in the Danish population (145;151), smoking is still very common in Denmark, especially among people with relatively low socioeconomic status (152). In 1999, the overall proportions of smokers among men and women were 39% and 30%, respectively (145). Over the same period of 30 years, the proportion of heavy smokers (≥ 25 g of tobacco / day) has increased considerably, from 11% to 21% among men and from 7% to 14% among women (145;153-156), see Appendix Figure 1 (Appendix B).

In the present thesis, the smoking proportions assumed for the calculations are based on an omnibus survey conducted by PLS-Consult comprising 2,565 men and women over 13 years of age, of whom 1,947 subjects (1,110 men and 837 women) were 30 years old or more (145). This survey was chosen in preference to other available data such as the somewhat larger study 'Sundhed og sygelighed i Danmark 1994' from DIKE (Danish Institute for Clinical Epidemiology) (157) because it:

- provided data on the smoking habits of the Danish population in the year 1999, which is the base year for the cost estimates,
- has categorized the quantity of daily tobacco consumption in accordance with the study by Prescott et al. (26), and
- has determined the smoking habits by 10 years age groups for the 30-69 years old.

In addition, it was found that a similar omnibus survey from 1996 (130), asking the same questions to a similar number of respondents as in the 1999-survey, was in very good agreement with the findings of the DIKE study from 1994 (157).

During the telephone interview, the respondents were asked, whether or not they smoked and, if they affirmed smoking, the amount of cigarettes smoked per day. Smoking status was assigned on the basis of the study by Prescott et al. (26) into the categories never-smokers, former smokers and current smokers. For the age groups from 30 to 69 years old, the proportion of smokers was interpolated linearly from 10-year age-groups to 5-year groups, while the observed proportion of smokers among the survey-sample of 70+ years old was assumed to be the same for all 5-year age groups over 70 years of age. In addition, current smokers were categorized according to the amount of tobacco consumed per day (equating one cigarette to one gram of tobacco) into three groups, namely light smokers: 1-14 grams of tobacco per day; moderate smokers: 15-24 grams of tobacco per day, and heavy smokers: ≥ 25 grams of tobacco per day. Current smokers, who do not smoke every day, are categorized as light smokers. The proportions of smokers by the quantity of daily tobacco consumption, age, and gender are shown in Appendix Table 1 (Appendix B).

3.1.2 Relative risk-estimates

Relative risks of smoking-related mortality are derived from the prospective cohort study by Prescott et al. (26). In this study, the data were pooled from three prospective population studies conducted in Copenhagen⁷ to compare total and cause-specific mortality in relation to smoking habits. A total of 30,917 subjects initially examined between 1964 and 1992 were followed until 1994 for date and cause of death. In the thesis, the RR-estimates with-in four disease groups were used: cancer (ICD-10: C00-C99), cardiovascular diseases (ICD-10: I00-I99), respiratory diseases (ICD-10: J00-J99), and 'all other diseases' to determine the PAR%s. Estimating life expectancy by the daily quantity of tobacco consumption, the RR-estimates for death of all causes were used, separately for <65 years and ≥ 65 years.

Several studies have documented that, compared to continuing to smoke, quitting smoking reduces the risks of several diseases and the risk of premature death (6). Since there is some uncertainty concerning the precise time course of risk reduction after smoking cessation (6), the following assumption was made in the estimation of the PAR%s for ex-smokers: irrespective of the amount of tobacco consumed per day before they quit, the RR-estimates for ex-smokers decrease linearly over a 15 years period to the level of the never-smokers' risks. The RR-estimates used in the studies of this thesis are shown in Appendix Table 2 (Appendix C).

⁷ The epidemiological data are drawn from three longitudinal population studies: the Copenhagen City Heart Study (CCHS), the Glostrup Population Studies (GPS), and the Copenhagen Male Study (CMS).

3.2 Cost-of-illness

The COI approach is a commonly used method that assesses the burden of poor living habits. The COI method has been considered an appropriate approach for a comparative analysis of the health costs of two groups, smokers and non-smokers, because the COI method is based on a pecuniary valuation of the use of resources (direct costs), the productivity lost (productivity costs), and the deterioration in the quality of life (intangible costs) related to a particular health problem, here smoking. Besides, some of the cost-of-illness-estimates can be an important input for a cost-effectiveness analysis (158), an economic evaluation method used to assess the outcomes and costs of health care interventions. By providing estimates of outcomes (for example years of life gained) and costs of two or more competing interventions, a CEA shows the possible tradeoff involved in choosing among the competing options. The results of the thesis may therefore be used as data for future Danish cost effectiveness analyses of specific smoking cessation interventions and will as such provide information that can be useful for policy decisions on which preventive efforts to give priority.

In accordance with the principles of welfare economic theory, in which the impact on resource utilization and non monetary welfare losses is determined from the social viewpoint,⁸ a societal perspective (108) is adopted and the lifetime health costs of smoking are calculated by applying the COI approach developed by Rice et al. (118) and Hodgson and Meiners (159) and taking the difference in life expectancy between smokers and non-smokers into account. In cost-of-illness analyses the resources and the costs, which in this case are attributable to smoking related diseases and deaths, comprise according to the recommendations: direct health care costs, productivity costs and intangible costs (101). The last mentioned category is, however, rarely included in actual cost-of-illness analyses. As an assessment from the societal perspective is extremely ambitious, it has not been possible within the time frame of a PhD thesis to perform a complete analysis from this perspective. It has therefore been necessary to make some choices with regard to the cost categories to include, accepting the limitations entailed by this. The result is a cost-of-illness analysis performed comprising: 1) direct present and future related and unrelated medical health care costs in relation to active smoking determined on the basis of data from public authorities, plus 2) the productivity costs. No attempts at determining the intangible costs of smoking (e.g. uncertainty, fear and pain due to smoking related morbidity and mortality) has been made. Such negative effects of illness do not normally represent costs defined as changes in the available resources and there are no registered data available in Denmark (nor in any

⁸ In welfare economics economists view the maximization of social utility as the ultimate goal of any resource allocation scheme.

other country) for these cost items. In a similar vein, neither has the benefits to smokers of tobacco consumption been included in the assessment.

In accordance with Garbers reasoning⁹ (120) the future health care costs, for related as well as for unrelated diseases, are included in the assessment. The direct health care costs comprise hospital admissions, outpatient visits (including emergency wards), consultations with general practitioners, and the consumption of pharmaceuticals. All of these are determined according to five-year age groups and gender. Omitted from the determination of the direct costs are the costs of prevention, costs falling on the social sector and the costs of rehabilitation and nursing in the municipal sector, since in Denmark these types of data are not recorded according to diagnoses. Table 1 in section 2.2.4 indicates which other cost categories (marked with a “++”) ought to be included in a complete cost determination according to a societal perspective. It should be noted that transfers within society (e.g. welfare benefits and revenues from excise taxes) are not included, because the total resources available to society are not affected by such transfers. Neither is the deadweight loss of taxes to finance the transfer payments included in the determination. It has been considered, whether general consumption in the future, category (3) in the description of categories of future costs in section 2.2.5, should be deducted. But the nonhealth care costs are not included in the assessment, for the following reasons:

1. Danish estimates of future consumption based on Danish data are not available.
2. To the best of my knowledge, no comparison of the costs of non-health consumption of smokers versus non-smokers have been published.
3. None of the other studies of the costs of smoking have included this cost category.
4. The Danish guideline for economic evaluations (114) does not recommend inclusion of this type of cost.

Consequently, any determination of the costs of future consumption for smokers and non-smokers, respectively, would be entirely speculative, and it would not be possible to compare the results with the results from any other study of the costs of smoking.

The productivity costs include morbidity costs (days absent from work, rehabilitation, early retirement) and mortality costs, determined according to five-year age groups and gender. The most widely applied method for estimation of productivity costs in a COI analysis, the human capital approach (104), was selected for the determination of the productivity costs due to

⁹ There are practical and conceptual problems in disentangling the “related” and “unrelated” components of costs for “related” diseases. The comprehensive exclusion of future “unrelated” costs would therefore be difficult, if not impossible, in practice

smoking-related morbidity and mortality. The calculations here are based on information on the nominal labour income, depending on gender and age group, the average individual concerned would have been expected to earn during his or her expected remaining time in the active labour force (160). These expectations are combined with empirical estimates of the rate of active labour market participation (161). Here, the calculations of the productivity costs have been truncated at the age of 69, effectively assuming that the present value of human capital for persons older than 69 years is equal to zero. The algorithm used for determining the values of human capital is presented in Appendix D.

The direct and productivity costs are calculated and allocated within the four disease groups cancer, cardiovascular diseases, respiratory diseases and 'all other diseases'.

In summary, this study is thus a partial cost of-illness analysis of the costs of smoking using a dynamic life cycle approach (taking survival probabilities into account) including present and future smoking-related medical health care costs, and present and future unrelated medical health care costs, plus the value of productive output lost due to morbidity, disability and premature mortality.

3.2.1 Annual direct health care costs and productivity costs attributable to smoking

In the calculation of the annual direct health care costs and productivity costs attributable to smoking for ever-smokers (Study I), the estimated PAR%*s* for ever-smokers, depending on age, gender and group of diseases, are applied to the yearly costs according to age, gender, group of diseases and cost category. Subsequently, the annual costs per person-year are calculated by smoking status, age, gender, disease, and cost category, assuming that the remaining costs are independent of smoking status. The algorithm for determining the total costs is shown in Appendix E.

In general, the use of resources should be valued at their opportunity costs, i.e. the value of their best alternative use. Under certain assumptions, the market price under perfect competition can be considered a valid estimate of these opportunity costs, but in the health care sector perfect competition can not be assumed and most prices, if they exist, are negotiated. In the present study, the unit prices used for the valuation of hospital costs are based on, respectively, the NordDRG (diagnosis-related groups) and tariffs, the costs of physiotherapy treatments are based on fees of general practitioners, and the costs of medications are determined using pharmacy outlet prices. The productivity costs are estimated based on average annual labour income according to age and gender.

All the data and sources of data have been described in the two studies (I and II). Additional details concerning the calculation of the annual direct costs of hospital admissions, outpatient visits, consultations with general practitioners and physiotherapists, and medications are shown in the Appendices F-H. Details concerning the calculation of the annual productivity costs of mortality, early retirement, rehabilitation, and days of sickness absence attributable to smoking are shown in the Appendices I-L.

The sum of annual disease-specific smoking-attributable costs, estimated from the disease-specific PAR-estimates by age and gender, exceed the annual smoking-attributable costs from all causes, estimated by the all-causes PAR-estimates by age and gender. Therefore each estimate of the annual disease-specific costs attributable to smoking is calibrated by a reduction factor proportional to their share of the sum of annual disease-specific costs attributable to smoking. In the calculation of the annual smoking-related direct and productivity costs for current smokers (Study II), these calibrated smoking-related costs by age, gender and disease are further distributed by quantity of daily tobacco consumption. This is made by multiplying the annual smoking-related direct and productivity costs for current smokers by a factor representing the share of the quantity-specific PAR% (by age, gender and disease) of the overall ever-smokers' estimated PAR% (by age, gender and disease).

3.3 Life expectancy and lifetime costs

The time horizon of the analysis should extend far enough into the future to capture the major health and economic consequences. The present study applies a long-term time horizon in order to capture the full life span for the included age groups, truncated at 89 years of age. For the youngest age groups, the analysis thus comprises a horizon of fifty years.

By multiplying the annual costs per person by the survival probabilities and discounting by 5% per year (see the next section), total, direct and productivity health costs are obtained for men and women by smoking status and age (35-89, 40-89, etc. up to 75-89 years). The estimation of total lifetime health costs assumes that the estimated present cost per person-year for a 45 years old is an appropriate estimate of the cost per person-year ten years ahead for a person who is now 35 years old (a stationarity assumption).

In the first study, the standard life table from Statistics Denmark (146) is used to estimate the survival probabilities for never-smokers and ever-smokers by gender, conditional on being alive at given ages (35, 40, ..., 75), and truncated at 89 years. In the second study, the survival probabilities are estimated for current smokers and for ex-smokers by gender and quantity of daily tobacco consumption, conditional on being alive at age 35.

The algorithms for estimating life expectancies by smoking status are shown in Appendices M and N and for estimating lifetime costs in Appendix O, respectively. Appendix Figure 2 (Appendix P) reports the estimated probabilities used in the thesis.

3.4 Discounting

The determination of the lifetime health care costs of smoking and smoking cessation requires the calculation and summing of costs accruing over a long time period. Discounting effectively enables calculation of the present value of a time series of costs or benefits, in which the present valuation of each item (cost or benefit) diminishes by the distance in time, hence the term discounting. There has traditionally been two competing economic theories regarding how to appropriately select a social discount rate for the evaluation of public investment projects: a) the opportunity cost approach, and b) the social rate of time preference approach (162).

The opportunity cost approach is based on the notion that public investments can compete with or crowd out private investments. The appropriate social discount rate for public programmes is accordingly the expected rate of return on private investments, which, under particular conditions, may be assumed to be reflected by the average market rate of interest.

Alternatively, the social rate of time preference may be claimed to be the aggregate of the time preference rates of the individuals that comprise the society, and a number of arguments are advanced to justify a general assumption of positive time preference for the individuals, i.e. a preference for benefits today rather than in the future (and, adversely, for postponing costs into the future): 1) individuals may have a short-term view of life; 2) the future is uncertain, so a good available now is worth more than the same good at a future time; 3) with positive economic growth, individuals expect to be richer in the future and, assuming decreasing marginal utility of income, a given sum of money now is worth more than in the future.

There are thus two approaches to the weighting of future, as compared to, present benefits and costs, and accordingly, there is no such thing as one single correct rate of discount. The choice of any particular rate may therefore be characterized as somewhat arbitrary. Using the life cycle approach to determine the costs of smoking, the discount rate selected for the estimation of the present value of future direct costs and productivity costs may have a significant impact on the cost estimates, so it is very important to select an appropriate rate and also to perform sensitivity analyses based on several alternative rates (see the paragraph on sensitivity analysis). The rates most frequently recommended and applied in pharmacoeconomic studies are 3% and 5% (163;164). Here, I have used a discount rate of 5% per year for the base case calculations.

3.5 Sensitivity analyses

In this determination of the economic impacts of smoking and smoking cessation, a synthesis of data from a number of different sources has been made. The application of these data and the way, in which they have been combined, is to a certain extent based on assumptions, and this engenders uncertainty regarding the results of the analysis. According to Manning, Fryback, and Weinstein (165), one should distinguish between different forms of uncertainty:

- Parameter uncertainty, i.e. uncertainty about the true numerical value of the parameters used as inputs.
- Model uncertainty, i.e. uncertainty about the correct way of combining the parameters used (model structure uncertainty) and uncertainty introduced by the combination of decisions made by the individual analyst (modeling process uncertainty).

These different types of uncertainty should be handled differently.

The standard way of dealing with these types of uncertainty in economic studies has been to perform sensitivity analyses, in which some critical components in the calculation are changed by reasonable amounts or varied between extremes in worst/best case scenarios. In cases, where the calculations rely on assumptions, the impact of alternative assumptions may be examined in the sensitivity analysis. But, there are several ways to deal with multiple sources of uncertainty. The traditional approach to sensitivity analysis is to examine one variable at a time (165). However, such one-way sensitivity analyses can not be considered to reflect appropriately the entire uncertainty surrounding the result, which will typically be underestimated by this approach. It may therefore be reasonable to perform a multivariate sensitivity analysis, for instance by combining the uncertainty estimated for those components that have most impact on the result. If this type of sensitivity analysis is applied, it is important to realize that the use of extreme values of the parameters to produce overall worst or best estimates may in some cases result in an exaggerated estimate of the uncertainty.

The sensitivity analyses performed here have taken into account both parameter uncertainty and uncertainty regarding the model structure. The robustness of the results of the analyses was examined by repeating the analysis after varying the parameters and assumptions considered having the greatest impact.

In the first study (17), the sensitivity analyses performed comprise:

1. Different RR-estimates, i.e. lower (RR_L) and upper (RR_H) bounds of each RR being $1+0.5(RR-1)$ and $1+1.5(RR-1)$.
2. A narrower definition of smoking-related diseases, an RR of 1.0 for 'all other diseases' other than respiratory, cardiovascular and cancer.

3. The rate of discount, i.e. the analyses are redone with the following, alternative rates of discount: 3%, 8%, and 0% (no discounting).
4. A combination of: a) different RR-estimates and discount rates; and b) the more narrow definition of smoking-related diseases and different discount rates.

In the second study (18), the following sensitivity analyses are performed:

5. Various RR-estimates, i.e. lower (RR_L) and upper (RR_H) bounds of each RR being $1+0.5(RR-1)$ and $1+1.5(RR-1)$.
6. Different time-spans over which the mortality risk of ex-smokers is reduced to the level for never-smokers: lower (RR_{long}) and upper (RR_{short}) bounds being $15\text{years}+(0.5*15\text{years})$ and $15\text{years}-(0.5*15\text{years})$.
7. The rate of discount, i.e. repeating the analysis with different discount rates: 3%, 8% and 0%.
8. A combination of: a) different RR-estimates and discount rates; and b) various time lags for the risks of ex-smokers to be reduced to the level of never-smokers and different discount rates.

Handling model process uncertainty would ultimately require that a given study be repeated independently by one or several other analysts not having any contact with the original analysts. In the context of the present thesis, the process has been that the model chosen for the analysis, the assumptions made and the handling of the data have been discussed continuously, and at times modified, in a close collaboration with my supervisors.

4. Results

In this section, a summary of the main results of Study I (17) and Study II (18) is first presented; the details are described in the original papers. Subsequently, the results of the sensitivity analyses are presented.

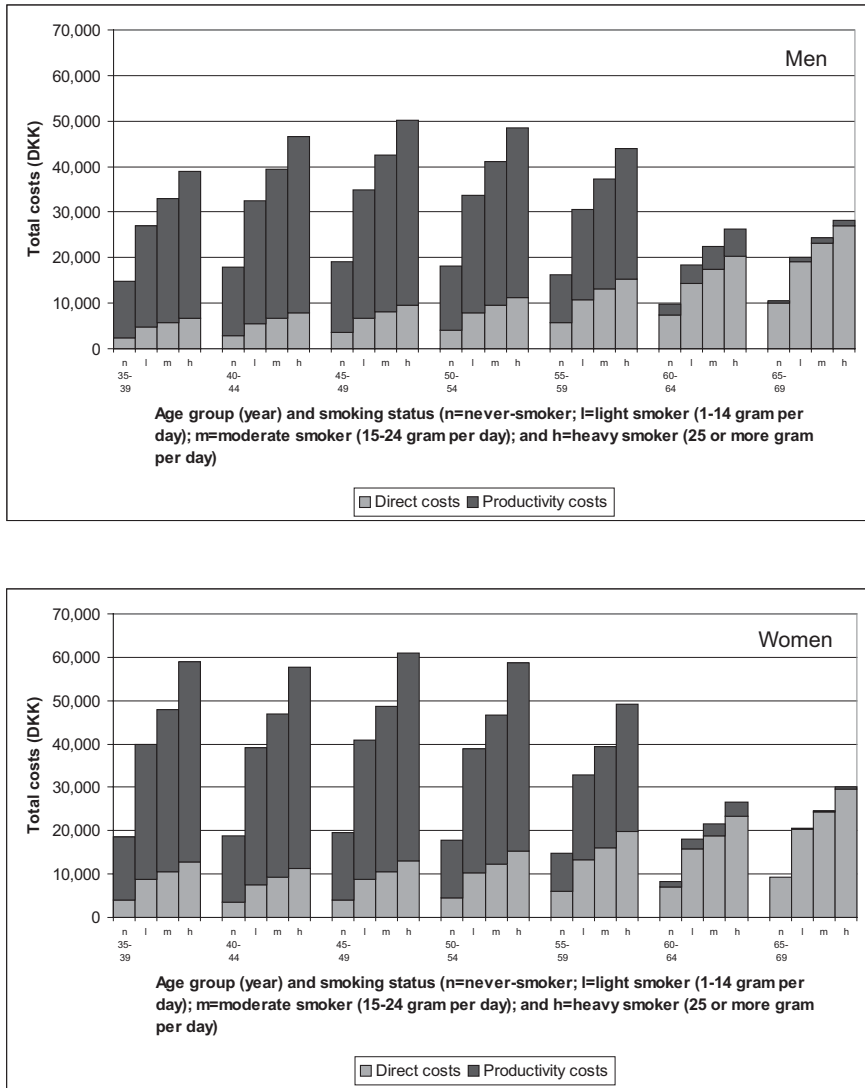
4.1 The annual direct health care costs and productivity costs attributable to smoking

The first study shows that, estimated on an annual basis, smoking imposes substantial health-related economic costs on society. In 1999, the estimated direct health care costs and productivity costs, respectively, amounted to 9,720 million DKK (34.0% of the overall annual direct health care costs of people aged 35 to 89) and 13,940 million DKK (34.8% of the annual productivity costs of people aged 35 to 69). The sources of information for these estimates and the annual direct health care costs by cost categories appear from Table 1 (Study I, Appendix R) (17).

4.2 The annual direct health care costs and productivity costs of never-smokers and ever-smokers

Figure 1 (Study I, Appendix R) (17) shows that, for both men and women and all age-groups, ever-smokers incur both higher annual direct health care costs and higher annual productivity costs than never-smokers. A summary of the annual direct health care costs and productivity costs by age, gender, and amount of tobacco smoked per day, as estimated in Study I (17) and Study II (18), is provided by Figure 1. It appears that, irrespective of smoking status, direct health care costs rose sharply at age 35 for men and age 40 for women, whereas productivity costs per person-year rose slightly with age till age 45 for both men and women and decrease thereafter.

Figure 1. Annual total health costs per person by costs categories, smoking status, age, and gender. Denmark, 1999.



4.3 The lifetime direct health care costs and productivity costs of ever-smokers and never-smokers

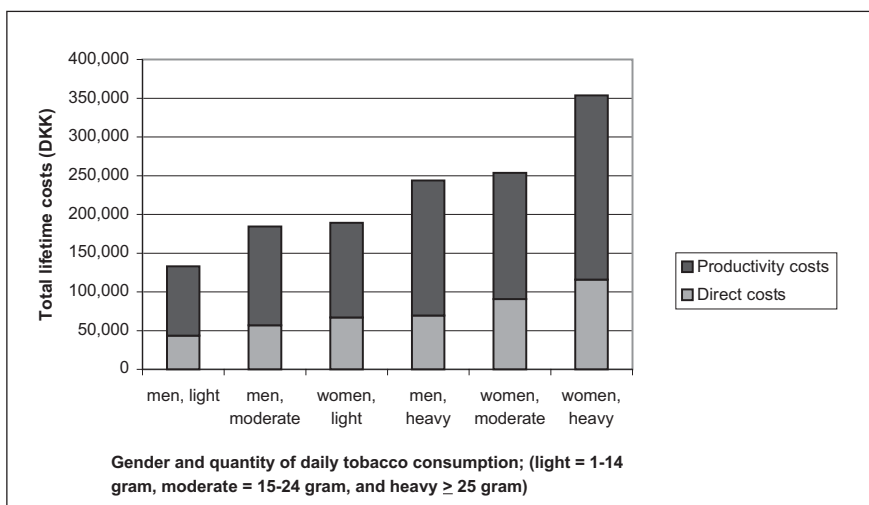
However, the estimated annual costs per person ignore the differences in expected longevity between smokers and never-smokers. These differences are substantial: it is estimated that for ever-smokers, 68% of those alive at age 35 would still be alive at 70, while this per cent would be 82% for never-smoking men. For women, the corresponding proportions are 75% for ever-smokers and 85% for never-smokers. Taking the differences in life expectancies into account (Figure 2, Appendix P), it has been shown (Figure 2 (Study I, Appendix R)) (17) that, even though never-smokers live longer than ever-smokers, the costs they incur over their lifetime are smaller, both in terms of direct health care costs and productivity costs. From Table 2 (Study I, Appendix R) (17) it appears that for men, the lifetime direct health care costs, productivity costs and total costs, respectively, of a 35-years old ever-smoker are 1.66, 1.83, and 1.78 times higher, respectively, than those of a never-smoker of the same age. For women, the corresponding ratios are 1.74, 1.79, and 1.77. It also appears that the costs of ever-smokers exceed those of never-smokers within every type of disease, but particularly so for respiratory diseases.

4.4 The reduction of direct health care costs and productivity costs attributable to smoking cessation

The complete results of the analysis of the economic impact of smoking cessation are shown in Figure 1 (Study II, Appendix S) (18). It appears from the table that, when direct health care costs and productivity costs are determined over a lifetime perspective, it is economically beneficial for the society, if smokers between 35 and 55 years of age quit smoking. For those older, smoking cessation is of little economic consequence for society. The estimated percentage reductions of direct health care costs and productivity costs, respectively, vary from 30% to 43% and 25% to 38%, respectively, depending on age and gender. A summary for the 35-years old is given in Figure 2. Comparing ex-smokers, who quit smoking at age 35, with smokers of the same age who continue to smoke, it is shown that the reduction of direct health care costs and productivity costs is highest for moderately and heavily smoking women.

Table 1 (Study II, Appendix S) (18) shows that for all types of disease, the costs of a 35-years old ex-smoker are below the costs of those continuing to smoke. This finding is particularly noticeable for the diseases with the highest excess risk for smokers, namely cancers and respiratory diseases.

Figure 2. The reduction of lifetime societal costs due to smoking cessation for a 35-years old, by gender, quantity of daily tobacco consumption and cost category. Direct health care costs and productivity costs are truncated at ages 89 and 69, respectively. 5% discount rate. Denmark, 1999.



4.5 Sensitivity analyses

In Table 3, an overview of sensitivity analyses based on Study I is presented as rate ratios (ever-smokers / never-smokers) for men and women 35 years old. In general, the table shows that the results for both men and women are the same across a broad range of RR-estimates and discount rates. But it also appears that the lifetime direct health costs of ever-smokers exceed that of never-smokers only slightly under the extreme assumption that the RR-estimate is 1.0 for 'all other diseases' than cancer, cardiovascular and respiratory diseases, and when future costs are not discounted.

Table 3. The lifetime health costs of 35 years-old by smoking status, gender, cost, and discount rate. Direct and productivity costs are truncated at age 89 and 69, respectively. Denmark, 1999. 1000 DKK.

Gender and discount rate	Cost	Cost (1000 DKK)		Cost ratio (sensitivity range) ^a			Cost ratio (sensitivity range)		
		Ever-smoker	Never-smoker	Ever-smoker/never-smoker			Ever-smoker/never-smoker		
				RR	RR _L	RR _H	RR ^b	RR _L	RR _H
Men									
0%	Direct	445	308	1.45	(1.23	1.65)	1.02	(1.02	1.03)
	Productivity ^c	613	339	1.81	(1.41	2.18)	1.14	(1.08	1.17)
3%	Direct	210	133	1.58	(1.30	1.84)	1.08	(1.05	1.10)
	Productivity	441	243	1.82	(1.42	2.20)	1.13	(1.08	1.17)
5%	Direct	140	84	1.66	(1.34	1.97)	1.10	(1.06	1.13)
	Productivity	365	200	1.83	(1.42	2.22)	1.13	(1.08	1.16)
8%	Direct	87	49	1.77	(1.40	2.14)	1.13	(1.08	1.17)
	Productivity	285	155	1.84	(1.43	2.23)	1.12	(1.08	1.16)
Women									
0%	Direct	543	356	1.52	(1.29	1.74)	1.07	(1.05	1.07)
	Productivity	625	351	1.78	(1.40	2.15)	1.13	(1.08	1.16)
3%	Direct	259	156	1.66	(1.36	1.95)	1.12	(1.08	1.14)
	Productivity	459	257	1.79	(1.41	2.16)	1.13	(1.08	1.16)
5%	Direct	176	101	1.74	(1.39	2.06)	1.13	(1.09	1.16)
	Productivity	384	214	1.79	(1.41	2.16)	1.12	(1.08	1.16)
8%	Direct	113	62	1.82	(1.43	2.19)	1.15	(1.10	1.18)
	Productivity	304	169	1.79	(1.41	2.16)	1.12	(1.07	1.15)

a: The sensitivity range was calculated with the lower ($RR_L = 1 + 0.5(RR - 1)$) and upper bounds ($RR_H = 1 + 1.5(RR - 1)$) of the relative risks.

b: $RR = 1.0$ for 'other diseases'.

c: Estimated with the human capital method.

Source: Relative risk-estimates are based on Prescott et al. (26).

In Table 4, an overview of the sensitivity analyses based on Study II is presented as rate ratios (current smokers / former smokers) for men and women 35 years old. Table 4 shows that the lifetime direct health care costs and productivity costs of current smokers exceed that of former smokers. It also appears that, for both men and women, the results are the same across a broad range of assumptions regarding the time required for the mortality risk of former smokers to decline to that of never-smokers in combination with different discount rates. The table also shows that the results are robust across a broad range of RR-estimates combined with different discount rates.

Table 4. The lifetime health costs of 35 years-old by smoking status, quantity of daily tobacco consumption^a, gender, cost, and discount rate. Direct and productivity costs are truncated at age 89 and 69, respectively. Denmark, 1999, 1000 DKK.

Gender and discount rate	Daily quantity of tobacco consumption and smoking status										Daily quantity of tobacco consumption and smoking status										Daily quantity of tobacco consumption and smoking status										
	Cost			Cost ratio (sensitivity range) ^b			Cost			Cost ratio (sensitivity range)			Cost			Cost ratio (sensitivity range)			Cost			Cost ratio (sensitivity range)			Cost			Cost ratio (sensitivity range)			
	Current	Former	RR	RR _L	RR _H	RR _{long}	RR _{short}	Current	Former	RR	RR _H	RR _{long}	RR _{short}	Current	Former	RR	RR _H	RR _{long}	RR _{short}	Current	Former	RR	RR _H	RR _{long}	RR _{short}	Current	Former	RR	RR _L	RR _H	RR _{long}
Men	0%	Direct	463	332	1.39	(1.21	1.56)	(1.35	1.44)	500	340	1.47	(1.25	1.65)	(1.41	1.53)	383	198	1.94	(1.52	2.28)	(1.75	2.13)	852	507	1.68	(1.41	1.87)	(1.44	2.02)	
		Productivity ^d	604	426	1.42	(1.24	1.56)	(1.29	1.58)	722	468	1.54	(1.32	1.70)	(1.36	1.79)	222	122	1.82	(1.47	2.09)	(1.62	2.07)	612	386	1.59	(1.36	1.73)	(1.37	1.93)	
	3%	Direct	217	151	1.43	(1.23	1.61)	(1.36	1.51)	242	159	1.53	(1.29	1.72)	(1.43	1.64)	163	94	1.74	(1.43	1.96)	(1.54	2.01)	505	330	1.53	(1.33	1.66)	(1.33	1.87)	
		Productivity	432	316	1.37	(1.21	1.49)	(1.25	1.54)	518	353	1.47	(1.29	1.59)	(1.30	1.72)	111	69	1.62	(1.37	1.79)	(1.44	1.92)	393	270	1.45	(1.28	1.56)	(1.28	1.79)	
Women	0%	Direct	88	63	1.40	(1.23	1.54)	(1.30	1.54)	103	69	1.49	(1.27	1.63)	(1.36	1.68)	735	421	1.75	(1.45	1.98)	(1.63	1.87)	1024	566	1.81	(1.51	2.01)	(1.51	2.26)	
		Productivity	277	214	1.29	(1.17	1.38)	(1.19	1.47)	333	243	1.37	(1.23	1.45)	(1.23	1.62)	380	211	1.80	(1.48	2.02)	(1.63	2.02)	751	446	1.68	(1.43	1.84)	(1.43	2.11)	
	3%	Direct	288	187	1.54	(1.31	1.73)	(1.45	1.66)	333	197	1.69	(1.43	1.89)	(1.57	1.85)	268	153	1.76	(1.46	1.96)	(1.57	2.03)	627	390	1.61	(1.39	1.74)	(1.38	2.03)	
		Productivity	512	355	1.44	(1.27	1.56)	(1.29	1.68)	609	399	1.52	(1.34	1.64)	(1.33	1.85)	178	108	1.65	(1.40	1.81)	(1.47	1.96)	496	327	1.52	(1.33	1.63)	(1.32	1.91)	
5%	Direct	196	129	1.52	(1.30	1.68)	(1.41	1.67)	230	139	1.65	(1.42	1.82)	(1.52	1.85)	380	211	1.80	(1.48	2.02)	(1.63	2.02)	751	446	1.68	(1.43	1.84)	(1.43	2.11)		
	Productivity	427	305	1.40	(1.25	1.50)	(1.26	1.63)	509	346	1.47	(1.31	1.56)	(1.29	1.79)	268	153	1.76	(1.46	1.96)	(1.57	2.03)	627	390	1.61	(1.39	1.74)	(1.38	2.03)		
8%	Direct	126	87	1.45	(1.27	1.57)	(1.34	1.63)	150	96	1.56	(1.38	1.68)	(1.42	1.80)	178	108	1.65	(1.40	1.81)	(1.47	1.96)	496	327	1.52	(1.33	1.63)	(1.32	1.91)		
	Productivity	338	251	1.34	(1.22	1.43)	(1.22	1.57)	402	287	1.40	(1.27	1.47)	(1.25	1.70)	496	327	1.52	(1.33	1.63)	(1.32	1.91)	496	327	1.52	(1.33	1.63)	(1.32	1.91)		

a. Light: 1-14 gram daily tobacco consumption, moderate: 15-24 gram daily tobacco consumption, heavy: 25 or more gram daily tobacco consumption.

b. The sensitivity range was calculated with the lower (RR_L=1+0.5*(RR-1)) and upper bounds (RR_H=1+1.5*(RR-1)) of the relative risks; and with different years lowering the excess risk of death caused by smoking lower (RR_{short}=15 years+(0.5*15 years)) and upper bounds (RR_{long}=15 years+(0.5*15 years)).

c. Quitting smoking at the age of 35.

d. Estimated with the human capital method.

Source: Relative risk-estimates are based on Prescott et al. (26).

5. Discussion

5.1 Comparison of own results with other findings

The present thesis confirms previously published results from several countries (ie. the United States and Canada (9;166;167), and other countries such as Norway (168), Denmark (169), Finland (135), Germany (144;149), South Africa (170), China (139), Japan (171) and Korea (172)). Estimated on an annual basis, smoking imposes substantial costs on society.

By applying a dynamic life-cycle approach, it has furthermore been shown that, although never-smokers have a longer expected lifetime than ever-smokers, they are less costly in a lifetime perspective, with regard to both direct health care costs and productivity costs. Taking into consideration the difference in expected lifetime and the reduction in the excess risks of ex-smokers after they quit smoking, it is shown that smoking cessation leads to substantial reductions of the societal smoking-related costs, again for both types of costs. Although the cost reductions due to smoking cessation vary depending on gender as well as on the quantity consumed and the person's age at the time of quitting, smoking cessation leads to a sizeable reduction of total lifetime costs for all smokers between 35 and 55 years of age.

The results of other studies estimating the lifetime costs of smoking vary depending on the data used and the assumptions made. Leu and Schaub, Lippiat, and Barendregt et al. report that the lifetime costs of non-smokers are higher than those of smokers (13-15;134), while Manning et al., Hodgson, Oster et al., and Roberts and Lindgren, (11;12;16;119) reach the opposite result, in accordance with what is reported here.

Presumably, Leu and Schaub (14;134), who find that smoking does not increase lifetime medical costs, have seriously underestimated the difference in annual medical resource use and costs between smokers and non-smokers. As pointed out by Hodgson (11), Rice et al. (118) found, in a national survey carried out in the US that the average male smoker has 2.4 times more physician visits and 6.3 times more hospital days than what appears from the data used by Leu and Schaub. It must be assumed that, if this pattern of consumption of medical care was to be found in Switzerland as well, the conclusion of Leu and Schaub would be different. Contrary to the results from Leu and Schaub, Oster et al. (16) found that the lifetime costs are increasing with the quantity of tobacco consumed per day, but their study did not take the difference in expected lifetime of smokers and non-smokers into account. Adjusting Oster et al.'s cost figures (16) for smokers by deducting the average annual medical costs for non-smokers over 65 years

old for each year of life lost based on the estimates of Leu and Schaub (14), Lippiat found that smoking lowers lifetime medical costs (15). However, Lippiat's estimate of a non-smoker's annual medical costs may be considered as overstated, because Leu and Schaub severely underestimated the difference in annual medical care use and costs between smokers and non-smokers. In addition, Lippiat limited the smoking-related diseases to three (lung cancer, coronary heart disease and emphysema), thereby severely underestimating the lifetime medical costs of smoking by disregarding substantial amounts of morbidity, mortality and health care utilization attributable to smoking. In a study published later, Barendregt et al. showed that the ratio between the undiscounted lifetime direct cost of smokers and non-smokers was 0.87 and 0.85 for men and women, respectively (13). This discrepancy in results can not be explained by the classification of ex-smokers (into the group of non-smokers versus the group of ever-smokers), as the lifetime health costs of ex-smokers presumably lie between those of never-smokers and those of current smokers. But, by limiting the smoking-related diseases to five groups only (heart disease, lung cancer, stroke, other cancers, and chronic obstructive pulmonary disease) and assuming that the costs of all other diagnoses are independent of smoking status, Barendregt et al. omitted substantial smoking-related direct health costs, thereby underestimating the lifetime direct health costs for smokers while overestimating those for non-smokers. In the Dutch study it was found that smokers' lifetime direct health costs exceed those of non-smokers, if future costs are discounted by 4.5% for men and 5.5% for women. Finally, if Barendregt et al. had included more diseases in the group attributable to smoking and omitted the assumption that the costs for all other diagnoses were independent of smoking status, the lifetime direct health costs of Dutch smokers would probably exceed those of non-smokers even without discounting (13).

On the other hand, Roberts and Lindgren find that smokers use health care services and sickness and early retirement benefits so extensively that the effect of their shorter expected lifetime is offset (119). Corresponding to this result, Hodgson found that total lifetime health care costs of smoking men are 1.32 higher than for never-smoking men, while the corresponding ratio for women is 1.24 (11). These results are confirmed by Kiiskinen et al.'s econometric follow-up study (135), which found that the direct health care costs and the productivity costs of current smokers exceeded those of never-smokers by 46% and 90%, respectively. The study by Manning et al. (12) and Viscusi's update of their results (103) provide clear illustrations of the possibly decisive impact that the choice of discount rate may have on the results. With a discount rate of 5% the total lifetime net external costs of smokers are higher than those of non-smokers, while the relation is reversed, with no discounting.

5.2 Limitations of the study

This thesis is based on different types of data from various sources and on a specific set of assumptions, and this implies that the calculations are subject to a number of uncertainties. The most important types of uncertainties and their possible impact on the results will be discussed in the following.

5.2.1 The incidence-based method

The incidence-based method may be used to predict future consequences of current changes in the pattern of consumption. The method relies on annual costs derived from patients at various stages in the disease process and on current treatment practices to calculate incidence costs. It means that the natural history of disease and medical care use and costs are assumed to remain constant over time. The drawback of this approach is, consequently, that it is sensitive to unpredictable future medical, technological, demographic or other changes. This means, for example, that the lifetime direct health care costs of smokers will be underestimated if, during the prediction period, the costs of treating smoking-related chronic diseases increase thereby leading to an increase of the annual direct health care costs of smokers. In consequence, the difference between smokers and non-smokers' lifetime direct health care costs will be underestimated. Vice versa, of course, if those costs should decrease.

5.2.2 The population attributable risk per cent

The PAR-estimate is a theoretical construct based on specific assumptions. The PAR is an expression of the number of cases of the disease in the population one would expect to be prevented if a particular causal component, in this case smoking, was completely eliminated. However, estimated PAR%s may add up to more than 100%, as there may be more than one method to prevent a given disease (173).

In applying the PAR% construct as well as in interpreting the results of assessments based on this, there are some general as well as some specific conditions that should be given careful attention:

The distribution of costs is based on PAR%s derived from RR-estimates for mortality, which are applied to both mortality and morbidity data as well. This may be justified by the findings of several studies that indicate that smoking-related risks of days of sickness absence, hospital admissions, early retirement, visits to general practitioners, and use of prescription medicines are of similar size as those of all-cause mortality (118;174-176).

As the sum of annual disease-specific smoking-attributable costs exceeded the annual smoking-attributable costs from all causes the disease-specific annual costs were calibrated. This reduced the cost reductions achievable by smoking cessation except for heavily smoking men, but does not affect the relative reductions of lifetime costs.

Generally, the PAR-calculation may be underestimated because the PAR-estimates are based on the prevalence of current and former smokers in a given year. But, the smoking-related diseases and deaths that occur in 1999 are primarily among persons who started smoking maybe 30 years earlier, many of whom may at present have stopped smoking, and the prevalence of smokers was at that time much higher for persons of the same age, about 75% and 50% higher for men and women, respectively (145;151).

In relation to the smoking prevalence proportion:

The smoking- prevalence proportion (P) must be valid. There may be some uncertainty regarding the proportion of smokers assumed, as these estimates are based on a telephone interview, which make under- or misreporting of current tobacco consumption a possible error. There is, however, no reason to assume that this should be the case. From a meta-analysis of the validity of self-reported smoking it is reported that, across the studies included, the sensitivity of self-reported smoking is 87% and the specificity 89%, when self-reported smoking is biomedically validated. The results of the meta-analysis suggest that interviewer-administered questionnaires yielded higher accuracy in terms of sensitivity and specificity than self-administered questionnaires and, in addition, that the validity is higher in population-based surveys than in intervention studies, where people under-report more (177).

Furthermore, it must be assumed that it is feasible to reduce the prevalence of smoking, as it has been shown that reduction of the amount smoked per smoker has not been associated with any significant benefits compared to continuous heavy smoking (178). This assumption is supported by the fact that it has been possible to reduce the proportion of everyday smokers by around 40% between 1970 and 1999 (145;151).

In relation to the RR-estimates:

This study has several advantages. The RR-estimates are based on Danish data¹⁰ with gender and disease group specific RR-estimates adjusted for age, study population-, and calendar period effects. Furthermore, the RR-estimates for death of all causes are based on RR-estimates for respectively <65 years and >65 years old. Finally, the RR-estimates are rather robust in relation to confounding; in Danish studies, based on the same study populations as the epidemiological study on which this study is based, there has been adjusted for several potential confounders depending on disease group (49;179;180).

¹⁰ The Copenhagen City Heart Study (CCHS), the Glostrup Population Studies (GPS), and the Copenhagen Male Study (CMS).

The measures of PARs are subject to some limitations in relation to the RR-estimates. Firstly, the RR-estimates are based on the assumption that the risk factor is causally associated with the diseases of interest. Secondly, they are based on the assumption that if smokers had not become smokers, they would have had the same incidence of diseases attributable to smoking as never-smokers, because it is assumed that other etiological factors are equally distributed among smokers and non-smokers. Only under this condition will the RR-estimates be valid and not biased by confounding and interaction. Confounding occurs when an estimate of the association between an exposure and an outcome is affected by the real effect of another exposure on the same outcome, where the two exposures are correlated. If there is substantial variation between the stratum-specific estimates of effect, this is an indication of the presence of interaction between the exposure of interest and the so-called confounding factor (181).

Generally, age and gender are obvious potential confounders in practically all studies. Estimating the health effects of various behavioural factors will often be encumbered by potential confounding from diverse socioeconomic and psychosocial factors that should probably be regarded just as proxy measures of more direct, but unknown, causes of disease. Potential confounders in the epidemiological study, on which the present study is based, will vary with disease entity and include socioeconomic factors like social position, measured by income, education (182;183), and employment grade (182;183), psychosocial factors like a stressful life-style (184), depression (185-187), and perhaps some aspects of diet (188), and physical inactivity (189;190). Other cardiovascular risk factors, e.g. overweight, hypertension and increased cholesterol values could also be potential confounders. The quantitative effect of smoking will vary with the prevalence of confounders, but on the other hand, not all the potential confounders mentioned above actually lead to confounding in a given study. However, the risk of confounding needs careful consideration and adjustments for relevant factors must be considered, either in the design of the epidemiological study or in the analysis.

Lung cancers constitute the majority of the smoking-related cancers. For lung cancer, there are virtually no other risk factors than smoking with a substantial impact in public health, so the impact on the estimated burden of this disease that would result from accounting for other risk factors would be extremely limited (191). Accordingly, the RR-estimates for lung cancer are not affected by controlling for length of education as a proxy for occupational exposure (180). The estimated RRs for cancer, on which the present study is based, may, however, be confounded to a minor extent by alcohol. Alcohol consumption increases the risks of cirrhosis of the liver, cancers of the mouth, pharynx, larynx and oesophagus (192), but these cancers only make up a small part of all deaths of cancers about 2% in women and 3%

in men, respectively. Adjusting for alcohol consumption in the case of oral cancer is inappropriate, however, because alcohol not only is a potential confounder but also acts synergistically with smoking to increase the risk of oral cancer. For almost four decades it has been accepted that cigarette smoking and asbestos fibres separately are potential causes of lung cancer, while it is still discussed what the interaction of the two agents may imply; a multiplicative or an additive relation (193-196). It should be noted, however, that asbestos-related cancers only make up a negligible part of the total numbers of cancers.

Similarly, in relation to the respiratory diseases among which COPD constitutes the greater part of the smoking-related diseases, it is well established that, compared to smoking, there are not any considerable risk factors (191). Furthermore, in a longitudinal population study based on two¹¹ of the three Danish population studies it has been shown that adjusting for socioeconomic status using length of education as a proxy does not affect the smoking-related risk of hospitalization for COPD (179).

For cardiovascular diseases, there are several potential confounders. Notwithstanding this, analyses based on the same study populations as the present have shown that the estimated smoking-related gender- and age-specific relative risks of myocardial infarction were not affected after multiple adjustments for other risk factors, including socioeconomic and psychosocial factors such as educational level and physical activity, and in addition to those arterial blood pressure, blood lipids, body mass index, diabetes, height, and alcohol consumption. Furthermore, there was no interaction between smoking and other risk factors (49). There is some correlation between smoking and alcohol consumption. In this context it should be remarked that alcohol consumption apparently reduces the risks of ischaemic heart disease (192;197) and stroke; in particular, it has been shown that wine consumption is associated with lower risk of stroke (see e.g. (198)). Psychosocial factors could be potential confounders in relation to the smoking-related RR-estimates for cardiovascular diseases. E.g. symptoms of fatigue and depression have been shown to predict cardiovascular disease and are also associated with smoking (199). However, in the recently published INTERHEART Study it appears that stress is associated with acute myocardial infarction but at the same time stress is correlated with high income and high education (200). Thus, possible confounding might act in both directions in relation to RR-estimates applied for smoking.

For the heterogeneous group "all other diseases" it is similarly the case that possible confounding might act in both directions in relation to the RR-estimates applied for smoking.

¹¹ The Copenhagen City Heart Study (CCHS), the Glostrup Population Studies (GPS).

Previous studies based on the CPS-II Study have been criticized for overestimating the smoking-related attributable fractions and the smoking-attributable mortality estimate owing to the use of only partially adjusted RR-estimates (201). On the other hand, Thun et al. have shown that adjusting for socioeconomic and lifestyle factors reduces the CPS II Study's age- and sex-adjusted RR-estimates only slightly and decreases the overall estimate of deaths attributable to smoking in the United States by only 1%. In contrast, it might be argued that controlling for factors like physical inactivity and low body mass index may lead to underestimated PAR-estimates, as they can be caused by smoking or smoking related diseases. Thun et al. consider three factors as possible explanations of the finding that adjusting for socioeconomic and lifestyle factors only minimally changes the RR-estimates and the estimates of smoking-attributable deaths. First, because smokers and non-smokers in the study population are recruited primarily from friends and families of volunteers, they are more homogenous with respect to socioeconomic and educational status than the entire United States population. Second, not all of the behavioural factors associated with smoking were detrimentally associated with survival (e.g. alcohol consumption is mentioned in relation to lower cardiovascular mortality). Third, the decrease, after adjustment, in smoking attributable deaths among female former smokers was partly counterbalanced by the increase among male current smokers (202). Acknowledging that the aggregation of PARs for tobacco and alcohol consumption may imply an overestimation of the aggregate effect, Holman and Armstrong have, based on seven diseases,¹² which are associated with both tobacco and alcohol, estimated that the extent of the possible double counting is only 3% (203).

Risk and reduction of risk in relation to time

In estimating population attributable risks, it has been assumed that the risk of diseases for smokers depends only on the quantity of tobacco currently smoked per day (measured in grams). However, for cancers and COPD the risk depends critically on the amount of tobacco consumption accumulated over time (19;180). While the RR-estimates for Danish smoking men will probably not increase any more, it may turn out that the RR-estimates applied for women are too small, as it has been shown that the average female smoker in 1992 had started smoking at a younger age than the average female smoker in 1977 (26;35). Although a wide range of RR estimates have been used for the sensitivity analyses, this may imply that the lifetime health care costs for smoking women may have been underestimated. The RR estimates for respiratory diseases applied for women were higher than those for men (higher risk estimates for women have been reported in a number of recent studies (204)). However, respiratory diseases account for

¹² Lip cancer, oral cancer, pharyngeal cancer, oesophageal cancer, pancreatic cancer, larynx cancer, and stroke.

a relatively low proportion of the total lifetime health costs, for which reason the overall conclusion is shown to be relatively insensitive to the wide range of RR-estimates considered here. As there is some uncertainty regarding the precise time course of risk reduction for ex-smokers after quitting, it was assumed in the second study that the overall and disease-specific risks for ex-smokers, regardless of the amount of daily consumption before quitting, reverse linearly to the level of never-smokers over a 15 years period (18).

Misclassification in relation to the epidemiological study

Misclassification of smoking status is inevitable in cohort studies, but this will not necessarily lead to biased RR-estimates. Misclassification may imply an over- just as well as an under-estimation of the RR-estimates for smokers: There are smokers who have quit smoking during the follow-up period of the epidemiological study, and this will lead to an underestimation of the risks of smoking. There are also smokers that only stop smoking after they begin to be affected by some life threatening condition, irrespective of the ultimate cause of the illness. It appears from a recent publication from the British doctor-study that the latter may be quite predominant (205). This may lead to a reduction of the mortality of current smokers and consequently to an underestimation of the RR-estimates.

Summary

To summarize, there is a risk that the RR-estimates may be confounded, but it may arguably be maintained that it is unlikely that the RR-estimates have been influenced significantly by the combined effect of all these factors that may cause under or over-estimation of the risk associated with smoking. The reasons for this assessment are that several studies based on the same population samples as the present have controlled for important confounders without this having a significant impact on the RR-estimates, and those confounders that have not been controlled for may work in both directions. Non-differential misclassification will tend to lead to an underestimation of the RR-estimates. In addition, other studies (202;203) indicate that the problems caused by confounding and interactions and the use of PAR are not very important and do not have a significant impact on the main result. Finally, as an additional check sensitivity analyses have been performed and these indicate that changing the RR-estimates over a fairly wide range¹³ does not have much impact on the results. When reexamining the data with an RR for "other diseases" equal to 1.0, the direct lifetime health care costs of ever-smokers still exceed those of never-smokers albeit only slightly. Neither does changing the period of risk adjustment after smoking cessation over a fairly wide range (from 7.5 to 22.5 years) have much impact on the results.

¹³ With the lower bound of the relative risks being $RR_L = 1 + 0.5(RR - 1)$ and the upper bound being $RR_H = 1 + 1.5(RR + 1)$.

5.2.3 The survival probabilities

The survival probabilities applied may influence the validity of the calculations reported here, but the estimates are in very good agreement with the findings of a Danish empirical study of never-smokers and smokers with different smoking habits (22).

5.2.4 Data and the determination of the direct costs

When a generalization of cost implications to a national level is necessary, the use of average costs rather than marginal costs is recommended. Also when longer-term cost consequences are calculated, average costs may be more appropriate, because many costs-items that are fixed in the short term, may become variable in the long term (132). Usually, the average prices include both variable costs and fixed costs, such as costs (depreciation) of hospital buildings, whereas the marginal costs only measure the costs of producing one more unit of outcome of the intervention.

The costing of the hospital stays and outpatients visits is based on NordDRG (the Nordic diagnosis-related groups). However, the DRG-tariffs include only all the operational costs associated with diagnosing, treatment and nursing of patients (206). By spreading out the initial capital outlay over the useful life of the asset, the capital costs could be incorporated and allocated into the DRG-tariffs. However, such depreciation costs are not included, and this implies that the costs of hospital stays and outpatients visits are underestimated. Arriving at estimates of the capital costs would necessitate inclusion of both depreciation of existing capital and investment in future capital. Subsequently, the capital costs should be allocated to the different disease categories, and an appropriate time horizon should be selected, but this may be problematic especially during a period with continuous changes of the health care sector. For both stationary (or hospitalized) and ambulatory patients, the frequencies extracted from the National Register of Patients (LPR) have been based only on the primary diagnoses, and this is a further reason to suppose that the lifetime hospital costs of smokers should probably be considered underestimated in the present study.

The use of average costs engenders difficulties in estimating the cost savings associated with smoking cessation. For instance, the extent to which costs can be saved when hospital stays are shortened and the number of beds needed or the number of outpatient consultations are decreased depends on the flexibility available and the time period over which the change is made and assessed. Presumably, the cost savings obtainable from reduction of the proportions of smokers are lower than the difference between the average costs of smokers and the average costs of ex-smokers. In practice, it can be difficult to reallocate excess time for nurses and physicians and use it efficiently for other adequate tasks, and the order of magnitude of these costs can not be estimated properly by using average

costs. For solving this kind of problem, the use of marginal cost estimates has been found useful and appropriate (207).

As patient contacts with general practitioners and physiotherapists are not registered by diagnosis, the proportion of such contacts attributable to smoking assumed here was taken from a Danish cross-sectional multi-centre study (208) and applied to assessments of the total costs of all general practitioners consultations (about 63% of all costs of GPs' services) and of all physiotherapy treatments (about 94% of the total costs of treatments by private physiotherapists), respectively. By using data from a multi-centre study, the results can be assumed to be much more generally valid than results from single practice studies would be, as the data represent results from many practitioners and their patients. However, the distribution of these costs on diagnoses is subject to the reservation that the ICPC-codes (Wonica's International Classification of Primary Care) are not directly comparable to the ICD-10-codes, whereas the order of magnitude of the estimated costs may be considered appropriate. It is, accordingly, likely that the costs of physiotherapy for cancer patients have been overestimated, while those of the residual group 'other diseases' must be considered underestimated, as physiotherapeutic treatments predominantly concern the musculoskeletal and locomotion systems.

The estimates of the use and costs of pharmaceuticals were based on the grouping into 14 principal ATC-groups (Anatomical Therapeutic Chemical Classification System) of the national medicine statistical data. The costs of drugs attributable to smoking for respiratory diseases are probably underestimated, as they are based only on the cost of drugs against asthma (unlike what is the case for cancers and cardiovascular diseases, there is no single principal ATC-group for respiratory diseases). This is not considered to have any major impact on the determination of the total cost of pharmaceuticals attributable to smoking.

The costs of smoking cessation courses partly or entirely financed by the public sector have not been included in this assessment, as there have not yet been published cost estimates based on the Danish "Stop-smoking" database. This is considered not to be of major importance for the calculation of lifetime direct costs of ex-smokers, because the amounts involved are quite limited. An estimate based on 2001-data from three counties indicates that the public costs for smoking cessation courses range from 600 DKK to 1,300 DKK per participant, depending on the payment or not of public subsidies for nicotine substitutes (209).

5.2.5 Data and the determination of productivity costs

The data on deaths were derived from the national Register of Causes of Deaths. The validity of Danish death certificates has been criticized for being

insufficiently diagnosis specific (210) while the coding in the Register of Causes of Deaths must be considered valid (211). However, the former condition is of minor importance for the thesis, as the cause of deaths has been classified in only four disease groups. By assuming that all persons allocated a pension or early retirement benefits are unable to work, the estimated productivity costs of early retirement must be somewhat overestimated, as persons allocated the intermediate level of early retirement benefits and the ordinary and the raised ordinary old age pensions must be considered to have a certain working capacity left.

The estimations of the productivity costs of sickness absence days attributable to smoking were based on official data from Statistics Denmark on spells of sickness benefits (212-214), supplemented by results plus notes from a study performed by The Danish Working Environment Authority (215;216), as the official data do not comprise all sickness absences. Therefore, a number of assumptions were required for performing the calculations, and this implies that the distribution of the costs on the various diagnoses should be regarded with certain reservations, whereas the order of magnitude of the estimated costs is considered appropriate.

As opposed to the normative question whether productivity costs should be taken into account in social decision making or not, the approach used to value the loss of production due to illness is a subject of methodological discussion. The official requirements with regard to how productivity costs should be reported are highly variable across countries. As an example, the Canadian guidelines require that productivity costs should be documented and reported when relevant as part of the description of the impact of the intervention (131). In Australia they should only be included, if the analysts document that they are important and relevant, and in that case they should be reported separately from the direct health care costs (217). The Danish guidelines for the reporting of pharmaco-economic analyses agree with the Australian that productivity costs should be reported separately (114).

Here, productivity costs have been estimated by applying the human capital method, because this is the most widely applied. It should be made absolutely clear, however, that the choice of method for calculating productivity costs has a decisive impact on the result of the economic calculations.

Advocates of the friction cost method have criticized the human capital approach for providing an estimate of the potential and not the actual loss of production, arguing that it most often is possible to rearrange or postpone work, when an employee is absent due to illness (106). In the US, it is recommended for cost effectiveness analyses that the productivity costs, if included, are estimated with the friction cost method (100), but so far only few studies have actually used the method (218-223). The illustrative study

by Koopmanschap et al. (107) shows that the total productivity costs (mortality and morbidity costs combined) are 8.5 times higher when calculated by means of the human capital method than when the friction cost approach is used. Similarly does it appear from the present thesis that the lifetime productivity costs are 4-10 times higher (depending on gender, the RR estimates, and the discount rate) when estimated by the human capital rather than the friction cost method (results not shown).

The uncertainty concerning the present determination of the productivity costs of smoking follows from the general disadvantages of the applied method, and as such they are more of a conceptual character. As the human capital approach is based on earned income, the method can be criticized for only according a value to the lives of persons earning a labour income, while non-paid work performed by for instance children, unemployed, house wives, or pensioners is accorded a very low value or none at all, which implies that the opportunity costs of the work performed are not reflected. As a consequence of this, the human capital method will generally underestimate the costs. Including the value of unpaid household labour lead to a 4.8 fold increase of the avoidable tangible costs of tobacco smoking in an Australian study (from AUS \$501 million to 2,399 million in 1996) (224).

It is worth noting that the difference in the estimates of the productivity costs calculated with the human capital approach and the friction cost method, respectively, reflect a conceptual uncertainty rather than an uncertainty due to the data applied. There is hardly any economic truth with respect to the choice of approach to estimation, it is rather a matter of the viewpoint on the valuation of time or productivity costs adhered to by the analyst. Brouwer and Koopmanschap claim that economists that choose the welfarist approach to cost analyses will tend to use the human capital approach for the productivity costs, while economists taking the extra-welfarist (or decision makers' perspective) approach use the friction cost method (133).

5.3 Discounting

The length of expected lifetime and discounting of future costs affect the estimates of lifetime costs. But, the overall results are rather insensitive to a broad range of discount rates (from 0% to 8% per year). Omission of discounting increases the total lifetime health costs, while at the same time reducing the percentage difference between ever-smokers and never-smokers. But even without discounting, the total lifetime health costs of never-smokers are below those of ever-smokers of the same age and gender. It should be noted, though, that under the extreme assumption of setting the RR-estimate of 'all other diseases' than cancers, cardiovascular diseases

and respiratory diseases equal to 1, the lifetime direct health care cost of ever-smokers just barely exceed those of never-smokers.

Although a higher discount rate (8% per year) considerably diminish the reduction of smoking-related costs following from smoking cessation, there are still sizeable reductions of lifetime direct health care costs of ex-smokers, who quit smoking while aged between 35 and 50 years old. However, with this discount rate the reductions of lifetime productivity costs are minimal for ex-smokers, who quit smoking at the age of 45 or older.

5.4 External and internal costs of smoking

There are different economic theories about smoking behaviour and, more generally, about consumption of habit forming consumption goods. The leading theory is probably the 'rational addiction' theory, originally proposed by Becker and Murphy (225). According to this theory, smokers are conscious of the habit-forming consequences of their consumption choice, but make the decision to start and to continue smoking, because the current benefits exceed the costs (including the price of cigarettes, the future health costs and other costs caused by dependency). The theory has a number of implications that can be tested empirically, and these have been confirmed by a number of studies.

In the present context, it is the tax policy implications of the theory that are of primary interest. To summarise, the principal implication of the theory is that tobacco duties should reflect only the external costs of smoking (the costs of smoking borne by non-smokers). As smokers arguably make a rational choice, the tobacco duties should not include the internal costs of smoking (the costs of smoking borne by smokers). When determining the appropriate level of tobacco duties, only the external costs of smoking therefore have to be included. However, until now focus has primarily been on the health care costs caused by smokers' increased risks of a number of diseases, while less attention has been given to the external costs due to passive smoking. As health care costs primarily are paid by a third party payer, e.g. private health insurance, compulsory social insurance or via general taxes as in the Nordic countries, this implies that smokers impose their excess health care costs on non-smokers, and the tobacco duties can be justified on these grounds.

Many economists' interest in the costs of smoking and in formulating models for estimating the costs of smoking should be seen in this context. The American economist Viscusi has argued that the external costs of smoking are beneficial for the society, because the shorter lifespan of smokers will compensate for their excess annual health care costs during their lifetime (103). This argument received a certain support by the Dutch study from

1997 (13). In the US, Viscusi's claim and the results of the Dutch study have been debated extensively. Amongst other arguments, it has been contended that a number of additional costs should be included in the determination of the external costs of smoking, such as health care costs due to passive smoking, health care costs imposed on the embryos of pregnant smokers, reduced work productivity outside what is measurable in terms of more frequent absences from work, problems of bad odours and other nuisances imposed on non-smokers.

I do agree that the above mentioned components are relevant costs of smoking, but I have chosen to focus on the primary costs of smoking in terms of the health care costs of smokers.

Some have questioned the theory of 'rational addiction' as an explanation of the individual's decision about starting and continuing to smoke. Gruber and Köszegi (226) have used the theory of 'time-inconsistent' behaviour, which claims that (at least many) individuals have grave difficulties in making rational decisions when facing choices with both short- and long-term costs and benefits. With regard to smoking behaviour, it can be contended that decisions are simply made with a too short time horizon, and that (many) smokers therefore are incapable of determining their desired quantity of smoking in the future. Gruber and Köszegi (226) refer to experimental time preference studies, which seem to indicate that the rate of time preference diminishes, when the distance in time of the consequences considered is increased. They also refer to evidence that many smokers claim that they wish to quit smoking without actually achieving to do so (226), and that many smokers use various tricks intended to reduce the short-term benefits of smoking (227) (for example by betting with others, telling others about their decision to quit and otherwise making it embarrassing to smoke). Such behaviour can be interpreted as indications of a time-inconsistent smoker, i.e. a smoker who wants to smoke now but to quit in the future.

Assuming this more recent theory about smokers' time-inconsistent behaviour, the implication is, contrary to what follows from the theory of 'rational addiction', that the government should lead a more active smoking cessation policy and not least a policy with increased tobacco duties that include at least some of the internal health care costs of smoking, namely those health care costs that smokers have not taken into account in their decision to smoke. This implies that smokers' willingness to pay for avoiding the morbidity and mortality risks that follow a particular smoking behaviour should be assessed and added to the external costs of smoking. For several reasons, such an assessment has not been attempted in the present thesis, but it could be a subject for future research within this field. The primary reason for not attempting an assessment like that is that such a task is outside the scope of the objective of this thesis, another is that there is insufficient knowledge about the number of smokers that are time-inconsistent.

5.5 Summary of the most important limitations of the present calculations of lifetime direct health care costs and productivity costs

This study includes the present and the future smoking related medical health care costs, the present and the future unrelated medical health care costs, plus the value of productive output lost due to morbidity, disability and premature mortality attributable to smoking. In any cost assessment there will be circumstances that may lead to a degree of uncertainty regarding the results relative to the perspective chosen for the assessment. In the present study, this uncertainty primarily concerns the estimation of the RR-estimates and the PAR%*s* derived from these, but there are also limitations in the inclusion of cost categories.

It can not be excluded that the RR-estimates applied may be confounded, but it is contended that it is unlikely that the RR-estimates have been influenced significantly by the combined effect of all these.

The primary reason for considering it likely that the reported estimates of the lifetime direct health care costs for never-smokers as well as for ex-smokers and those continuing to smoke could be underestimated is that the estimations do not include all smoking related costs:

- The costs of rehabilitation and nursing delivered by the municipal sector are insufficiently covered.
- The estimates of hospital costs use NordDRG from the diagnosis-related groups system, which only include all operational costs related to diagnosing, nursing and treating hospitalized patients, while excluding all capital costs and costs related to education and research.
- The costs of consultations with general practitioners are only based on the costs for consultations (about 63% of all the costs of general practice) and do not include the capitation fee of the GPs.
- Costs imposed by smokers on non-smokers in terms of passive smoking, pre-term births and low birth-weight have not been included in the determination of the lifetime health care costs of smokers.

There is, however, another important fact, which may contribute to an over-estimation of the possible cost-reductions from smoking cessation and the consequent reduced morbidity. In practice, it may be difficult to reallocate and efficiently use resources freed in this way for other non-smoking related purposes. This may be the case for the available time of hospital personnel and GPs as well as for the use of beds and buildings. So, it may occur that the actually realized cost savings are smaller than the estimated difference in lifetime costs between ever-smokers and ex-smokers.

It can reasonably be contended that when the abovementioned considerations are combined, the estimates presented here of the direct related and unrelated medical health care costs of smoking should be considered conservative and likely to underestimate not only the lifetime direct medical health care costs for never-smokers, but also for ex-smokers and those continuing to smoke. The relative difference between the lifetime direct health care costs for ever-smokers and never-smokers is considered a good estimate of the order of magnitude of the real difference. However, the relative difference between the lifetime direct health care costs for ever-smokers and ex-smokers may be slightly overestimated.

The productivity cost element of cost-of-illness estimates, estimated with the human capital approach, also tends to be underestimated (if accepting the chosen method), thus leading to an underestimation of the lifetime productivity costs for all groups, never-smokers as well as ex-smokers, and ever-smokers. This is primarily because unpaid labour is not included in the calculations when using the human capital approach. However, in comparison with the friction method the present estimates are leading to an overestimation of the lifetime productivity costs for all groups, irrespective of smoking status.

If the perspective of the assessment of the costs of smoking or the delimitation of cost categories included was to be changed, making the assessment comprise, for instance, a number of non-medical direct cost items (e.g. transportation costs, damages on buildings due to smoking-related fires, plus the costs of time spent by patients and their relatives on consulting e.g. physicians or for treatment and nursing), losses due to tax distortions and the future nonhealth care costs, the estimated costs would increase for all groups, never-smokers as well as ever-smokers. It is not possible on the basis of the present study to indicate what the combined impact of these overall increases would be on the estimated differences in lifetime costs in the comparisons between ever-smokers and never-smokers and between ever-smokers and ex-smokers, respectively.

5.6 Some other policy issues related to smoking

Taxation, addiction and knowledge

The foregoing sections have described the calculation of lifetime costs of smoking based on a cost-of-illness approach. The obvious question of the most appropriate level of taxes on cigarettes is outside the range of this study's objectives, but may nevertheless be briefly discussed here towards the end. In economic terms, the optimal tax would be one that equated the marginal social cost of the last cigarette consumed with its marginal social benefits. One of the necessary conditions for providing an answer to this question is a determination of the external costs of smoking. Most econo-

mists would consider the costs that smokers cause other people, not including members of their own family, as external costs. However, Markandya has argued that how the costs of smoking are distributed on private and social costs must depend, among other things, on the extent to which smokers are dependent and informed about the health risks caused by smoking (228). Elleman-Jensen (229) has, based on the matrix of assumptions introduced by Atkinson and Meade (230), made calculations of the annual costs of smoking under, amongst others, the following assumptions: a) all smokers are completely dependent and ignorant about the health risks of smoking, and b) smokers are not dependent and are fully informed about the risks of smoking. His results are reported in Appendix Table 3 (Appendix Q). From the study of Elleman-Jensen, it appears that prevalence-based calculations of the costs of smoking reach very different results depending on the assumptions regarding the smokers' dependency and level of risk information. Under the extreme assumption that smokers are completely dependent and unaware of the health risks the result is that the societal costs of smoking are positive (2,638 million DKK in 1983-prices), thus giving a welfare economic justification for increasing the tobacco duties. Under the opposite extreme assumption that smokers are fully informed about the health risks and that they are not dependent at all, the societal costs are negative (-5,367 million DKK in 1983-prices). This would indicate that the existing tobacco duties exert a heavy excess tax burden on smokers (229). It is not obvious, what the appropriate assumptions with regard to smokers' level of information and degree of dependency are for performing such calculations. Even though it may be reasonable to assume that smokers in high income countries in general are well aware of the risks of smoking, it is equally sensible to claim that many people probably underestimate these risks relative to others and that they may also fail to internalize the risks (231). And the 1988 US Surgeon General report's conclusion that cigarettes as well as other forms of tobacco are addictive (232) seems obviously corroborated by the difficulties experienced by many smokers wishing to quit smoking.

Price elasticities and cost effectiveness analyses

A related issue is price elasticity studies, which have not yet been performed in Denmark, i.e. studies of how changes in the cigarette taxation may affect both the amount of cigarettes smoked by each smoker and the number of smokers. Neither has any Danish studies been published of the economic impact of restrictions on or outright bans of tobacco advertising, nor of the economic impacts of the possible implementation of laws or policies intended to limit smoking in public places. It would be relevant to include such consequences in a CEA of a policy to promote smoking cessation.

6. Overall conclusions and implications

The annual direct health care costs and productivity costs attributable to smoking in Denmark amounted to 9,720 and 13,940 million DKK (1999), respectively, and ever-smokers incurred higher annual direct health care costs and productivity costs than never-smokers, regardless of gender and age. Taking life expectancies into account, smoking imposes costs on society both in terms of excess health care utilization and in terms of reduced labour supply. For both men and women, the lifetime direct health care costs of ever-smokers exceed those of never-smokers for all age-groups from 35 to 75 years old, and their lifetime productivity costs exceed those of never-smokers for all ages from 35 to 69. Even when taking the lower expected lifetime of smokers into consideration, smoking cessation engenders substantial reductions of societal health care costs, both direct health care costs and productivity costs. The size of the reduction in lifetime costs varies with the quantity of daily tobacco consumption, age at quitting and gender, but all men and women quitting smoking between age 35 and 55 generate sizeable reductions in total lifetime costs. For smokers, who quit after age 55, the total reduction of total lifetime health costs due to smoking cessation are of little economic consequence to society.

The literature survey has provided convincing evidence that there are high societal costs of smoking. Some studies reach the opposite result, but they are probably not tenable. An across studies quantification of the costs is very difficult because of the great heterogeneity in terminology and methods used and in the cost components included in the cost calculations. Viewed in their entirety, however, the studies indicate that smokers are more costly for society than non-smokers. If research in this area is to result in a more 'definite' quantification of these costs, a standardization and homogenization of methods, terminology and definitions, entirely different from what has been witnessed over the past 30-40 years, will be required. Whether interventions to induce smokers either to reduce their consumption or to quit entirely will be economically worthwhile can only be determined by actually carrying out CEAs of specific interventions, but at present there are only rudimentary estimates of the costs of implementing a comprehensive program to control tobacco consumption. However, even the most expensive smoking cessation programme has been shown to be highly cost effective compared to the majority of those medical treatments that have been assessed in actual economic evaluations (233;234).

From a public health perspective it is important to point out that, although there are differences in the methods of calculation and in the order of magnitude of the estimated costs of smoking across countries, and even though the economic implications of smoking may be less than fully elucidated and the resulting estimates sometimes in contradiction, smoking has other costs than just the costs estimated in the present thesis. That is, the health status of smokers is reduced in term of self rated good health compared to that of non-smokers because of various chronic or long-lasting diseases (24). To this must be added the inconveniences imposed on non-smokers by environmental smoke plus the pain and suffering of relatives caused by a smoker's disease or premature death. A country's decision on taking measures to prevent smoking or offering publicly provided interventions to help quit smoking should therefore not be based solely on analyses comprising direct and productivity costs of smoking. In this connection, Sørensen submits that physicians should pay attention to trying to influence the smoking habits of their patients, because part of a physician's calling is to assist in preventing that patients contract diseases. The importance of this is underlined by the obvious disease preventing impact of smoking cessation, which is unmatched by any other interventions towards disease causing factors in the current society (235).

7. Danish summary

I vestlige lande, hvor det i årtier har været almindeligt at ryge, har det vist sig, at rygning har alvorlige sundhedsskadelige konsekvenser. Epidemiologiske studier har dokumenteret, at cigaretrygning er positivt associeret med mange former for kræft, hjerte-kar-sygdomme og luftvejssygdomme. Flere studier har endvidere vist, at rygeophør umiddelbart har stor og langtidsvirkende effekt på sundheden blandt mænd og kvinder i alle aldre. Skønt rygeophør og ikke-rygning er ønskeligt fra et sundhedspolitisk perspektiv, er de samfundsøkonomiske konsekvenser kontroversielle. Adskillige studier har vist, at rygning hvert år medfører betragtelige omkostninger for samfundet, men de eksisterende økonomiske fund er ikke klare, når omkostningerne beregnes over et livsforløb og medtager den forventede kortere levetid for rygerne. Formålet med denne afhandling er derfor:

1. At beregne de samfundsøkonomiske omkostninger ved rygning i Danmark på basis af sammenlignelige livstidsopgørelser af aldrig-rygeres og rygeres (ex-rygeres og nuværende rygeres) direkte sundhedsomkostninger og produktionstab grundet sygdom og for tidlig død.
2. At bestemme den potentielle reduktion af de samfundsøkonomiske omkostninger ved rygeophør på basis af sammenlignelige beregninger over et livsforløb af de direkte sundhedsomkostninger for ex-rygere og de, som fortsætter med at ryge, og beregninger af reduktionen af produktionstab grundet rygeophør.

Afhandlingen bygger på tre fundamentale komponenter: 1) De ætiologiske fraktioner i befolkningen, som er beregnet på basis af danske rygeprævalenser (PLS Consult (1999)) og danske relative risiko-værdier ved rygning (Prescott et al. (1998)), 2) the cost-of-illness og 3) danske overlevelsessandsynligheder (Danmarks Statistik (1998/1999)).

Studierne omfatter nuværende og fremtidige rygerrelaterede og ikke-rygerrelaterede sundhedsomkostninger baseret på offentlige registerdata – samt produktionstab grundet sygdom og død. De årlige frekvenser og bestemmelsen af omkostningerne ved en række sundhedsydelse er baseret på følgende danske registre og kilder: Hospitalsudskrivning og ambulans behandling samt omkostningerne herved (Det Danske Sundhedsministerium og Sundhedsstyrelsen; DRG-takster (1999)); konsultationer og omkostninger ved alment praktiserende læger og fysioterapeuter (et multicenterstudie fra Århus Amt (1997) og Sygesikringens Forhandlingudvalg (1999)) og medicinforbrug og omkostningerne herved (Lægemiddelstyrelsen (1999)). Beregningen af produktionstab er baseret på data omfattende: Dødsfald

(Dødsårsagsregisteret (1999)), førtidspension (Den sociale Ankestyrelse (1999)) og sygefravær (Arbejdstilsynet (1995) og Danmarks Statistik (1999)). Bestemmelsen af værdien af den mistede produktion inkluderer data om årsindkomst, beskæftigelses- og erhvervsfrekvenser (Danmarks Statistik (1997 og 1999)).

Studie 1: Baseret på en beregning af de årlige omkostninger for 1999 overstiger de gennemsnitlige direkte sundhedsomkostninger og produktionstab for rygere (ex-rygere og nuværende rygere) aldrig-rygeres uanset køn og aldersgruppe. Når rygeres og aldrig-rygeres forskellige overlevelsessandsynligheder medtages i beregningerne, og der diskonteres med 5% årligt, er livstidsomkostningerne for de direkte sundhedsomkostninger og produktionsomkostningerne blandt mænd, der ryger og er fyldt 35 år, henholdsvis 66% og 83% større end aldrig-rygende mænds omkostninger. De tilsvarende resultater for kvinder er henholdsvis 74% og 79%. En følsomhedsanalyse viser, at disse resultater er robuste over et temmelig bredt spænd af relativ risiko-værdier og diskonteringsrater (0%, 3% og 8% per år). Imidlertid forsvinder rygerens ekstra omkostninger, når der gøres den ekstreme antagelse at de rygerelaterede sygdomme begrænses til at omfatte kræft, hjertekar-sygdomme og luftvejssygdomme, forudsat at de fremtidige omkostninger ikke diskonteres (17).

Studie 2: Den totale reduktion af livstidssundhedsomkostningerne som følge af rygeophør er størst i de yngste aldersgrupper. Reduktionen af omkostningerne varierer med personens alder ved rygeophør, dagligt tobaksforbrug og køn, men alle ex-rygere, som ophører med at ryge i alderen 35 til 55 år, afføder en betragtelig reduktion af omkostningerne opgjort over et livsforløb og diskonteret med 5%. Blandt moderat rygende mænd, som ophører med at ryge som 35 årige, er de beregnede reduktioner af livstidssundhedsomkostningerne med hensyn til de totale -, de direkte omkostninger og produktionstab henholdsvis 184.500 kroner, 56.700 kroner og 127.800 kroner. De tilsvarende reduktioner af omkostningerne er henholdsvis 253.600 kroner, 90.900 kroner og 162.700 kroner blandt kvinder. Ved alternativt at bruge en diskonteringsrate på 8% er reduktionen af livstidsomkostningerne efter rygeophør betragteligt mindre, men reduktionen af de direkte livstidssundhedsomkostninger er stadig betragtelig for ex-rygere, som ophører med at ryge i 35 til 50 års alderen. Men ved en diskontering på 8% er reduktionen af produktionsomkostningerne over et livsforløb minimale for de ex-rygere, som ophører med at ryge som 45 årige eller ældre (18).

Det skal bemærkes, at for begge studier tenderer de direkte omkostninger mod at være konservativt estimerede, fordi ikke alle rygerelaterede omkostninger indgår i beregningerne. Det betyder, at ikke blot er aldrig-rygerens livstidssundhedsomkostninger undervurderede, men det er også tilfældet for ex-rygerne og de, som fortsat ryger. Den relative difference mellem de direk-

te livstidssundhedsomkostninger for rygere og aldrig-rygere vurderes at være et godt estimat for størrelsesordenen af den sande forskel. Den relative forskel mellem de direkte livstidssundhedsomkostninger for rygere og ex-rygere må imidlertid anses for at være overvurderede, mens livstidsproduktionstabet, hvis accepteret beregnet med humankapitalmetoden, sandsynligvis er undervurderet for alle grupper; rygere, ex-rygere og aldrig-ryger. Den væsentligste grund hertil er at metoden ikke inkluderer ulønnet arbejde og aktiviteter.

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- (239) Nord-Larsen M. Tabel 6.6 Vigtigste årsag til sygemeldingen i 1988 blandt de langvarigt sygemeldte. Procent. [The main cause of illness among persons with long-term sickness absence in 1988. Per cent.] In: Langvarig sygdom – problemer og konsekvenser. København: Socialforskningsinstituttet, 1991: 61.
- (240) Tabel 1. Dagpengesager fordelt efter tilfældets art, antal modtagere, dagpengeuger og udbetalte beløb i året. Opdelt på køn. 1992 [Table 1. Sickness benefits cases according to type, number of beneficiaries, duration of benefits periods and the amount of benefits paid during the year. According to gender. 1992]. *Statistiske Efterretninger: Social sikring og retsvæsen* 1994:(1994:3):6.

Appendix

Appendix A: Population attributable risks

Age-(a), gender-(g) and disease-specific attributable risks PAR_{agd} were estimated as:

$$PAR_{agd} = \frac{((P_{ag}^{former} * (RR_{gd}^{former} - 1)) + (P_{ag}^{light} * (RR_{gd}^{light} - 1)) + (P_{ag}^{moderate} * (RR_{gd}^{moderate} - 1)) + (P_{ag}^{heavy} * (RR_{gd}^{heavy} - 1)))}{((P_{ag}^{former} * (RR_{gd}^{former} - 1)) + (P_{ag}^{light} * (RR_{gd}^{light} - 1)) + (P_{ag}^{moderate} * (RR_{gd}^{moderate} - 1)) + (P_{ag}^{heavy} * (RR_{gd}^{heavy} - 1)) + 1)}$$

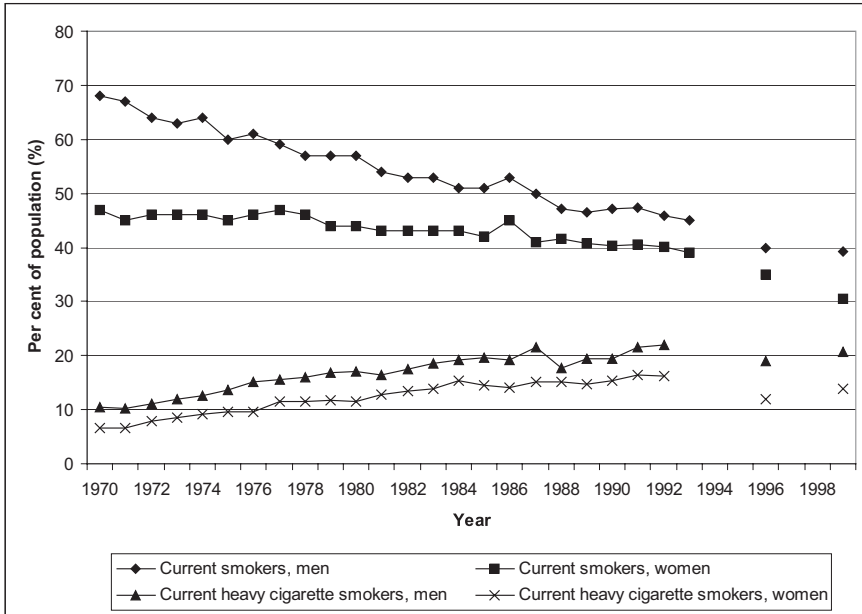
(for a=35-39, 40-44, , . . . , 85-89)

P_{ag}^{former} , P_{ag}^{light} , $P_{ag}^{moderate}$, and P_{ag}^{heavy} are the proportions of former, light moderate, and heavy smokers of age a and gender g, respectively. RR_{gd}^{former} , RR_{gd}^{light} , $RR_{gd}^{moderate}$, and RR_{gd}^{heavy} are the disease-specific relative risk of death for former, light moderate, and heavy smokers of age a and gender g, respectively.

The population attributable risks percentages (PAR%)s were used as indicators for parts of outcome as well as parts of costs attributable to smoking. The equation of population attributable risks was derived from the work of Levin (150) and the specific population attributable risks have been used by e.g. King et al. (236). Levin defined the attributable risk in terms of lung cancer and smoking as 'the maximum proportion of lung cancers attributable to cigarette smoking'. It should be noted that the measurement of Levin is based on the assumption that, if smokers had not become smokers they would have had the same incidence of diseases attributable to smoking as never-smokers. To this must be added the assumption that other etiological factors are equally distributed among smokers and never-smokers.

Appendix B: Smoking proportions

Appendix Figure 1. Smoking proportions by gender and smoking habit^a. Denmark, 1970-1999. (%).



a: Heavy smokers; 15 cigarettes daily.

Sources: Data from 1970-1987 are based on Nielsen et al. (154) and Osler (156). Data from 1988-1993 are based on Nielsen and Sørensen (155). Data from 1996 and 1999 are based on Gallup (153) and PLS Consult (145), respectively.

The smoking proportion estimates used are shown in the Appendix Table 1.

Appendix Table 1. Smoking proportion (%) by smoking status, quantity of daily tobacco consumption^a, gender, and age. Denmark, 1999.

Gender and age	Smoking status				
	Never-smokers	Former smokers	Current smokers		
			Daily quantity of tobacco consumption		
			Light	Moderate	Heavy
Men					
15-19	68	6	18	6	2
20-29	49	13	21	14	4
30-39	43	17	15	20	5
40-49	36	22	15	17	10
50-59	25	30	22	16	8
60-69	22	42	15	16	5
70+	23	43	25	9	0
Women					
15-19	62	5	29	4	0
20-29	51	16	18	13	1
30-39	48	21	16	12	2
40-49	36	24	16	22	2
50-59	44	26	12	14	4
60-69	40	29	20	11	1
70+	48	34	14	3	0

a: Light; 1-14 gram daily tobacco consumption, moderate; 15-24 gram daily tobacco consumption, heavy; 25 or more gram daily tobacco consumption.

Source: Based on PLS Consult (145), cigarettes are weighted as 1 gram of tobacco and cigars as 3 gram of tobacco.

Appendix C: Relative mortality risk estimates

The RR-estimates used are shown in the Appendix Table 2. In the second study, it has been assumed that the risks of ex-smokers are reduced linearly over a period of 15 years to the level of never-smokers (18).

Appendix Table 2. Age-adjusted excess mortality in inhaling smoking men and women by quantity of daily tobacco consumption^a and in ex-smoking men and women expressed as relative mortality risk with never-smokers' risk set at 1.

Gender and cause of death ^b	Never-smokers	Relative risk to never-smokers			
		Light	Moderate	Heavy	Ex-smokers
Men					
Cancer	1	2.0	2.8	3.7	1.3
Vascular disease	1	1.7	1.9	1.9	1.2
Respiratory disease	1	4.2	4.7	4.8	2.2
All other causes	1	2.0	2.5	2.2	1.4
All causes, <65 years ^c	1	2.5	3.4	3.5	1.7
All causes, ≥65 years ^c	1	1.7	2.0	2.2	1.2
Women					
Cancer	1	1.9	2.1	3.3	1.0
Vascular disease	1	2.4	2.8	3.0	1.2
Respiratory disease	1	7.5	10.4	12.5	2.2
All other causes	1	2.0	2.4	2.9	1.3
All causes, <65 years ^c	1	2.3	2.6	3.4	1.4
All causes, ≥65 years ^c	1	2.2	2.6	3.3	1.2

a: Light: 1-14 gram daily tobacco consumption, moderate; 15-24 gram daily tobacco consumption, heavy; 25 or more gram daily tobacco consumption.

b: Relative risks are adjusted for age for cancer (ICD-10: C00-C99), vascular disease (ICD-10: I00-I99), respiratory disease (ICD-10: J00-J99), and 'all other causes'.

c: Based on personal communication from Prescott.

Source: Prescott et al. (26) Table 3 and 4.

Appendix D: The human capital approach

The present value of present and future labour income, or the human capital $HC_{ag}(W)$ for a person of age (a) and gender (g) was estimated as:

$$HC_{ag}(W) = \sum_{t=a}^{69} W_{tg} * E_{tg} * B_{tg} * Se_{t-a,g|a} * (1 + rp)^{t-a} / (1 + d)^{(t-a)} \text{ (for } a=35, 36, \dots, 69)$$

where W_{tg} is the average annual labour income according to age (a) and gender (g), E_{tg} is the proportion of this specific age and gender segment of the population which is in the active labour force; B_{tg} is the proportion of this segment of the labour force actually working; $Se_{t-a,g|a}$ is the age- and gender-specific conditional survival probability; d is the annual rate of discount; and rp is the annual rate of growth of productivity (assumed fixed at 1.2% p.a.). A further assumption of stationarity was that the labour income ten years ahead for a person currently 35 years old would be equal to the current labour income of a 45-years old times $1.291 = 1.012^{10}$.

Data on survival probabilities (1998/1999) (146), frequencies of employment and rates of participation in the labour force (1999) were extracted from tables from Statistics Denmark by age (one-year age groups) and gender (161). Data on labour incomes by age and gender (1997) from Statistics Denmark (160) were adjusted to 1999 DKK by the rate of increase of the consumer price index 1997-99 and linearly interpolated from five-years age groups to one-year age groups. For women, the estimates of annual labour income were based on data on the taxable income of single women.

Appendix E: Annual direct costs and productivity costs

Annual direct and productivity for every cost category per person alive of ever-smokers and never-smokers at age a (in 5-year age-groups from age 35 through age 89 for direct costs and from age 35 through age 69 for the productivity costs) and gender g were estimated. The formulas for determining the direct costs DCe_{ag} for ever-smokers and DCn_{ag} for never-smokers, respectively, are:

$$DCe_{ag} = \sum_{d=1}^4 [PAR_{agd} * DC_{agd} + (1 - PAR_{agd}) * DC_{agd} * P_{ag}] / Ne_{ag} \text{ with } Ne_{ag} = N_{ag} * P_{ag}$$

and

$$DCn_{ag} = \sum_{d=1}^4 [(1 - PAR_{agd}) * DC_{agd} * (1 - P_{ag})] / Nn_{ag} \text{ with } Nn_{ag} = N_{ag} * (1 - P_{ag})$$

Here, P_{ag} is the prevalence of smoking for age a and gender g; PAR_{agd} is the age-(a), gender-(g), and disease-specific-(d) population attributable risk for disease category d; DC_{agd} is the direct costs for the combination of age a, gender g, and disease group d; and N_{ag} is the number of persons in the population of age a and gender g. Costs are calculated for four groups of diseases: cancer, cardiovascular diseases, respiratory diseases and all other diseases (residuals). Assuming that the remaining parts of annual direct costs and productivity costs that could not be attributed to smoking were independent of smoking status, they were assigned by age and gender.

Similar estimates were made for determining the productivity costs for ever-smokers and never-smokers, respectively.

As the attributable fractions sum up to more than 100% and because of sample variation of the PAR-estimates, the sum of annual disease-specific smoking-attributable costs, estimated from the disease-specific PAR_{agd} -estimates by age and gender, exceeded the annual smoking-attributable costs of all causes estimated from the all-causes PAR_{ag} -estimates by age and gender. To correct for this, each of the estimates of the annual disease-specific costs attributable to smoking were calibrated by a reduction proportional to their share of the sum of annual disease-specific costs attributed to smoking.

In the estimation of annual direct costs and productivity costs for current smokers (Study II) (18), these calibrated smoking-attributable costs for ever-smokers by age, gender and disease were multiplied by the share of the quantity-, age, gender, and disease-specific $PAR_{agd}^{quantity}$; as an example, the proportion for a light smoker of age a, gender g, and for disease d the PAR_{agd}^{light} was estimated as:

$$PAR_{agd}^{light} =$$

$$\frac{(P_{ag}^{light} * (RR_{gd}^{light} - 1))}{((P_{ag}^{former} * (RR_{gd}^{former} - 1)) + (P_{ag}^{light} * (RR_{gd}^{light} - 1)) + (P_{ag}^{moderate} * (RR_{gd}^{moderate} - 1)) + (P_{ag}^{heavy} * (RR_{gd}^{heavy} - 1)) + 1)}$$

(for a=35-39, 40-44, , . . . , 85-89)

P_{ag}^{former} , P_{ag}^{light} , $P_{ag}^{moderate}$, and P_{ag}^{heavy} are the proportions of former, light moderate, and heavy smokers of age a and gender g, respectively. RR_{gd}^{former} , RR_{gd}^{light} , $RR_{gd}^{moderate}$, and RR_{gd}^{heavy} are the disease-specific relative risk of death for former, light moderate, and heavy smokers of age a and gender g, respectively.

The remaining costs were assumed to be independent of the quantity of tobacco consumption and were simply assigned by age and gender.

Similar estimates were made for moderate and heavy smokers.

Appendix F: Annual frequencies of hospital admissions and hospital costs attributable to smoking

The calculation of the annual costs of hospitalisations was based on data on frequencies of discharges from hospital and outpatients (including emergency ward visits and stays in day care ward). The gender- and age-specific (in 5-years age groups) frequencies of discharges from hospital and outpatients were based on information from The Danish Ministry of Health and The National Health Board (1999). The unit prices for the valuation of hospital costs were based on the NordDRG (diagnosis-related groups) version 1.7 (206) adjusted to 1999 prices with the index of prices and wages (the PL-index). The NordDRG are based on the twelfth version of the American DRG grouping, the HCFA12 (Health Care Financing Administration). The DRG-system comprises all operational costs associated with the diagnosis, treatment and nursing of patients admitted, while excluding all capital costs and costs related to education and research (206).

The NordDRG employs a grouping procedure that reflect the primary diagnosis, secondary diagnoses / complications, surgical operations / procedures, gender, and age plus the destination of discharge. The NordDRG-system categorize the discharges from hospital within 495 disease groups and with tariffs from 2,494 DKK to 652,937 DKK, and a average tariff at 19,840 DKK for a discharge from hospital. The system operates with a maximum length of stay for each of the disease groups, a point of cut-off. In case a patient's length of stay exceeds the cut-off point of the disease group concerned, a fixed tariff per day (1,316 DKK) is set for the remaining days of the patient's stay as an in-patient.

In addition, the DRG-system operates with 29 specific DRG-groups, which are characterized as grey area DRG-groups. The grey area tariffs are based on the average costs of outpatient costs and the DRG-tariff for admission in the DRG-group in question.

For outpatient consultations and stays in day care wards the tariffs are, respectively, 2,553 DKK and 1,741 DKK when the patients are in dialysis or in cancer treatment. For visits including surgical operations / procedures the tariffs are 953 – 8,655 DKK. For all other outpatients consultations and stays in day care ward the tariff is 1,073 DKK. The tariff of emergency ward visits is 574 DKK.

For the calculation of the annual smoking-related costs of hospitalisations, the age-, gender-, and disease-specific PAR% were multiplied by the data on age-, gender-, and disease-specific discharges of hospital, remaining days, and outpatient visits, respectively. Subsequently, these products were multiplied with the relevant unit prices in order to determine the costs.

Appendix G: Annual number and costs of consultations with general practitioners and physiotherapists attributable to smoking

Data on the frequencies and costs of consultations with general practitioners (GPs) and physiotherapists (according to age, gender, and disease group) are not available in Denmark. Therefore, the estimation of the annual number and costs of GP and physiotherapy consultations attributable to smoking were based on a Danish cross-sectional multicentre-study including all GPs in the county of Århus (208). This GP-study ran from February 1, 1993 to December 31, 1993, and was performed to examine the cause of all patient-contacts and to classify the diagnoses according to the ICPC-codes (Wonica's International Classification of Primary Care). All the GPs of the county were randomized to record all patient-contacts, except the out-of-hours work, on a particular date. 88% (327) of the GPs participated in the study, which comprised 12,237 contacts within 15 major ICPC diagnosis groups (h). 7,309 contacts concerned men (2,682) and women (4,627) aged 35 years or older. The calculation of the costs of GP consultations was based on unit cost data from The National Health Security System regarding the fees of GPs in Denmark (1999).

In Supplement 3 (of the GP study), the number of patient contacts is shown by age (t), (t=0-4,5-14, 15-24, ..., 65-74, 75+), gender, and major ICPC diagnosis group h, including the groups K: cardiovascular disease, R: respiratory organs, D: digestion, and U: urinary system. In Supplement 5 (of the GP study), the frequency of patient contacts is shown by detailed ICPC diagnosis and gender. However, the ICPC diagnoses are not directly usable for the present thesis, which is based on the ICD-10 classification of diseases. To remedy this, all the detailed patient contact diagnoses from the GP-study were examined and reclassified according to the ICD-10 classification, and the gender-specific (g) proportion of all the patient contact diagnoses corresponding to a particular disease (d), (f_{gd}) was determined. It was thus estimated that 0.4% (16) of all the patient contacts with men concerned cancer (C00-C99 according to ICD-10), 5.5% (249) of all the patient contacts with men had cardiovascular disease as cause (I00-I99 of ICD-10), while 14.1% (622) of the patient contacts with men concerned respiratory diseases (J00-J99 according to ICD-10). Similar proportions were seen for the patient contacts with women.

The frequencies of GP contacts for patients in 5-year age groups between 35 and 74 years of age were estimated by linear interpolation from data based on 10-year age groups. For the following three 5-year age groups, 75-79, 80-84 and 85-89, it was assumed that each could be ascribed one fourth of all the contacts with patients of age 75+. It was further assumed that the partition of patient contacts on men and women observed in the GP study could be applied to all GP contacts with patients in 1999. A final

assumption was that the gender-specific partition of patient-contacts (f_{gd}) was the same for all the age groups of the GP study.

Subsequently, the annual costs of GP consultations, $AC(GP)e_{ag}^{cancer}$, in ever-smokers of age a and gender g attributable to smoking was estimated as:

$$ACe(GP)_{ag}^{cancer} = (N_{ag}^{cancer} / N_g^{cancer}) * f_g^{cancer} * TF_g * C_{average}(GP) * PAR_{agd}$$

(for a=35-39, 40-44, . . . , 85-89)

where N_{ag}^{cancer} is the number of patient-contacts in the GP-study with patients of age a, gender g, and cancer as the diagnosis of interest; N_g^{cancer} is the sum of all patient-contacts in the GP study with cancer patients of gender g; f_g^{cancer} is the gender-specific (g) proportion of patient-contacts with cancer of all the patient-contacts in the GP-study; TF_g is the total number of annual consultations with GPs per gender; $C_{average}(GP)$ is the average cost per GP consultation; and PAR_{ag}^{cancer} is the age-(a) and gender-specific (g) part of this risk that can be attributed to smoking. Similar estimates were made for the three other disease groups.

The calculation of the costs of physiotherapy treatments was based on unit cost data from The National Health Security System regarding the fees of GPs in Denmark (1999) (about 94% of the total costs of treatments by private physiotherapists were included). For the estimation of the annual costs of consultations with physiotherapists in ever-smokers that can be attributed to smoking, it was assumed that consultations with physiotherapists are distributed in the same way as GP consultations with respect to age, gender and disease groups (17). In the second study, the costs of consultations with physiotherapists for current smokers and ex-smokers were estimated by using the same approach and assumptions (18).

Appendix H: Annual costs of medications attributable to smoking

Determination of the use and costs of medications were based on drugs statistics from the Danish Medicines Agency (1999), which include the consumption of drugs by individuals in the primary health care sector, the medications used by GPs in their practices and the consumption by the elderly living in old people's homes. The drugs statistics are grouped according to the ATC system (Anatomical Therapeutic Chemical Classification System) with 14 disease groups from A to V, by gender and age (10-year age groups from 16-84 years and one joint group for the 85+ years old). The costs of medications are based on the pharmacy outlet prices (i.e. the costs include the pharmacy dispensation charges).

The estimation of the costs of anti-cancer drugs was based on the ATC-group L: cancer drugs. The costs of medications for cardiovascular diseases were calculated based on the ATC groups C: heart and circulation and B01: drugs against thrombosis, while for respiratory diseases the costs of drugs in ATC group R03: drugs against asthma were included. To this was added the costs of medications from ATC-group N07B: anti-smoking drugs. The remaining costs of medications were included under the costs of 'all other diseases'.

To derive the cost of medications for the 5-year age groups used here, the costs of the 10-year age groups in the data available were interpolated linearly. It was furthermore assumed that 2/3 of the costs of medications among the population 85+ years old could be ascribed to persons in the age group 85-89. In estimating the annual costs of medications that could be attributed to smoking, the age-, gender-, and disease-specific PAR%s were multiplied by age-, gender-, and disease-specific costs of medications. All costs of anti-smoking drugs were allocated to ever-smokers.

Appendix I: The productivity costs of mortality attributable to smoking

The estimation of the productivity costs due to mortality that can be attributed to smoking was based on data from The National Register of Causes of Death, which give the principal diagnoses of deceased persons according to age (5-year age groups) and gender. The productivity costs due to mortality in ever-smokers attributable to smoking, $PCE_m(M)$, were estimated as:

$$PCE_{agd}(M) = Ne_{agd}(M) * HC_{ag}(W) \text{ (for } a=35-39, 40-44, \dots, 65-69)$$

where $Ne_{agd}(M)$ is the mortality attributed to smoking in ever-smokers of age a , gender g and disease d ; $HC_{ag}(W)$ is the average human capital per 5-year groups according to age and gender. These costs are determined for four groups of diseases: cancers, cardiovascular diseases, respiratory diseases, and all other diseases (residuals). Equivalent estimates were derived for current and former smokers.

Appendix J: Productivity costs of early retirement attributable to smoking

The estimation of the costs of early retirement attributable to smoking among persons between 35 and 66 years of age (persons 67 years old or more are not eligible for early retirement benefits) was based on information from The Social Appeals Board (1999), which provides data on early retirement benefits awarded distinguishing between 267 groups of diagnoses. The data are distributed according to gender and age (5-year age groups except for the age group 60-66 years). The number of persons with early retirement benefits awarded due to cancer, cardiovascular diseases, respiratory diseases and all other diseases were assessed by applying the following diagnosis codes: 'tumours: 007-033', 'diseases in the circulatory organs: 114-131', 'diseases in the respiratory organs: 132-39', and 'all diagnosis codes: 1-267'. Included in the assessment were persons awarded the intermediate level of early retirement benefits ([Social Pension Law. Consolidate Act no. 22 of January 14, 1998] §14, part 4.1), the highest level of early retirement benefits (§14, part 4.2), and also persons awarded the ordinary and the raised ordinary retirement pension according to §14 part 3.1. Not included were persons awarded early retirement benefits according to §14 part 3.1 and §14 part 3.3, because it is considered that benefits awarded according to these paragraphs are mainly justified by social considerations. Neither were persons awarded disablement benefits included, as this is a supplement for persons still working. In the calculation of the productivity costs of early retirement, it was assumed that 1/6 of the pensions awarded for the age group from 60 to 66 years can be assigned to the 66 years old.

Assuming that a person awarded early retirement benefit has definitively left the labour force, the productivity costs of early retirement attributable to smoking $PCe_m(ER)$ for ever-smokers was estimated equivalently to the estimation of the productivity costs of mortality:

$$PCe_{agd}(ER) = Ne_{agd}(ER) \cdot HC_{ag}(W) \text{ (for } a=35-39, 40-44, \dots, 60-64, 65-66)$$

where $Ne_{agd}(ER)$ is the proportion of early retirement benefit awards attributable to smoking in ever-smokers of age a , gender g , and disease d ; $HC_{ag}(W)$ is the average human capital according to gender g across each 5-year age group a . Costs were calculated for four groups of diseases: cancers, cardiovascular diseases, respiratory diseases, and all other diseases (residual). Equivalent estimations were carried out for current and former smokers.

Appendix K: Productivity costs of rehabilitation attributable to smoking

Usually, persons applying for early retirement benefits go through a period of rehabilitation previous to being awarded the pension. It has here been assumed that the average duration of this rehabilitation period is six months, so that the persons awarded early retirement benefits are assumed to have been out of production half a year before being granted the pension. The calculation of the productivity costs due to this period of rehabilitation applies the same methods as were applied for the calculation of the productivity costs of mortality and early retirement attributable to smoking.

Appendix L: Productivity costs of days absent from work attributable to smoking

The productivity costs of days absent from work attributable to smoking were estimated based on official data from Statistics Denmark on spells of sickness and the ensuing sickness benefits (212). These statistics are classified according to categories of employment:

- For employees in the private sector, only sickness benefits paid after two weeks of absence are registered, because private employers are obliged to pay the employee's sickness benefits during the first two weeks of absence without any public compensation (this is referred to as the employer period).
- For employees in the public sector, no payments of sickness benefits are registered, because the public sector employers are obliged to pay sickness benefits or the salary of the employee during the entire period of absence due to sickness, no matter its duration.
- For independents, only sickness benefits after more than two weeks of absence due to sickness are registered, unless these have taken out a self-insurance contract.
- Employees with a loose attachment to the labour market receive public sickness benefits during the first two weeks of absence due to sickness, if 1) the employer has taken out an insurance against the obligation to pay sickness benefits, 2) the employee does not fulfill the statutory requirements with regard to the employment (i.e. employed minimum 120 hours by the employer within the last 13 weeks), 3) in case of chronic disease, and 4) in case of unemployment and certain forms of workplace injuries.

According to Statistics Denmark, the total amount of public sickness benefits paid in 1999 corresponds to 2,956,000 weeks of sickness absence.

In order to estimate the total number of days of sickness absence based on these official data, I applied the results and notes from a study conducted by The Danish Working Environment Authority (215;216). This study resulted in an estimate of the total number of days of absence from work due to sickness for independents and employees in both the private and public sector (including employees only loosely attached to the labour market), which is about twice the amount of weeks of sickness absence registered by Statistics Denmark. This assessment by The Danish Working Environment Authority of the absenteeism of public and private employees due to sickness is based partly on data on the amount of absenteeism with public sickness benefits (in 1992, public sector employees were paid public sickness benefits after 13 weeks of absence due to sickness), and partly on the average amount of days of absence due to sickness among women and

men employed in the public sector (the Ministry of Finance, and Bovin and Wandall (237)) and in the private (wages statistics from the Danish Employers' Confederation), respectively. The estimation of the absenteeism of independents and of employees loosely attached to the labour market is based on the registered number of weeks of absence with publicly paid sickness benefits. In the calculations by The Danish Working Environment Authority it was further assumed, based on the results from Bovin and Wandall (237), that 25% of the sickness absences among public employees and independents could be assigned to long-term illness (exceeding the 13 weeks). The percentage distribution of sickness absences across 13 groups of diseases has been determined based on published studies of absenteeism due to sickness (238;239). From these it appears that 4.5% and 3%, respectively, of all short-term and long-term sickness absences, respectively, can be assigned to cancer; for cardiovascular diseases the corresponding per cents are 8.7% and 7%, respectively; and 4% of all absences, no matter their duration, can be attributed to respiratory diseases.

From Table 1 of Statistics Denmark (the 1999 and 1992 issues, respectively) (212;240) it appears that over this 8-years period the number of weeks of absence with publicly paid sickness benefits has increased by 28% for male employees and by 37% for female employees. For independents, on the contrary, a reduction of the number of weeks by 14-16% is observed.

These percentage changes from 1992 to 1999 in the number of weeks of absence covered by public sickness benefits have here been used for an adjustment of the number of sickness absence days of publicly and privately employed men and women estimated by The Danish Working Environment Authority (subsequently referred to as the adjusted number of days of sickness absence by gender, $N(wad)_g$). The assessment of sickness absence for independents and people loosely attached to the labour market is based on the data registered by Statistics Denmark. The resultant number of weeks of absence due to disease in 1999 becomes 6,160,100 weeks, partitioned with 2,818,500 weeks for men and 3,341,600 for women. Following is a description of the assumptions made and the method applied for the assignment of sickness absence days to age-groups and types of disease.

In Table 11, the data from Statistics Denmark on the average number of weeks with sickness benefits after the two week employer period are shown, distributed according to age and gender (214). From Table 1 of Statistics Denmark (212) it appears that half of all the beneficiaries of public sickness benefits are employees receiving public benefits after the expiration of the employer period, and, consequently, that the other half of the beneficiaries must be persons receiving public sickness benefits for absences of a duration shorter than two weeks. Assuming this fraction to be independent

of age and gender, it was applied to the numbers of recipients of sickness benefits by age and gender, $N(rsb)_{ag}$ (reported in Statistics Denmark Table 4 (213) for (a ≤19, 20-29, , ...,50-59, 60-65, 67+)) in the estimation of the productivity costs due to sickness absences.

Based on a further assumption that the average number of weeks of sickness absence was identical for employees and independents, the percentage distribution of weeks of sickness absence after the two weeks according to age and gender, $Np(wsb^{>2})_{ag}$, was estimated as:

$$Np(wsb^{>2})_{ag} = N(rsb^{>2})_{ag} * N^{average}(wsb^{>2})_{ag} / TN(wsb^{>2})_g \text{ with } N(rsb^{>2})_{ag} = N(rsb)_{ag} * 0.5$$

(for a = ≤19, 20-29, 30-39, , . . . , 50-59, 60-65, 67+)

$Np(wsb^{>2})_{ag}$ is the number of sickness benefits after two weeks according to age and gender, $N^{average}(wsb^{>2})_{ag}$ is the average number of weeks of sickness benefits after two weeks by age and gender, $TN(wsb^{>2})_g$ is the total number of weeks of sickness benefits after two weeks for gender g, and $N(rsb)_{ag}$ is the number of recipients of sickness benefits by age and gender.

Subsequently, the number of weeks of sickness absence per age (from age 35 through age 69) and gender group $N(wad)_{ag}$ was estimated from the adjusted number of weeks of sickness absence by gender $N(wad)_g$ as:

$$N(wad)_{ag} = Np(wsb^{>2})_{ag} * N(wad)_g$$

For the groups between 30 and 64 years of age, these estimates were then transformed to 5-year age groups by linear interpolation, while the sickness absence days of those older were assigned to the age group 65-69 years.

The last mentioned estimate was based on two assumptions: (1) that the percentage distribution was the same among recipients of sickness benefits during the first two weeks of absence as among the recipients of sickness benefits after two weeks of sickness absence, and (2) that the distribution of days of sickness absence on age and gender corresponded to the age and gender distribution of sickness benefits recipients.

Subsequently, the absences due to sickness were distributed across diseases by applying the distributions determined by The Danish Working Environment Authority. For absences after two weeks, the percentage distribution for long-term illnesses was applied. The determined numbers of weeks of sickness absence were then standardized as proportions of a normal working year and valued by multiplying by the average annual labour income per 5-year age group. Finally were the productivity costs due to sickness absences and according to age and gender estimated by applying the same approach as has been used for the other calculations of productivity costs.

Appendix M: The probability of death within one year

From life tables (146), the probabilities of death within one year for a never-smoker in age group a , ($Dn_{a+1,g|a}$) and for an ever-smoker in age group a ($De_{a+1,g|a}$) by gender g were estimated as, respectively:

$$Dn_{a+1,g|a} = (1 - S_{a+1,g|a}) / \left(P_{0ag} + \sum_{q=1}^4 RR_{qag} * P_{qag} \right) \text{ (for } a=35-89, 40-89, \dots, 75-89)$$

and

$$De_{a+1,g|a} = Dn_{a+1,g} * \sum_{k=1}^4 \left(RR_{kag} * P_{kag} / \sum_{k=1}^4 P_{kag} \right) \text{ (for } a=35-89, 40-89, \dots, 75-89)$$

k has five different values according to smoking status, $k=0$ for never-smokers, $k=1, 2$ or 3 for current smokers dependent on quantity of daily tobacco consumption according to Appendix Table 1, and $k=4$ for former smokers. I have used the one year survival probability ($S_{g|a}$) by gender (g) and conditional on being alive at age (a) in a mixed Danish population; age- (a) and gender- (g) specific relative risk estimates (RR_{kag}) for death of all causes (<65 years and ≥ 65 years) according to smoking-status (k); and age- (a) and gender- (g) specific smoking proportions (P_{kag}) according to smoking status (k).

In the second study, the gender-specific probability of death within one year for a current light smoker of age-group a , ($Dc_{a+1,g|a}^{1-14}$), was estimated as:

$$Dc_{a+1,g|a}^{1-14} = Dn_{a+1,g} * RR_{ag}^{1-14} \text{ (for } a=35-89)$$

Here, ($Dn_{a+1,g|a}$) is the probability of death within one year for a never-smoker of age a , and RR_{ag}^{1-4} is the relative risk-estimates for death of all causes (<65 years and ≥ 65 years) for the group of light smokers.

Similar estimates were made for currently smoking men and women with a moderate or heavy consumption. For an ex-smoker of age group a , who quit smoking at a particular age, the probability of death within one year was estimated based on the RR-estimates of current smokers until the time of quitting; after this time, the linearly reduced RR-estimates for current smokers were used.

Appendix N: The conditional probability of death

In the first study, the probability for an ever-smoker of being alive at year (t-a) conditional on being alive at age 35, ($Se_{t-a,g|35}$), was estimated as cumulative survival probabilities:

$$Se_{t-a,g|35} = \prod_{a=35}^{t-1} (1 - De_{a+1|a})$$

where ($De_{a+1,g}$) is the probability of death within one year for an a-year old ever-smoker. Similar estimates were made for ever-smokers conditional on being alive at ages 40, 45, , ..., 75 years and for never-smokers conditional on being alive at ages 35, 40, , ..., 75 years.

In the second study, similar estimates were made for current and former smokers according to the quantity of daily tobacco consumption and conditional on being alive at age 35 (18).

Appendix O: Lifetime costs

By multiplying direct costs per person-year, DCe_{tg} , with the conditional survival probabilities, $Se_{t-a,gl}$, the direct lifetime costs for ever-smokers $DLCe_{ag}$ according to gender and age and truncated at age 89 years were estimated as:

$$DLCe_{ag} = \sum_{t=a}^{89} DCe_{tg} * Se_{t-a,gl} / (1 + d)^{(t-a)}$$

for $a=35, 40, \dots, 75$ years of age and with d the annual discount rate. Equivalent estimations were performed for never-smokers and for current and former smokers for $a=35$ years.

The lifetime productivity costs (truncated at age 69) for ever-smokers of gender g and age-group a , $PLCe_{ag}$, were estimated by multiplying the productivity costs per year PCE_{tg} with the conditional survival probabilities $Se_{t-a,gl}$ as:

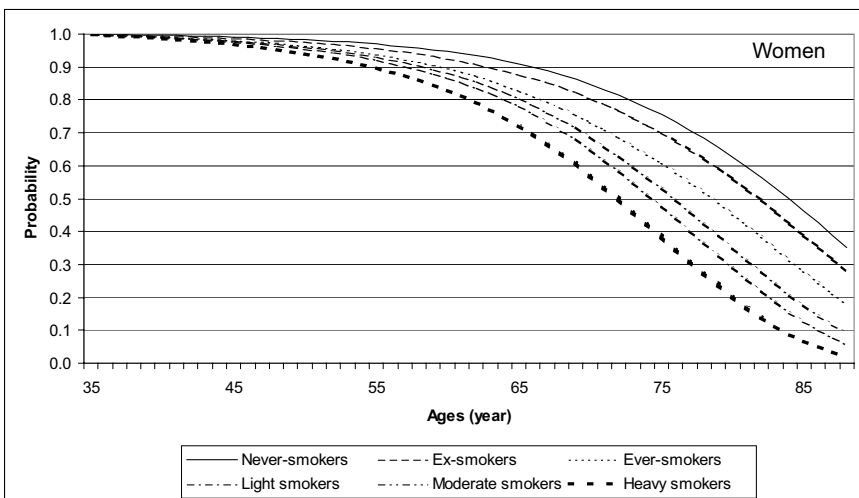
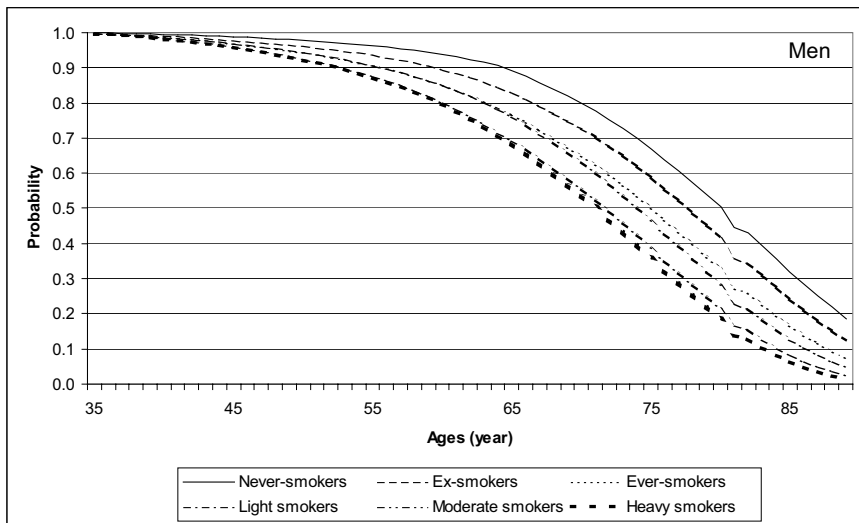
$$PLCe_{ag} = \sum_{t=a}^{69} PCE_{tg} * Se_{t-a,gl} / (1 + d)^{(t-a)}$$

for $a=35, 40, \dots, 65$ years and with d the annual discount rate. Equivalent estimations were done for never-smokers and for current and former smokers, with $a=35$ years.

Appendix P: Probability of survival

The estimated probabilities used in the present thesis are shown in the figures below.

Appendix Figure 2. Probability of survival to given ages for never-smokers, ex-smokers, ever-smokers, light smokers (1-14 gram tobacco daily), moderate smokers (15-24 gram tobacco daily), and heavy smokers (≥ 25 gram tobacco daily) given survival to age 35. The estimates are based on Danish life tables (1998-1999) (146), relative risk-estimates from Prescott et al. (26), and smoking proportions from PLS Consult (145).



Appendix Q: The socioeconomic costs due to tobacco smoking estimated by Elleman-Jensen

Appendix Table 3. The socioeconomic costs due to tobacco smoking by costs components, smokers' level of risk information and dependency. Denmark, 1983. Million DKK. 4% discount rate.

No. and cost components	Smokers unaware of health risk and totally addicted	Smokers aware of health risk and not addicted
1 Medical treatment costs	482	482
2 Lost earnings:		
as a result of days sickness absence	21	-
as a result of early retirement	535	-
2a Sickness benefit paid in case of sickness		275
3 Costs of premature death	1,295	-
3a Effect on income taxes and transfer payments in the case of premature death:		
income taxes	-	1,264
retirement pension	-	-1,481
4 Resources employed in the production of tobacco	290	-
5 Tax revenue from the tobacco duty	-	-5,922
6 Pain and suffering to relatives	-	?
7 Nuisance to non-smokers and other externalities (here only including fire risk)	15	15
The total socioeconomic costs	2,638	-5,367

Source: From Elleman-Jensen (229) Table 15, based on Atkinson & Meade (230).

Appendix R: Study I

The first study (Study I) published in the European Journal of Public Health (17) is reprinted in this Appendix with permission from the editor of European Journal of Public Health.

The total lifetime costs of smoking

SUSANNE R. RASMUSSEN, EVA PRESCOTT, THORKILD I.A. SØRENSEN, JES SØGAARD*

Background: Net costs of smoking in a lifetime perspective and, hence, the economic interests in antismoking policies have been questioned. It has been proposed that the health-related costs of smoking are balanced by smaller expenditure due to shorter life expectancy. **Method:** A dynamic (life cycle) method taking differences in life expectancy into account. **Main outcome measures** were direct and indirect lifetime health costs for ever-smokers and never-smokers, and cost ratios (ever-smokers to never-smokers). The estimations were based on annual disease rates of use of the healthcare services, smoking relative risks, smoking prevalences, and costs. **Results:** Annual direct and indirect costs of ever-smokers were higher than for never-smokers in all age groups of both genders. The direct and indirect cost ratios were highest at age 45 for women, and at age 35 and 40 for men, respectively. Taking life expectancy differences into account, direct and indirect lifetime health costs for men aged 35, discounted by 5% per year were 66% and 83% higher in ever-smokers than in never-smokers. Corresponding results for women were 74% and 79%, respectively. The results are insensitive to a broad range of relative risk-estimates and discount rates including no discounting. Excess costs of ever-smokers disappear if the inclusion of smoking-related diseases is narrowed to that of previous studies. **Conclusion:** Smoking imposes costs to society even when taking life expectancy into consideration – both in direct and indirect costs.

Keywords: age groups, Denmark, health care costs, life tables, smoking-economics

Smoking is a major health hazard.^{1,2} Yet the economic issue of smoking-related health costs remains undetermined. Smoking imposes substantial health-related economic costs to society estimated on an annual basis.^{3,4} However, findings are unclear when the longer life span of non-smokers is taken into account. Two studies found higher average lifetime health care costs in smokers compared to non-smokers,^{5,6} and three studies found the opposite.^{7–9}

In particular the frequently quoted study from the Netherlands,⁹ reported 15% higher lifetime health care costs in non-smokers than in smokers and claimed antismoking interventions to be unattractive in a narrow economic sense. This study by Barendregt *et al.* has had great impact on the concept of economic costs related to smoking and hence the economic benefits related to smoking cessation policies.⁹ However, this study had several limitations. Most importantly Barendregt *et al.* assumed that costs for all diseases other than heart disease, chronic obstructive pulmonary disease and cancers were not related to smoking, and that smoking-related diseases constituted less than 20% of the total lifetime costs. Further, the study did not include indirect costs related to smoking, i.e. value of lost productivity.

We have estimated total lifetime health costs of ever-smokers and never-smokers in Denmark, and decomposed the costs in direct (health care) lifetime costs and indirect lifetime costs, i.e. costs due to reduced labour supply. We included a broader set of smoking related diseases than previous studies⁹ and performed extensive sensitivity analyses to ensure that results were robust to the assumptions applied.

METHODS

The economic effect of active smoking has been examined in a lifetime perspective comparing the health costs of never-smokers

and ever-smokers (current smokers and former smokers) by age and gender. The health costs include all costs related to smoking from age 35 to age 89 years under the assumption that outside this age interval, the effects of smoking on the health costs are negligible. Operationally, total health costs were defined as the sum of direct costs and indirect costs. Costs of the Danish population in 1999 were studied within four disease groups: cancer (ICD-10: C00–C99), vascular disease (ICD-10: I00–I99), respiratory disease (ICD-10: J00–J99), and all other diseases.

Direct costs included frequencies and costs of discharges (including casualty ward) by cost weights according to diagnosis-related groups and costs of outpatients by speciality specific prices – all based on data from The Danish Ministry of Health. The use and cost of drugs was based on the selling prices of drugs (including charge of dispensary) from The Danish Medicines Agency. The frequencies of consultations with general practitioners by groups of diseases was based on a Danish cross-sectional study¹⁰ and applied to frequencies of consultations data and costs from The National Health Security System for general practitioners' fees as well as physiotherapists' fees. Estimation of indirect costs was based on information on early retirement from The Social Appeals Board, which provides this information by 99 groups of diagnoses. Information on absentee days was provided by Statistics Denmark and the distribution of absence by diagnostic groups of diseases by The Danish Working Environment Authority.¹¹ Mortality data was based on the national Register of Causes of Deaths. Duration of rehabilitation was assumed to be equivalent to being out of production for half a year before the granting of early retirement. Data on survival probability (1998/1999), private income (1997), frequencies of occupation, and employment (1999) were extracted from tables from Statistics Denmark. Private income was adjusted to 1999 DKK using the consumer price index. All the information was age- and gender-specific. Table 1 provides a summary of the sources of information and the annual total health costs by cost categories included in the present analysis.

Estimation of the total lifetime health costs of smoking combines cost-of-illness¹² and life expectancy for a given smoking status (ever-smokers and never-smokers). An earlier cost-of-illness analysis,¹³ which included direct and indirect costs, was updated using data from 1999. Direct costs were estimated by the

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economic resources used in the health care sector, i.e. costs of diagnostics, nursing and treatment of diseases. Indirect costs were estimated by the human capital method as the value of lost production by short-period and long-period disease and premature death (equivalent to the production a sick or dead person statistically could have produced up to age 69 inclusive, if the person was an active member of the workforce).

Population attributable risk percentages were used as indicators for parts of output¹⁴ as well as parts of costs attributable to smoking. Using Danish smoking proportions¹⁵ and Danish estimates of relative mortality risks (RR),¹ we estimated age-, gender-, and disease-specific population attributable risks with the estimation algorithm shown in, for example, a New Zealand study.¹⁶ To estimate the direct and indirect smoking-related costs per person-year by smoking status, age, gender, and disease category, the direct and indirect costs were multiplied by the population attributable risk percentages and afterwards calibrated and divided by the number of persons in the category in question. The remaining direct and indirect costs were assumed to be independent of smoking status, and they were assigned according to age and gender. The total costs per person-year were estimated by smoking status, age, and gender by adding the direct and indirect smoking-related costs to the direct and indirect remaining costs.

Based on the standard life table from Statistics Denmark (1998–1999), the survival probabilities were estimated by smoking status and gender, conditionally on being alive at given ages (35, 40, ..., 75), and truncated at 89 years. By multiplying costs per person-year by the survival probabilities and discounting by 5% per year, total, direct, and indirect lifetime health costs were obtained for men and women by smoking status and age (35–89, 40–89, up to 75–89 years). Total lifetime health cost estimation assumes that a 45-year-old's costs per person-year are an appropriate estimate of a 35-year-old's costs per person-year in ten years (stationarity assumption).

The sensitivity of the results of the analysis was examined by repeating the analysis

- with different RRs, lower and upper bounds of each RR being $1+0.5(RR-1)$ and $1+1.5(RR-1)$;
- with different discount rates (3%, 8% and no discounting);
- with a narrower definition of smoking-related diseases, i.e. an

RR of 1.0 for 'all other diseases' other than respiratory, cardiovascular, and neoplasm, as in the Dutch study.⁹

RESULTS

Annual direct and indirect costs attributable to smoking in Denmark (population: five million; overall smoking prevalence among adults: 35%) amounted to 9,720 and 13,940 million DKK, respectively (100 DKK \approx \$ 11.6 by GDP-PPP 1999 conversion, OECD Data Health Files, 2000). Ever-smokers incurred higher annual direct and indirect costs than never-smokers in all ages in both men and women. Direct costs rose sharply with age for men aged 35 to 85 and for women aged 40 to 85, whereas indirect costs per person-year rose slightly to age 45 in both men and women and decreased afterwards (figure 1). The direct and indirect cost ratios (ever-smokers to never-smokers) were highest at age 45 for women, and at 35 and 40 for men, respectively.

Taking lifetime expectancies into account, figure 2 shows direct and indirect lifetime health costs by smoking status, age and gender, up to 89 years. The direct and indirect lifetime health costs of ever-smokers exceed never-smokers' costs in all ages from 35 to 75, and from ages from 35 to 69, respectively, in both men and women. The total lifetime health costs as well as the ratios for total lifetime health costs for ever-smokers to never-smokers decrease with age in both men and women.

In table 2 the direct and indirect lifetime health costs of a 35-year-old person are presented by smoking status, disease category, and gender; costs are truncated at 89 years and discounted at 5%. It is shown that ever-smokers' total, direct, and indirect lifetime health costs are 1.78, 1.66, and 1.83 times higher than those of never-smokers in men and 1.77, 1.74 and 1.79 times in women, respectively. Further it is illustrated that ever-smokers' costs exceed never-smokers' costs in all the disease categories, especially in respiratory disease. Table 2 also shows that the overall results were the same within a broad range of RR-estimates. Discounting with different rates (no discounting, 3% per year, and 8% per year), ever-smokers' total lifetime health costs are 1.63, 1.73, and 1.82 times higher than those of never-smokers in men and 1.65, 1.74, and 1.80 times in women, respectively.

Table 1 Sources of information and the annual health costs per person-year by cost categories; Denmark, 1999, DKK

Category of data	Sources	Annual health costs per person year ^a	
		DKK	%
Direct health costs		9,961	41.6
The primary sector		2,876	12.0
Consultations with general practitioners	The National Health Security System and Ovesen <i>et al.</i> ⁸	658	2.7
The general physiotherapeutic treatments	The National Health Security System	107	0.4
Drugs	The Danish Medicines Agency	2,111	8.8
The secondary sector		7,085	29.6
Discharges	The Danish Ministry of Health	5,524	23.1
Outpatients and casualty ward	The Danish Ministry of Health	1,561	6.5
Indirect health costs ^b		13,963	58.4
Mortality	Registry of Causes of Death	3,354	14.0
Permanently stopped working (early retirement)	The Social Appeals Board	4,610	19.3
Temporarily stopped working (rehabilitation)	Assumption	383	1.6
Absentee days	Statistics Denmark and The Danish Working Environment Authority	5,616	23.5
Total health costs		23,924	100.0

a: For persons aged 35–89 years.

b: Estimated with the human capital method.

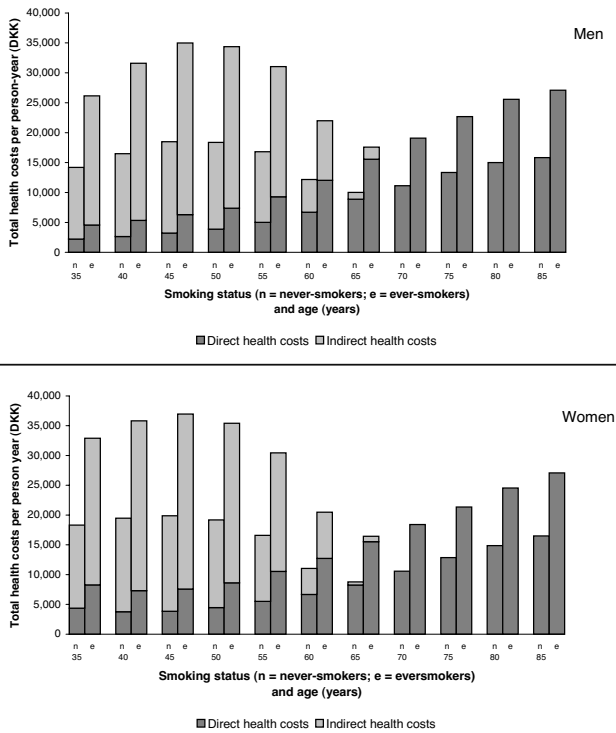


Figure 1 Total health costs per person-year by costs, smoking status, age, and gender; Denmark, 1999

DISCUSSION

The present study confirms recently published results from the USA.³ Smoking imposes substantial health-related economic costs to the society estimated on an annual basis. Furthermore, our analysis showed that even though never-smokers live longer than ever-smokers, they are less costly in a lifetime perspective in terms both of direct and indirect costs.

The validity of the estimated total lifetime health costs depends on unbiased estimates of epidemiological and economic parameters. This study did not include costs of prevention, costs from the social sector, and costs of rehabilitation and nursing in the municipal sector, since these cost data are unavailable in Denmark. Manning *et al.*⁵ find that non-smokers lifetime costs by nursing home exceed smokers' slightly, namely by \$0.03 per pack of cigarettes smoked in 1986 dollars discounted at 5%; Wang *et al.* find that smoking predicts nursing home admission although insignificantly.¹⁷ In view of the uncertainty of these results, it is assumed that the costs of prevention, the social sector, rehabilitation, and the nursing home will not affect the overall conclusion.

The analysis is limited by uncertainty of the RR-estimates, as they have been adjusted only for age and inhalation, and they may overestimate the effect of smoking due to positive confounding by, for example, socioeconomic factors. However, adjusting for socioeconomic and lifestyle factors has been shown to attenuate RR's only slightly.¹⁸

Time since quitting smoking is known to affect RRs differently for different disease categories; for example, risk of cardiovascular

disease is thought to decrease relatively rapidly whereas risk of lung cancer and COPD declines much more slowly. Since the precise time course of risk reduction is subject to some uncertainty, calculations were based on risk estimates for former smokers based on a mixed population with varying time since smoking cessation and mean duration of follow-up of approximately 15 years. Risk estimates for former smokers are thus considered conservative. The RR-estimates for respiratory disease applied were higher in women than in men presumably because they were based on a population sample with an unusually high prevalence of smoking among women with adjustments made for differences in inhalation habits and quantity smoked.¹⁹ Higher risk estimates in women have been reported in a number of recent studies (for a review, see Ref. 20). However, respiratory diseases make up a relative low proportion of the total lifetime health costs, for which reason the overall conclusion is shown to be relatively insensitive to the substantial lower sensitivity range of the RR-estimates. The distribution of costs was based on RRs derived from mortality rates and applied to both mortality- and morbidity-related data. However, several studies have indicated that smoking-related risks of absentee days, hospital discharges, early retirement, visits to general practitioner, and use of prescription medicines²¹⁻²⁴ are of similar size to that of all-cause mortality. In addition, this analysis was not sensitive to different RR-estimates over a broad range.

Furthermore, the present analysis is limited by uncertainty of the smoking proportions, which were based on an omnibus survey; however, self-report is generally accepted as a valid measure of

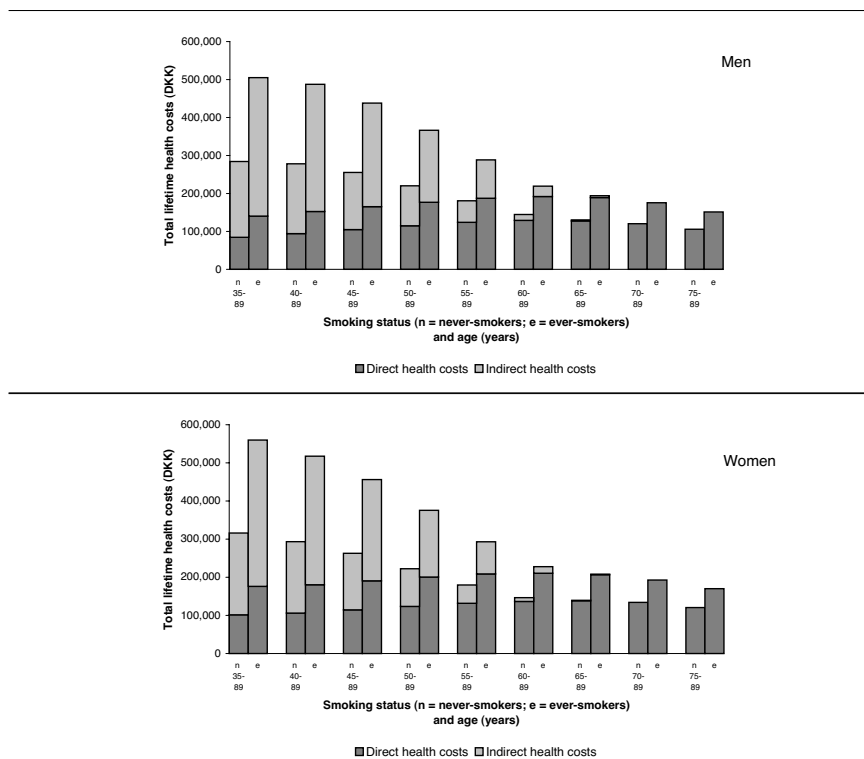


Figure 2 Total lifetime health costs at given ages by costs, smoking status, and gender. Truncated at 89 years, 5% discount rate per year; Denmark, 1999

smoking.²⁵ Finally, survival probabilities may influence the validity of this analysis, but the estimates agree very well with a Danish empirical study of never-smokers and smokers with different smoking habits.²⁶

Longevity and discounting of future costs affect lifetime costs. However, it is important to discount future costs, in judging any policy that has long-term effects.²⁷ By discounting one makes costs that occur at different times comparable; otherwise a given amount of money spent today would be worth more than the same nominal amount spent 15 years from now, even without inflation. Lower discount rates increased the total lifetime health cost-estimate and at the same time reduced the percentage difference between ever-smokers and never-smokers. Even with no discounting, however, the total lifetime health costs of never-smoking persons were smaller than those of ever-smokers of the same age and gender.

The direct costs by cost-off-illness-estimates tend to be conservative and thus lead to an underestimation of direct lifetime health costs. This was primarily for four reasons: i) insufficient coverage of costs of rehabilitation and nursing in the municipal sector; ii) the hospital cost estimates use Danish weights according to diagnosis-related groups. They include all running costs associated to diagnostics, nursing and treatment of diseases (equivalent to 60 to 65 % of the hospital costs), and exclude all capital costs;²⁸ iii) the speciality specific prices for outpatients were only based on doctors' and nurses' time expenditures; and iv) the costs of consultations with general practitioners were only

based on expenditures per consultation (about 63% of all costs in general practice).

The results, i.e. that lifetime health costs of ever-smokers exceed those of never-smokers, both with and without indirect lifetime health costs, agree with two previous studies^{5,6} and disagree with the three studies.⁷⁻⁹ In the latest published study, Barendregt *et al.* show that for 40-year-old men and women in the Netherlands the direct lifetime cost ratio between current smokers and non-smokers is 0.87 and 0.85 for men and women, respectively.⁹ This discrepancy between results cannot be explained by the classification of ex-smokers (in the group of non-smokers versus the group of ever-smokers), as ex-smokers' lifetime health costs presumably lie between never-smokers' and current smokers' costs. However, Barendregt *et al.* limited lifetime costs due to smoking to heart disease, lung cancer, stroke, other cancers, and chronic obstructive pulmonary, and assumed the costs for all other diagnoses to be independent of smoking status; furthermore, the five smoking-related diseases constituted less than 20% of the total lifetime costs. We disagree with this assumption, as smoking, in addition, has been documented to be associated with chronic bronchitis, peripheral artery occlusive diseases, and aortic aneurysm.^{29,30} Smoking also increases the risk of pneumonia, gastric and duodenal ulcers, osteoporosis, hip fractures, type 2 diabetes mellitus, and wound-related post-operative complications.³⁰⁻³⁴ To estimate population attributable risk percentages for 'all other diseases', this study used an RR of 1.2 to 2.9 (dependent on level of tobacco

consumption) based on Danish RR-estimates by quantity of daily tobacco consumption.¹ To compare the present results with the Dutch results, we have re-examined our data with

- an RR of 1.0 for 'all other diseases' other than respiratory, cardiovascular, and neoplasm, and
- used undiscounted costs as in the Dutch study.

Then it was found that ever-smokers' direct lifetime health costs exceeded never-smokers' only slightly; undiscounted ratios for direct lifetime health costs for ever-smokers to never-smokers were 1.02 in men and 1.07 in women, respectively compared to these present results, where the ratios were 1.66 in men and 1.74 in women, respectively. By limiting the smoking-related diseases to those five groups and assuming the costs for all other diagnoses to be independent of smoking status, Barendregt *et al.* omitted substantial direct lifetime health costs of smoking and thus underestimated direct lifetime health costs for smokers and overestimated direct lifetime health costs for non-smokers. However, the Dutch study does find that smokers' direct lifetime health costs exceed non-smokers' when discounting by 4.5% in men and 5.5% in women. If Barendregt *et al.* had included more smoking-related diseases and omitted the assumption that the

costs for all other diagnoses were independent of smoking status, then we expect the direct lifetime health costs for Dutch smokers would exceed non-smokers' even without discounting.

CONCLUSIONS

Smoking imposes costs on society even when taking life expectancy into consideration, both in excess health care utilization and in terms of reduced labour supply.

This study was funded by The Danish Medical Research Council and DSI Danish Institute for Health Services Research. The Danish Epidemiology Science Centre is supported by the Danish National Research Foundation.

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Table 2 Total lifetime health cost for a 35-year-old by costs, smoking status, gender, and disease. Truncated at 89 years, 5% discount rate; Denmark, 1999, DKK

Gender and cost category	Disease	Never-smokers	Ever-smokers	Cost ratio (sensitivity range) ^a Ever-smokers / never-smokers	
				RR _L	RR _H
Men					
	Direct lifetime health costs	84,464	140,390	1.66 (1.34 – 1.97)	
	Cancer	7,154	12,108	1.69 (1.35 – 2.02)	
	Vascular	23,204	30,660	1.32 (1.15 – 1.49)	
	Respiratory	3,615	9,917	2.74 (1.92 – 3.51)	
	Other diseases	50,491	87,704	1.74 (1.38 – 2.09)	
	Indirect lifetime health costs ^b	199,634	364,955	1.83 (1.42 – 2.22)	
	Cancer	18,075	37,416	2.07 (1.54 – 2.60)	
	Vascular	25,582	39,180	1.53 (1.26 – 1.80)	
	Respiratory	3,451	11,886	3.44 (2.25 – 4.59)	
	Other diseases	152,526	276,472	1.81 (1.41 – 2.19)	
	Total lifetime health costs	284,098	505,344	1.78 (1.40 – 2.14)	
	Cancer	25,229	49,525	1.96 (1.49 – 2.43)	
	Vascular	48,786	69,840	1.43 (1.21 – 1.65)	
	Respiratory	7,066	21,803	3.09 (2.09 – 4.03)	
	Other diseases	203,017	364,176	1.79 (1.40 – 2.17)	
Women					
	Direct lifetime health costs	101,428	176,029	1.74 (1.39 – 2.06)	
	Cancer	10,762	15,502	1.44 (1.22 – 1.65)	
	Vascular	13,899	22,898	1.65 (1.34 – 1.94)	
	Respiratory	3,489	13,567	3.89 (2.61 – 5.02)	
	Other diseases	73,278	124,062	1.69 (1.36 – 2.02)	
	Indirect lifetime health costs	214,477	383,779	1.79 (1.41 – 2.16)	
	Cancer	27,459	43,966	1.60 (1.30 – 1.90)	
	Vascular	14,650	28,970	1.98 (1.49 – 2.45)	
	Respiratory	1,886	9,653	5.12 (3.24 – 6.72)	
	Other diseases	170,482	301,191	1.77 (1.39 – 2.13)	
	Total lifetime health costs	315,905	559,808	1.77 (1.40 – 2.13)	
	Cancer	38,221	59,467	1.56 (1.28 – 1.83)	
	Vascular	28,549	51,868	1.82 (1.42 – 2.20)	
	Respiratory	5,375	23,219	4.32 (2.84 – 5.61)	
	Other diseases	243,759	425,253	1.74 (1.38 – 2.10)	

a: The sensitivity range was calculated with the lower (RR_L = 1+0.5(RR-1)) and upper bounds (RR_H = 1+1.5(RR+1)) of the relative risks.

b: Estimated with the human capital method.

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Received 22 July 2002, accepted 6 December 2002

Appendix S: Study II

The second study (Study II) published in the European Journal of Public Health (18) is reprinted in this Appendix with permission from the editor of European Journal of Public Health.

The total lifetime health cost savings of smoking cessation to society

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Background: Smoking cessation has major immediate and long-term health benefits. However, ex-smokers' total lifetime health costs and continuing smokers' costs remain uncomparably, and hence the economic savings of smoking cessation to society have not been determined. **Methods:** The economic effects of smoking cessation in a lifetime perspective have been examined by comparing the health costs of continuing smokers and ex-smokers by quantity of daily tobacco consumption, age, gender and disease group, while taking differences in life expectancy and the reductions in relative risks after cessation into account. **Results:** The total lifetime health cost savings of smoking cessation are highest at the younger ages. Although the economic savings vary with age at quitting, gender and quantity of daily tobacco consumption, all ex-smoking men and women who quit smoking at the age of 35 to 55 years generate sizeable total lifetime cost savings. At older ages, the total lifetime health cost savings of smoking cessation are of little economic consequence to the society. The total, direct and productivity lifetime cost savings of smoking cessation in moderate smokers who quit smoking at the age of 35 years are 24 800 €, 7600 €, and 17 200 € in men, and 34 100 €, 12 200 €, and 21 800 € in women, respectively. **Conclusions:** Lifetime health cost savings of smoking cessation to society are substantial at younger ages, in terms of both direct and productivity costs.

Keywords: cost savings, health care costs, life tables, smoking, smoking cessation

Smoking is harmful to health^{1,2} and the health benefits of smoking cessation have been documented.³ We have found that smoking imposes costs to society, even when taking non-smokers longer life span into consideration.⁴ However, from a policy point of view it is of interest what the savings of smoking cessation are. Few studies have estimated the economic impact of smoking cessation in a lifetime perspective, and findings are unclear. Oster *et al.*⁵ found the economic benefits of quitting, estimated from direct and productivity lifetime costs based on three smoking-related diseases, to be sizeable for all groups of smokers; however, they did not take life expectancy into account. Barendregt *et al.*⁶ included life expectancy and reported 15% higher direct lifetime health care costs in non-smokers (never smokers and ex-smokers) than in smokers, and characterize anti-smoking interventions as unattractive in a narrow economic sense. In Barendregt *et al.*'s results, only 20% of lifetime health care costs are related to smoking. This is based on the assumption that only costs for heart disease, chronic obstructive pulmonary disease and cancers are related to smoking. In our view, this may be an underestimation.

We estimated the economic savings of complete smoking cessation to the Danish society in a lifetime perspective comparing continuing smokers' and ex-smokers' total costs, and decomposed the costs in direct (health care) lifetime costs and productivity lifetime costs, i.e. costs due to reduced labour supply. We included a broader set of smoking-related diseases than previous studies.^{5,6} Extensive sensitivity analyses were performed to ensure that results were robust to the assumptions made.

Methods

The economic effect of smoking cessation was examined in a lifetime perspective, comparing the health costs of continuing smokers and ex-smokers by quantity of daily tobacco consumption (light smokers, 1–14 g; moderate smokers, 15–24 g; and heavy smokers, >24 g), age of quitting smoking, gender and disease group. The health costs and the savings of smoking cessation to the society included all costs related to smoking from age 35 years through age 89 years under the assumption that outside this age interval, the effects of smoking on the health costs are negligible. It was assumed that once smokers quit smoking, they are ex-smokers for life. We defined total health costs as the sum of direct costs and productivity costs. Costs of the Danish population in 1999 were studied within four disease groups: cancer (ICD-10: C00-C99), vascular disease (ICD-10: I00-I99), respiratory disease (ICD-10: J00-J99) and 'all other diseases'.

The estimation of the total, direct and productivity lifetime health costs for continuing smokers and ex-smokers were based on data from a previous study that estimated the total lifetime costs in 1999 for ever-smokers and never-smokers. Annual smoking-attributable direct and productivity costs (population 5 million; overall smoking prevalence among adults 35%) amounted to 1310 and 1880 million €, respectively (exchange rate 1999: 743.57 DDK per 100 €).⁴ The direct costs were estimated by the economic resources used in the health-care sector; including costs from discharges, outpatients (including casualty ward consultations), drugs and consultations with general practitioners and physiotherapists. The productivity costs included costs from morbidity (early retirement and absentee days) and mortality. The productivity costs were estimated by the human capital method, the most commonly used method, as the value of loss of production caused by short-term, long-term or permanent cessation of work activity caused by smoking related diseases and premature death.

Estimation of the total lifetime health cost savings of smoking cessation combines the cost of illness⁷ and life expectancy. Population attributable risk percentages (PAR) were used as indicators for parts of output⁸ as well as parts of smoking-attributable costs. Using Danish quantity-, age- and gender-specific smoking

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proportions for current smokers⁹ and Danish quantity-, gender- and disease-specific estimates of relative mortality risks (RR),¹ the quantity- (q), age- (a), gender- (g) and disease-specific (d) PARs (PAR_{qagd}) were estimated with an algorithm used by King *et al.*¹⁰ Furthermore, the quantity-, age- and gender-specific PARs (PAR_{qag}) were estimated based on RR estimates for all causes. Estimating the PAR_{qagd} and PAR_{qag} in ex-smokers it was assumed that 15 years after smoking cessation, the mortality risks among ex-smoking men and women reversed linearly to that of never-smokers, irrespective of the quantity of daily tobacco consumption.

In the international literature, it has been reported that the RR increases with amount of tobacco smoked.^{3,11–14} This pattern does apply to the Danish RR estimates, except for vascular diseases and 'all other diseases' in heavily smoking men. From the Danish study, it appears that heavily smoking women's RR estimates in vascular diseases and 'all other diseases' exceed moderately smoking women's by a factor 1.1 and 1.2, respectively.¹ Owing to some uncertainty in the Danish RR estimates, the RR estimates for vascular diseases and 'all other diseases' in heavily smoking men were increased proportional to moderately smoking men.

Continuing smokers' and ex-smokers' annual quantity-, age-, gender- and disease group-specific smoking-attributable direct (ADC_{qagd}) and productivity (APC_{qagd}) costs per person-year were estimated by multiplying the annual direct and productivity costs by age, gender and disease group by the PAR_{qgd} and afterwards by calibrating and multiplying by the fraction PAR_{qagd}/PAR_{qgd} and dividing by the number of persons in the category in question.

Owing to non-additivity and sample variation of the PAR estimates, the sum of annual disease-specific smoking-attributable costs (AC_{qagd}), estimated from the PAR_{qgd} estimates, exceeded annual smoking-attributable costs (AC_{qag}), estimated from the PAR_{qag} estimates. Therefore, AC_{qagd} were calibrated by excess reduction proportional to their share of the sum of AC_{qgd} .

As implicit in the estimation of PAR, the remaining annual direct and productivity costs were assumed to be independent of the smoking status, and they were assigned according to age, gender and disease group. The annual total costs per person-year were estimated by quantity of daily tobacco consumption, age, gender and disease group by adding the direct and productivity smoking-attributable costs to the annual direct and productivity remaining costs.

Based on the standard life table from Statistics Denmark (1998–1999), the survival probabilities were estimated by smoking status and gender, conditionally on being alive at given ages (35, 36, . . . , 89 years). By multiplying annual costs per person-year by the survival probabilities and discounting by 5% per year, total, direct and productivity lifetime health costs were obtained for continuing smokers by quantity of daily tobacco consumption and for ex-smokers by daily tobacco consumption and given age at quitting (u) (35, 40, . . . , 65 years). Total lifetime health cost estimation assumes that a 45-year-old's costs per person-year are an appropriate estimate of a 35-year-old's costs per person-year in 10 years (stationarity assumption).

The economic savings of smoking cessation to society were estimated as the difference in the total, direct and productivity lifetime health costs between 35-year-old continuing smokers and 35-year-old ex-smokers at given age at quitting. The relative total health cost savings of smoking cessation to society (TLC_{qgdscu}) in ex-smokers who quit smoking in given ages (u) by daily quantity of tobacco consumption (q), gender (g), disease group (d) and costs (c) (running from age 35 years to 89 years for the direct lifetime costs and from age 35 years to 69 years for the productivity lifetime costs) were estimated as: $TLC_{qgdscu} = (TLC_{c_{qgd}} - TLC_{c_{qgdscu}})/TLC_{c_{qgdscu}}$, where $TLC_{c_{qgd}}$ is the total lifetime health costs for continuing smokers by daily quantity of tobacco consumption, gender, disease group

and cost, and $TLC_{c_{qgdscu}}$ is the total lifetime health costs in ex-smokers by daily quantity of tobacco consumption, gender, disease group, cost and given age at quitting.

Sensitivity analyses

The sensitivity of the results of the analysis was examined by repeating the analysis: (i) with different time-span for ex-smokers mortality risk to reach never-smokers' level, lower (RR_l) and upper bounds (RR_u) being 15 years + (0.5 × 15 years) and 15 years – (0.5 × 15 years); and (ii) with different discount rates (no discounting and 8% per year).

Results

Figure 1 shows the total lifetime health cost savings of smoking cessation to society as 35-year-old continuing smokers' excess total lifetime health costs by quantity of daily tobacco consumption, gender and cost category compared with 35-year-old ex-smokers at given age at quitting. It is shown that the difference varies with age at quitting, quantity of daily tobacco consumption and gender. The total, direct and productivity lifetime health cost savings of smoking cessation in 35-year-old moderate smokers, who quit smoking at the age of 35 years, are 24 800 €, 7600 € and 17 200 € in men, and 34 100 €, 12 200 € and 21 800 € in women, respectively. Comparing 35-year-old ex-smoking men who quit smoking at the age of 35 years with 35-year-old continuing smokers, the direct lifetime health cost savings of smoking cessation to society are 30–42%. The corresponding results are 34–43% in ex-smoking women. However, the direct lifetime cost savings of smoking cessation to society is reduced to <12% in 35-year-old ex-smokers who quit smoking later than age 55 years. The productivity lifetime costs savings are minimal in ex-smokers who quit smoking after age 50 years.

Table 1 presents the total cost savings of smoking cessation to society in ex-smokers who quits smoking at the age of 35 years by disease group and cost. All disease groups are associated with lower costs in ex-smokers than in continuing smokers. This relation is particularly strong for the diseases with the highest excess risk: cancers and respiratory diseases. The direct lifetime health cost savings associated with cancers and respiratory diseases are as much as 33–57% and 51–52% in men, and as much as 35–53% and 63–68% in women, respectively. However, the direct lifetime health costs savings of cancers and respiratory diseases only amount to 20–23% of the direct lifetime health cost savings in men, and 24–28% in women, respectively. The direct lifetime health cost savings in 'all other diseases' are 29–41% and 29–38% in men and women, but amount to 58–65% and 58–61% of the direct lifetime health cost savings in men and women, respectively. The relative productive lifetime costs savings in men and women are very similar to the direct lifetime cost savings in the same disease groups. Table 1 also shows that the overall results were the same within a broad range of years decreasing ex-smokers' mortality risk to the never-smoker level.

Table 2 shows that ex-smokers' percentages for direct and productivity lifetime health costs savings are robust to different discounting rates in both men and women. Without discounting, 35-year-old ex-smokers' direct lifetime health cost savings are 28%, 32% and 48% in light, moderate and heavily smoking men, respectively. The corresponding direct lifetime health costs savings discounted with 8% per year are 29%, 33% and 38%, respectively. Very similar results are shown in women.

Discussion

We found that total lifetime health cost savings of smoking cessation are substantial. The direct and productivity lifetime health cost savings were highest at the younger ages, taking the

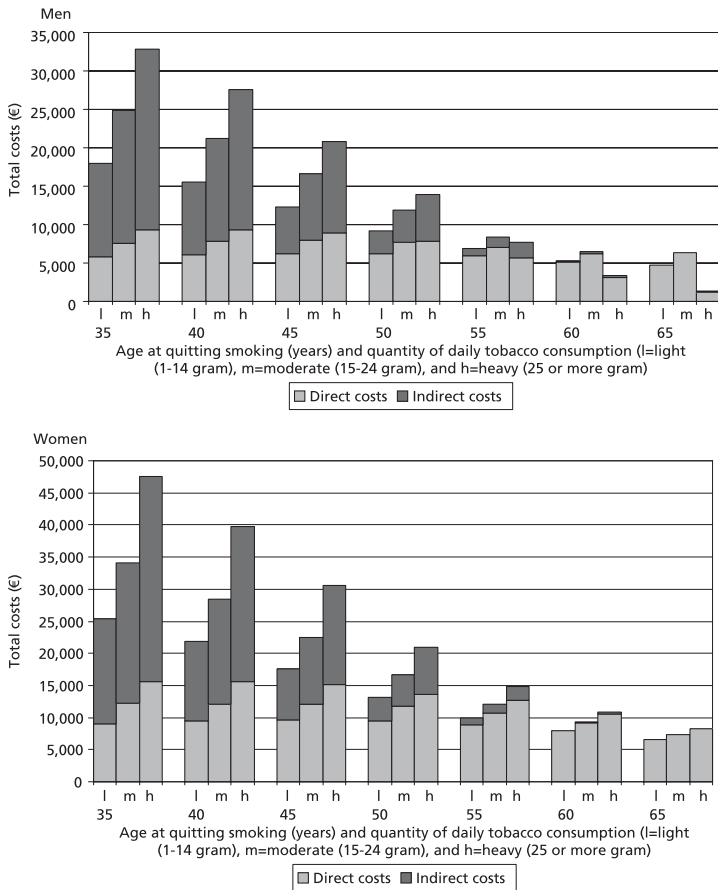


Figure 1 The total lifetime health cost savings of smoking cessation to society in 35-year-old ex-smokers at given age at quitting, by gender, cost and quantity of daily tobacco consumption. Direct and productivity lifetime health costs are truncated at the age of 89 and 69 years, respectively. Five percent discount rate; Denmark 1999; € (exchange rate 1999: 743.57 DDK per 100 €).

difference in life expectancy and the reduced smoking RR after smoking cessation into account. Although the savings vary with age at quitting, gender and quantity of daily tobacco consumption, all ex-smoking men and women who quit smoking at the age of 35–55 years generate sizeable total lifetime cost savings. At older ages, the total lifetime health cost savings have little economic consequences to society.

The validity of the estimated total lifetime health costs depends on unbiased estimates of epidemiological and economic parameters. The distribution of costs in this study was based on RRs derived from mortality rates and applied to both mortality- and morbidity-related data. Several studies have indicated that smoking-related risks of absentee days, hospital discharges, early retirement, visits to general practitioner and use of prescription medicines^{15–18} are of similar size to that of all-cause mortality. It has been shown that smokers have an increased risk of developing diseases such as pneumonia, gastric and duodenal ulcers, osteoporosis, hip fractures, and type 2 diabetes.^{15,19–21}

We therefore estimated the PARs for ‘all other diseases’ from the relative mortality risks. In addition, the present study was examined by repeating the analysis with different RRs, the lower and upper bounds of each RR being $1 + 0.5(RR - 1)$ and $1 + 1.5(RR - 1)$. Although lower RRs reduced the economic cost savings of smoking cessation (data not shown), there were still sizeable total lifetime health cost savings in ex-smokers who quit smoking at the age of 35–50 years.

By calibration of the AC_{aggd} , the sum of AC_{aggd} is reduced by 2–8% in light and moderate smokers and by 15–18% in heavily smoking women compared with AC_{agg} , whereas the sum of AC_{aggd} in heavily smoking men is increased by 5–12%. This reduces the economic cost savings of smoking cessation except for heavily smoking men, but does not effect the relative lifetime health cost savings.

The direct lifetime health cost savings reported are very similar to both the annual hospital costs (discharges and outpatients costs) and all the direct costs (consultations with

Table 1 The lifetime health costs savings of smoking cessation^a to society in 35-year-old ex-smokers^b by quantity of daily tobacco consumption, ^c gender, cost and disease group (truncated at 89 years, 5% discount rate, Denmark 1999, 1000 €^d)

Gender and cost	Disease group	Light			Moderate			Heavy		
		Cost savings 1000 €	Relative cost savings [% (sensitivity range)] ^e		Cost savings 1000 €	Relative cost savings [% (sensitivity range)] ^e		Cost savings 1000 €	Relative cost savings [% (sensitivity range)] ^e	
			RR	RR _l -RR _u		RR	RR _l -RR _u		RR	RR _l -RR _u
Men										
Direct costs		5.8	30	26-35	7.6	35	29-40	9.3	42	35-50
	Cancer	0.5	33	30-36	0.9	45	40-48	1.2	57	50-62
	Vascular	1.1	25	22-27	1.2	26	23-29	1.4	36	32-40
	Respiratory	0.8	52	47-58	0.8	51	45-58	0.7	52	45-60
	Other diseases	3.4	29	24-35	4.7	34	28-41	6.1	41	33-51
Productivity costs ^f		12.1	25	18-34	17.2	30	21-40	23.5	35	25-47
	Cancer	1.5	32	24-40	2.6	42	31-52	3.9	48	36-60
	Vascular	1.4	25	19-32	1.7	29	21-36	2.0	31	23-39
	Respiratory	0.8	44	32-57	0.9	44	33-58	0.9	46	34-59
	Other diseases	8.4	23	17-32	12.0	28	19-39	16.7	32	23-45
Women										
Direct costs		9.0	34	29-40	12.2	39	34-46	15.6	43	36-51
	Cancer	0.9	35	30-39	1.0	38	33-42	2.1	53	46-59
	Vascular	1.5	41	37-45	1.8	45	40-49	1.8	44	39-48
	Respiratory	1.4	63	57-70	2.0	66	58-73	2.3	68	61-76
	Other diseases	5.2	29	24-36	7.4	35	30-42	9.4	38	31-47
Productivity costs ^f		16.4	29	21-39	21.8	32	23-44	31.9	38	28-51
	Cancer	2.3	33	24-42	2.7	35	26-45	5.8	47	35-60
	Vascular	1.7	36	26-47	2.1	38	27-52	2.4	41	30-54
	Respiratory	0.9	56	42-70	1.2	55	39-72	1.6	61	46-75
	Other diseases	11.5	26	19-36	15.8	30	21-42	22.1	35	25-48

a: Estimated as [(current smokers lifetime health costs – former smokers lifetime health costs)/current smokers lifetime health costs]*100%

b: Quitting smoking at the age of 35 years

c: Light, 1–14 g daily tobacco consumption; moderate, 15–24 g daily tobacco consumption; heavy, ≥25 g daily tobacco consumption

d: Exchange rate (1999): 743.57 DDK per 100 €

e: The sensitivity range calculated with different years lowering the excess risk of death caused by smoking; lower (RR_l) and upper (RR_u) bounds are 15 years + (0.5*15 years) and 15 years – (0.5*15 years), respectively

f: Estimated with the human capital method, truncated at 69 years

general practitioners and physiotherapists, drugs and hospital costs), in men and women aged 35–89 years in 1999. Cancers and respiratory diseases in total amounted to 20% of the total hospital costs in both genders and the disease group 'all other diseases' amounted to 53% and 61%, respectively. The corresponding distribution for the annual direct costs for cancers and respiratory diseases was 27% and 20%, and for 'all other diseases' was 56% and 66%, respectively.

Several studies have documented that smoking cessation reduces the risk of diseases and the risk of premature death compared with continuing smoking.³ One American study showed that 16 years after quitting, the mortality risk among ex-smoking men of fewer than 21 cigarettes/day reached that of never-smokers, but remained elevated among ex-smokers of 21 cigarettes or more. Among ex-smoking women in both smoking categories, the mortality risk was comparable to that

of never-smokers after 16 years of abstinence.³ These results are broadly in agreement with other results.^{12,13} Time since quitting smoking is known to affect RRs differently for different disease categories; for example, risk of cardiovascular disease is believed to decrease relatively rapidly,^{3,22} whereas risk of lung cancer and chronic obstructive pulmonary disease declines much more slowly.³ Since the precise time course of risk reduction is subject to some uncertainty, we assumed in the present study that 15 years after smoking cessation the overall and cause-specific mortality risk in ex-smokers reversed linearly to that of never-smokers, irrespective of the quantity of tobacco consumption. Furthermore, we have a rather broad range of years for ex-smokers' disease risk to reach level of never-smokers.

The present analysis may be limited by uncertainty of the smoking proportions, which were based on an omnibus survey.

Table 2 The relative lifetime health cost savings to society^a in 35-year-old ex-smokers^b by gender, quantity of daily tobacco consumption^c, cost and discount rate (truncated at 89 years, Denmark 1999)

Gender and quantity of daily tobacco consumption	Relative lifetime health cost savings (sensitivity range) ^d					
	Direct lifetime cost savings			Productivity lifetime cost savings ^e		
	5%	8%	No discounting	5%	8%	No discounting
Men						
Light	30	29	28	25	23	30
Moderate	35	33	32	30	27	35
Heavy	42	38	48	35	31	41
Women						
Light	34	31	34	29	26	34
Moderate	39	36	40	32	29	38
Heavy	43	39	43	38	34	45

a: Estimated as [(current smokers lifetime health costs – ex-smokers lifetime health costs)/current smokers lifetime health costs] × 100%

b: Quitting smoking at the age of 35 years

c: Light, 1–14 g tobacco per day; moderate, 15–24 g per day; and heavy, >24 g per day

d: The sensitivity range calculated with 8% per year and no discounting

e: Estimated with the human capital method, truncated at 69 years

Self-report is generally accepted as a valid measure of smoking.²³ However, in the omnibus surveys from 1999⁹ and 1996,²⁴ there were no heavy smokers among men aged 70 years and over, for which reason it has been impossible to estimate the economic savings for this group.

Longevity and discounting of future costs affect lifetime costs. However, by discounting we made costs that occur at different times better comparable;²⁵ otherwise a given amount of money spent today would be worth more than the same nominal amount spent 15 years from now, even without inflation. No discounting increased the economic lifetime cost savings of smoking cessation and the relative direct and productivity lifetime health cost savings. Although higher discount rate (8% per year) considerably reduced the economic cost savings, there were still sizeable direct lifetime health cost savings for ex-smokers who quit smoking at the age of 35–50 years. However, at the 8% discount rate the productivity lifetime cost savings were minimal among ex-smokers who quit smoking at the age of 45 years and older.

The direct costs for both continuing smokers and ex-smokers tend to underestimate direct lifetime health costs and direct lifetime health cost savings after smoking cessation. This is primarily due to the insufficient coverage of costs of rehabilitation and nursing in the municipal sector, and the facts that costs weights according to diagnosis-related groups include only the accountable costs (60–65% of the hospital costs), the speciality-specific prices are only based on doctors' and nurses' time expenditures,²⁶ and, moreover, the costs from consultations with general practitioners were only based on expenditures per consultation (~63% of all costs in general practice). Owing to the fact that the lost value of health are not taken into account, the indirect costs for continuing smokers and ex-smokers, hence the indirect lifetime costs savings after smoking cessation, are underestimated.

Our findings that the lifetime health cost savings of smoking cessation are substantial are in agreement with a previous study by Oster *et al.*,⁵ who found higher cost reduction associated with smoking cessation among 35-year-olds than we do. However, Oster *et al.* did not take the shorter life span of smokers into account, and thereby presumably overestimating the lifetime health cost savings. On the other hand, Barendregt *et al.*⁶

reported higher direct lifetime health-care costs (indirect costs have not been included in the study) in 40-year-old non-smokers (never-smokers and ex-smokers) than in smokers aged 40 years old. This result was undiscounted and based on the assumptions (i) that only costs for heart disease, chronic obstructive pulmonary disease and cancers are related to smoking, and (ii) that the costs for all other diagnoses are independent of smoking status (accounting for 80% of direct lifetime health costs). Therefore, we expect the Dutch study to underestimate the direct lifetime health costs for smokers and overestimate the direct lifetime health costs for non-smokers.

Conclusions

The potential lifetime health cost savings of smoking cessation to society are substantial, in terms of both excess health-care utilization and reduced labour supply, even when the reduced life span of smokers is taken into account. The potential direct and productivity lifetime health cost savings of smoking cessation to society are highest at the younger ages.

Acknowledgements

This study was funded by The Danish Medical Research Council and DSI Danish Institute for Health Services Research. The Danish Epidemiology Science Centre is supported by the Danish National Research Foundation.

Key points

- What are the economic savings of smoking cessation to society estimated in a lifetime perspective?
- Direct lifetime health-care cost savings in a moderate smoker quitting as 35-year-old are €7,600 in men and €12,200 in women.
- All ex-smokers who quit smoking at the age of 35–55 years generate sizeable total lifetime cost savings.
- Smoking should be discouraged not only from a public health perspective but also from an economic perspective.

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Received 11 November 2003, accepted 24 May 2004

The lifetime costs of smoking and smoking cessation

PhD thesis

Det er kendt, at rygning har alvorlige sundhedsskadelige konsekvenser, og at rygeophør i alle aldre har en positiv effekt. Flere undersøgelser har også vist, at rygning hvert år medfører betragtelige omkostninger for samfundet. Derimod er resultaterne fra de økonomiske studier ikke klare, når omkostningerne beregnes over et helt livsforløb.

For første gang i Danmark er der i denne ph.d.-afhandling, som er skrevet på engelsk, brugt en dynamisk livstidsmetode til at beregne sundhedsrelaterede omkostninger ved en bestemt livsstilsfaktor – her rygning. I afhandlingen er der således beregnet livstidssundhedsomkostninger for rygning og rygeophør.

Rygning er dyrt for sundhedsvæsenet som følge af større behandlingsbehov. For en 35-årig mand, som ryger moderat er livstidssundhedsomkostningerne mere end 50% højere end for en 35-årig mand, som holder op med at ryge. Der er således en forskel på mere end 56.000 kroner mellem en 35-årig mand, som ryger moderat, og en, som ophører med at ryge som 35-årig. Tilsvarende er der en forskel på mere end 90.000 kroner for kvinder. I beregningerne indgår omkostninger til hospitalsindlæggelser, ambulant behandling, skadestuebesøg, konsultationer hos alment praktiserende læger og fysioterapeuter samt medicinforbrug.

Rygning medfører også høje indirekte omkostninger for samfundet som følge af mere sygefravær og sygdomsbetinget arbejdsophør. Vedvarende rygere og især storrygere koster sundhedsøkonomisk mange penge – og det er uanset alder og køn. Eksempelvis har en storrygende 35-årig kvinde set i et livsperspektiv over 600.000 kroner i indirekte omkostninger, hvilket er 200.000 kroner mere end for en 35-årig kvinde, som har et lille forbrug af tobak.