INCORPORATING EXTERNAL EFFECTS IN ECONOMIC EVALUATION: THE CASE OF SMOKING

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by

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ABSTRACT

The aim of this thesis is to explore methods to incorporate external effects on decision making of public health programmes in a UK setting, using smoking cessation as an example. The National Institute for Health and Clinical Excellence (NICE) methodological guidance for evaluating public health programmes is missing the incorporation of external effects. Therefore there is a need for considering their incorporation in such evaluations and to assess what are the appropiate methods to do so. Smoking cessation is an example where epidemiological evidence of external effects exists but has not generally been incorporated into economic evaluation.

This thesis therefore focused in measuring the impact, in terms of costs and QALYs lost, of the incorporation of passive smoking, smoking during pregnancy and transmission of smoking behavior into economic evaluation of smoking cessation programmes previously developed to inform policy. A static Markov model is used to incorporate passive smoking and smoking during pregnancy, whereas transmisison of smoking behaviour is incorporated through a dynamic model.

The findings show that some external effects can be incorporated without a system dynamic model, when this does occur, a static Markov model may be used to account for external effects in economic evaluation. Sometimes, to incorporate external effects, the model needs a change of population. Because smoking cessation interventions are generally highly cost-effective, the incorporation of external effects does not appear to change policy decisions, but there is a clear impact on the magnitude of the ICER. Passive smoking and smoking during pregnancy have higher impact in terms of costs and QALYs lost than transmission of smoking behaviour. Our discussion considers the validity of the methods used; how much the decision making process would be affected considering or not external effects on economic evaluation of smoking cessation interventions; and other valuation approaches for external effects, such as contingent valuation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF BOXES

LIST OF ABBREVIATIONS

BA	brief advice
BAS	brief advice plus self-help material
BASNRT	brief advice plus self-help material plus nicotine replacement therapy
BASNRTS	brief advice plus self-help material plus nicotine replacement therapy plus specialist clinic
BD	proactive calls, educational booklet, counselling and education interventions, concerning nicotine fading, relaxation and social support delivery
BAD	proactive calls, educational booklet, counselling and education interventions, concerning nicotine fading, relaxation and social support two weeks after delivery
CBA	cost-benefit analysis
CC	computer counselling
CEA	cost-effectiveness analysis
CEAC(s)	cost-effectiveness aceceptability curve(s)
CHD	coronary heart disease
CI	confident interval
COPD	chronic obstructive pulmonary disease
CO2	carbon dioxide
CRD	centre of reviews and dissemination
CUA	cost-utility analysis
DALY(s)	disability adjusted life year(s)
DCM	discrete choice modelling
DSA	deterministic sensitivity analysis
EE	external effect(s)
EQ5D	descriptive system of health-related quality of life states consisting of five dimensions
ETS	environmental tobacco smoke
EU	European Union
FEV	forced expiratory volume
FOI	force of infection
FOINS	force of infection never-smokers
FS	former smoker
GDP	gross domestic product
GHS	general household survey
GP	general practitioner
HEM	health education methods
HERG	health economics research group
HIA	health impact assessment
HIV	Human immunodeficiency virus

HP	hedonic price method (hedonic pricing)
HSE	health survey for England
HTA	health technology assessment
ICER	incremental cost-effectiveness ratio
IQR	interquartile range
LBW	low birth weight
LC	lung cancer
LICB	less intensive counselling and bupropion 150mg
MBA	midwife brief advice
MI	myocardial infarction
MICB	more intensive counselling and bupropion 150mg
MRC	medical research council
MSB	marginal social benefit
MSC	marginal social cost
NAO	national audit office
NHS	national health service
NHS EED	NHS Economic Evaluation Database
NICE	National Institute for Health and Clinical Excellence
NMB	net monetary benefit
NPGC	nicotine patch and weekly group counselling
NPIC	nicotine patch and weekly individual counselling
NPNC	nicotine patch and no counselling
NPPC	nicotine patch and pharmacist consultation
NPPCBP	nicotine patch, pharmacist consultation and comprehensive behavioural program
NRT	nicotine replacement therapy
NS	never-smokers
NPNS	non-passive never-smoker(s)
PNS	passive never-smoker(s)
ODPM	office of the Deputy Prime Minister
ONS	office for national statistics
OR	odds ratio
PC	peer counselling
PDG	programme development group
PHIAC	public health interventions advisory comittee
PSA	probabilistic sensitivity analysis
PSB	proactive calls best case
PSS	personal social service
PSW	proactive calls worst case
QALY(s)	quality adjusted life year(s)
RCP	royal college of physicians

RR	relative risk
R&D	research and development
S	smoker(s)
SIDS	Sudden infant death syndrome
SIR (model)	susceptible-infected-recovered (model)
SCOTH	scientific committee on tobacco and health
SF36	This comprehensive short-form with only 36 questions yields an 8-scale health profile as well as summary measures of health-related quality of life.
ST	stroke
TB	tuberculosis
UK	United Kingdom
UPLIFT	understanding the potential long term implementation on function with tiotropim
VOI	value of Information
WHO	world health organization
WTP	willingness-to-pay

Details of models used in this thesis

M1	Flack et al (2007) model
M2	replication of Flack et al (2007) model
M3	replication of Flack et al (2007) model with relevant changes considered
M4	replication of Flack et al (2007) model with relevant changes considered, and changes to the starting distribution of population
M5	replication of Flack et al (2007) model with relevant changes considered, changes to the starting distribution of population, and including passive smoking
M6	replication of Flack et al (2007) model, for females only, with relevant changes considered, and changes to the starting distribution of population
M7	replication of Flack et al (2007) model, for females only, with relevant changes considered, changes to the starting distribution of population, including impact of newborn babies from smokers mothers
M8	M3 used to model a cohort of 1000 smokers, and M4 used to model a cohort of 417 passive smokers generated by a smoker. Not including transmission of smoking behaviour
M9	M3 used to model a cohort of 1000 smokers, and M4 used to model a cohort of 417 passive smokers generated by a smoker. Not including transmission of smoking behaviour but including passive smoking
M10	M8 including transmission of smoking behaviour
M11	M9 including transmission of smoking behaviour and passive smoking

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DEDICATION

Dedicated to my husband and father-in-law, Kenneth and Angel

CHAPTER 1 Introduction

The National Institute for Health and Clinical Excellence (NICE) is responsible for the development of guidance on the promotion of good health and the prevention of ill health in the UK. NICE informs policy through economic evaluation and provides guidance on the prioritisation and allocation of resources for public health interventions. Economic evaluation, therefore, is an integral part of the public health guidance development process NICE (2009). However, delivering the largest possible improvement in public health depends on the existence of a body of knowledge about which interventions are the most cost-effective. The Public Health Interventions Advisory Committee (PHIAC) and the Programme Development Groups (PDGs) of NICE are therefore required to make decisions that are informed by the best available evidence on both effectiveness and cost effectiveness.

Evaluation of public health interventions raises methodological challenges because these interventions generate very broad costs and benefits that are often directed at populations or communities rather than specific individuals (Weatherly et al, 2009; Drummond et al, 2007). The costs and benefits of individual decisions that accrue to the general population are defined as 'external effects' but they are difficult to consider in economic evaluations. To date, external effects have been both rarely and poorly incorporated into economic evaluations of public health interventions. This may be attributed to the paucity of approaches to measure and value them. There is some recently published literature in this field, mainly about incorporation of the herd-immunity external effect from vaccination in cost-effectiveness analyses (Brisson and Edmunds, 2003; Melegaro and Edmunds, 2004; Claes and Rene Reinert, 2009; Rozenbaum et al, 2010), but decision making on vaccination is not driven by recommendations from NICE. In the context of NICE, there is a surprising gap between guidance on the importance of adopting a broad perspective when considering costs and benefits and the current practice on which policy recommendations are based.

External effects are a key focus of economic theory and have been widely researched outside health discipline (Beuthe et al, 2002; De Beer and Friend, 2006; Hamacher et al, 2001). In public health interventions, external effects have mainly been considered in terms of regulation of health interventions (i.e. regulation on tobacco control) but not in

terms of their provision (i.e. including external effects into economic evaluation, which informs smoking cessation programmes provision in a UK setting). Ignoring external effects can lead to biased and inefficient provision of public health interventions because social costs (or benefits) incurred by public health programmes are larger (or smaller) than private costs. However, private costs are the ones most widely considered in economic evaluation (Drummond et al, 2005).

Smoking cessation programmes are a good example of public health interventions in which documented epidemiological data and clinical evidence of external effects are used (Royal College of Physicians, 2010; Department of Health, 2004). A long list of external effects has been considered on the consumption side including: extra costs to the NHS for treating passive-smoking related diseases (WHO, 2008); costs created by household fires linked to smoking (Department for Comunities and Local Goverment, 2010); and cleaning and building maintenance costs due to smoking on the streets (Novotny and Zhao, 1999). On the production side they include: employment generated from the cultivation of tobacco or the contribution of the tobacco industry to the economy (Chaloupka and Warner, 2000), and damage caused by manufacturing and chemical waste from the tobacco industry (Novotny and Zhao, 1999). Choice about which external effect to use appears to be decided for a variety of reasons and purposes: to establish the full social costs and benefits as a basis for the efficient pricing and allocation of resources and to extend the scope of social cost or benefit (De Dios Ortuzar et al, 2000; Pretty et al, 2000; Wattage and Soussan, 2003; Lechon et al, 2003); to study the implications for economic evaluation of agricultural and food policy (Gray and Malla, 1998); and to value Pigovian taxes in order to internalise external effects on market prices (i.e internalisation of external effects) (Gibbons and O'Mahony, 2002). There are no established criteria for deciding which particular external effects to include in economic evaluation.

There is extensive epidemiological evidence on three important external effects related to smoking: (a) passive smoking: the burden of disease not only for smokers' own health but also for that of the people around them. 'Second-hand' tobacco smoke kills 600,000 people each year (WHO, 2008) and there is no safe level of exposure; (b) smoking during pregnancy: this could cause serious problems including increased risk of miscarriage, premature birth, complications during labour, still birth, low birth-weight and sudden unexpected death in infancy (Royal College of Physicians, 1992);

and (c) transmission of smoking behaviour: when a young person's decision to smoke is influenced by peers' smoking practices (Gilleskie and Strumpf, 2000). These three external effects are the focus of this thesis.

The overarching aim of this thesis is to quantify and compare the magnitude of external effects, in terms of costs and QALYs, and their impacts on an existing economic evaluation, which informed decision making in public health programmes, using smoking cessation as an example. Despite the range of external effects related to the smoking habit, little attention is paid to how these effects could be incorporated into the economic evaluation of smoking cessation programmes. A systematic complementary review conducted (section 3.1, Chapter 3) confirmed that current economic evaluation of smoking cessation programmes have so far failed to incorporate external effects into their analyses (Salize et al, 2009; Hall et al, 2005;Mueller-Riemenschneider et al, 2008). A number of benefits can be anticipated from the incorporation of external effects into economic evaluation. Firstly, it will provide recommendations about methods of economic evaluation and the policy decision making process. Secondly, it will help to develop the practice of measurement and valuation of external effects in the health sector. Finally, it will provide a new direction for research methods for public health interventions.

The thesis is structured in nine chapters.

Chapter 2 explains how economic theory of external effects relates to public health interventions and reviews the importance of external effects from an economic theoretical point of view. It highlights the particular case for consideration of external effects in the health care market and outlines the different types, categories and market forces that characterise them. It also reviews a range of solutions to internalise external effects, focusing on public health interventions.

Chapter 3 reviews ways in which external effects have been measured and valued across other sectors (i.e. transport, environment) noted for their evaluation of external effects. An early review identified these sectors as agriculture, environment, innovation, technology, telecommunications, network, transport and education. Reviewing the methods used in other sectors could lead to: a better understanding of how to value external effects in health; a summary of possible ways of incorporating external effects

into economic evaluation; and ideas on how to transfer relevant methods into public health programmes. The findings of the literature review presented in this chapter suggested that most external effects measured and valued had a negative impact. There appears to be no established criterion either for measuring and valuing a particular type or category of external effect, or for the choice of the most relevant external effects to consider. The decision to measure particular external effects appears to be based simply on the availability of data and/or the aims of the study. However, the most used valuation method is cost-benefit analysis, informed by contingent valuation approaches and the broader literature would support its use for capturing cross-sectoral and intra-sectoral costs and benefits accruing to the population. NICE recommends the use of cost-effectiveness as the primary analysis on which to base decisions and CBA as the second line analysis (NICE, 2009) because there is still some uncertainty around the use of CBA for decision making in the NICE context. As this thesis aims to inform NICE policy making, cost-effectiveness and cost-utility analysis are the recommended approaches to the analysis and valuation of external effects.

Subsequent chapters focus on empirical analyses of the impact of incorporating external effects into decision making, using smoking cessation as a specific example. The broad approach adopted is to conduct a literature review on economic evaluations of smoking cessation programmes, used to inform NICE decision making, which exclude external effects and to select and use one in particular to explore the impact of incorporating external effects in terms of costs and QALYs. The purpose of chapter 4 is to find and replicate an economic evaluation of smoking cessation programmes that has informed NICE decision making which does not incorporate external effects. Chapters 5, 6 and 7 incorporate alternative external effects into the replicated economic evaluation of smoking cessation programmes in Chapter 4 and study the magnitude of their impact.

Chapter 4 search and replicates an economic evaluation used to inform NICE decision-making on smoking cessation but which has not included external effects. The model replicated will be referred to as model 1 (M1). Because the aim of this thesis is to quantify and compare the magnitude of external effects on current decision making by NICE, this thesis incorporates external effects into a model for economic evaluation currently used to inform NICE decision making rather than building a new economic evaluation from scratch. The replication of this model will be called model 2 (M2).

Then, it demonstrates that the model is replicated appropriately, though as some critique is raised, this leads to an adaptation of the model, which is presented as model 3 (M3).

The next three chapters incorporate one external effect after the other in order to study the impact of each one on the economic evaluation of smoking cessation programmes.

In Chapter 5, the impact of passive smoking on economic evaluation is assessed using the economic evaluation replicated in chapter 4 with changes adopted in the model (M3) and, the incorporation of two new groups of population (non-passive and passive never smokers). The model excluding passive smoking in this chapter is referred to as model 4 (M4), and the one which includes passive smoking, as model 5 (M5). An adult population was modelled based on smoking habits. However, when accounting for external effects, the population was augmented by children who are passive smokers. The literature was reviewed to inform the parameters of this model (i.e. health effects and costs generated by passive smoking, etc). Although results show that ranking of the cost-effectiveness of interventions does not change, as expected, passive smoking generates extra costs and loss of QALYs which has an impact on the magnitude of the ICER. Existing models which do not incorporate external effects may underestimate the population effects of smoking cessation programmes and, therefore, not favour results obtained in current economic evaluations of smoking cessation programmes and lead to inaccurate decision making.

Chapter 6 investigates the effect of incorporating external effects associated with smoking during pregnancy using the same model structure as that used in chapter 5 to incorporate passive smoking, though the interventions and the population modelled were different. The model not including smoking during pregnancy is referred to as model 6 (M6) and that in which it is included as model 7 (M7). The population modelled was pregnant women between ages 16 and 44.5 years old, followed for the pregnancy period. When the external effect of smoking during pregnancy was incorporated, the average number of babies delivered by pregnant woman was also introduced in the model. Literature reviews were conducted to inform the parameters for this particular model (i.e. health effects and costs generated by smoking during pregnancy, etc). The main question is how to assess the impact of external effects on the cost-effectiveness of smoking during pregnancy interventions. Although no impact was

observed in terms of policy decision, as expected, a similar increase in costs and QALYs lost was observed to that reported in chapter 5.

Chapter 7 incorporates a third external effect into the economic evaluation of smoking cessation interventions - transmission of smoking behaviour. In this case, instead of using a static model as in Chapters 5 and 6, a dynamic model with two cohorts was created to account for the transmission of smoking behaviour. This was achieved by introducing a new concept in the model: that the never smoker's risk of becoming a smoker depends on the prevalence of smoking in the population. This external effect was introduced in an adult general smoker population. The impact of the transmission of smoking behaviour was studied alone and in combination with passive smoking. When the model includes transmission of smoking behaviour but not passive smoking it is referred to as model 10 (M10) and when both transmission of smoking behaviour and passive smoking are included, as model 11 (M11). This chapter shows that ignoring dynamic models can result in misleading estimates of the aggregated effects of smoking cessation interventions. When dynamics were introduced in the economic evaluation of smoking cessation programmes, differences in lifetime costs and QALYs lost were observed, though, in concordance with expectations, there was no impact on the ICER ranking.

Chapter 8 explores the impact of incorporating passive smoking, smoking during pregnancy and transmission of smoking behaviour on costs, QALYs lost and net monetary benefit (NMB) and, considers the potential impact on decision making for public health programmes. It first compares the results obtained from models M4 and M5 for a general population, then M6 with M7 for a pregnant population and, finally, M8 with M10 and M9 with M11 for a cohort of smokers and passive smokers, and assesses the area of measurement and valuation of external effects in the health sector. It then reflects on the differences across models, discusses their potential impact on policy and makes recommendations for methods of incorporating external effects into economic evaluation models and the policy making process.

Chapter 9 concludes by identifying the key contributions and limitations of this thesis, its policy implications and the research agenda. Incorporating external effects into economic evaluation of smoking cessation intervention has a positive impact on ICERs in terms of lifetime costs and lifetime QALYs lost. Incorporation of the health impacts

from transmission of smoking behaviour in economic evaluation appears to have a higher impact compared with passive smoking or smoking during pregnancy. However, the magnitude of the impact of each particular external effect is difficult to ascertain because the populations modelled to incorporate the different external effects differ. However, the evidence produced by this thesis indicates that it would be advantageous to use available epidemiological evidence to decide whether or not to incorporate external effects. The main research agenda for incorporation of external effects would be: to study the effects of including external effects on the production side (i.e. benefits to manufacturers of tobacco industry). This might be the only way in which the incorporation of external effects would change policy making in smoking cessation; and, the incorporation into decision making for public health interventions closer to the £20,000 threshold. The research agenda for smoking would involve further study the impact of transmission of smoking behaviour with better data.

This thesis contributes to knowledge in a variety of ways. Above all, it shows that cost-effectiveness analyses can incorporate negative external effects on the consumption side. The decision analysis presented in this thesis also provides an exemplar that complements economic evaluation with the economic theory of external effects. Secondly, it tackles the issue of using existing relevant evidence to account for the costs and benefits accruing to others but ignored by most economic evaluations of public health programmes. Thirdly, it demonstrates that some external effects, such as passive smoking or smoking during pregnancy, could be valued using either static or dynamic models. Fourthly, it provides the first empirical analysis of smoking cessation programmes that consider the impact of passive smoking, smoking during pregnancy and transmission of smoking behaviour. Findings indicate that their impact can be measured in terms of extra costs and QALYs lost to society at large if they are included in an economic evaluation. Moreover, it has measured and valued the impact of external effects and has incorporated them into a relevant, existing economic evaluation. Although, no impact on the cost-effectiveness ranking of the different interventions was observed, because this public health programme uses a cost-effectiveness strategy, the inclusion of external effects does have an impact on costs and QALY. It would be interesting to discover whether considering external effects in other less cost-effective behavioural programmes, such as obesity prevention/reduction, would have a greater impact on policy.

Research from this thesis has been presented in two editorial papers (See appendix 1.1 for Trapero-Bertran, 2009a; and, Appendix 1.2 for Trapero-Bertran, 2009b) and the author has also been invited to present results from this thesis at the 8th European Conference of Health Economics (ECHE), 7th to 10th of July 2010, and in the 5th European Conference on Tobacco or Health, 28th to 30th of March 2011. The Health Economics Research Group (HERG) was commissioned to conduct a research project to inform commissioners about the relative merits of local and regional tobacco control and smoking cessation initiatives. This research was intended to provide a toolkit to allow decision makers to estimate the economic impact of tobacco use and how control strategies might improve health. The toolkit was based on the M3 model presented in this thesis, which is the replication of Flack et al (2007) model with relevant adaptations. NICE has also requested a presentation based on the findings of this thesis to consider the place of external effects in the future research agenda.

CHAPTER 2 Economic theory of external effects: the case of health care markets

2.1 Introduction

The aim of this chapter is to set out how economic theory of external effects relates to public health interventions. The objectives are to:

(a) describe the resource allocation process and the 'external effects' (see paragraph 2.2.) of the health care market;
(b) specify the types, categories and the impact of market forces on the external effects of health care;
(c) review methods and solutions used to take into account external effects
(d) explore the importance of accounting for the external effects of health care in economic evaluations in the context of NICE; and,
(e) explain the need to review the measurement and value methods of external effects.

This chapter is structured in five sections. The first covers the allocation of resources within the health care market. The second details the economic theory of external effects and sets the context of external effects in the health care market. The third describes the types, size of market and categories of external effects and cites the existing evidence of categories of external effects. The fourth, explains the two solutions for internalising external effects and the fifth draws together the conclusions of the chapter.

2.2 Allocation of resources within the health care market: health care as an economic good

The World Health Organization (WHO) defines health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 1948). The value of health stems from its capacity to allow us to lead more fulfilling lives in terms of work and play than we might otherwise do (Mooney, 1986b). Health

care is the range of goods and services provided to promote health, or to prevent, alleviate or eliminate ill-health (Culyer, 2005). Therefore, the principal objective of all health care systems is to maximize the quality of health achieved (Cohen and Patel, 2009).

According to this definition, health care is an economic good such as labour, capital and raw material which is used to promote health. It is finite and costly and more of its resources can be devoted to the production and consumption of health care only by diverting them from some other use (Morris et al, 2007a). Our 'wants' for health care – what we would choose to consume, in the absence of constraints on our ability to pay for it as a nation or as a consumer – have no known bounds (Morris et al, 2007a). No health care system in the world has achieved levels of spending sufficient to meet all the perceived population wants for health care (Frankel, 1991).

Member states of the European Union devoted an average of 7.4%[1] of GDP to health care expenditure in 2007 (Eurostat 2007) but technological advances developed much more rapidly than the ability and willingness to pay for them (Mooney, 1986a). A clearly defined economic approach can improve understanding of a variety of relevant issues such as, for example, which resources are available; how they should be used and prioritised for the improvement of health care; who should provide access to them and how; and who will pay for them.

The choices that arise are captured in the concept of 'opportunity cost', i.e. the benefit forgone because those same resources cannot also be used in their next best way. Therefore, each action taken in the implementation of health care by patients, health care providers or governments, involves the sacrifice of benefits that could have been enjoyed if used in an alternative manner. For example, weighing up the costs and benefits of a decision to set up a smoking cessation programme involves assessing the potential benefits to smokers of that intervention, and comparing them with the benefits that might accrue from using those same resources for other health care interventions, such as the reduction of alcohol misuse or investment in education. Health care is not available in an endless supply and the more of it we choose, the more of something else

[1] According to Eurostat the indicator is defined as the share of sickness/health care expenditure in GDP. This expenditure covers [a] cash benefits that replace in whole or in part, the loss of earnings during temporary inability to work due to sickness or injury and [b] medical care provided in the framework of social protection to maintain, restore or improve the health of the people protected. Data for EU15, EU25, CZ, ES (2002 and 2003); IT (2003 and 2004); UK (2003); FR, ES, LV, LT, LU, NL, PL, PT, SI, SK, SE, DE, CZ (2004) are provisional; data for UK, EU15, EU25 (2004) are Eurostat estimates.

we must sacrifice. Because health care is so important to our welfare as human beings, making these choices is difficult and contentious (Morris et al, 2007a) but this is essentially what efficiency involves: getting the most out of the limited resources available.

To state that health care is an economic good is not to suggest that it is identical to other consumer goods and services. Indeed, a considerable part of past and current research in health economics is concerned with questions of whether and how health care is different and what implications this might have for the manner in which society organises its production and consumption. Economics is concerned with what is produced and how and for whom it is produced. The question to ask is should these issues be decided differently for health care? (Morris et al, 2007a).

One way in which these decisions might be made is to allow market forces to determine who gets what. This is precisely the way in which production and consumption decisions about most economic goods and services are made. Economic models of supply and demand predict how firms and consumers behave in such markets and in some cases these are relevant to health care (Morris et al, 2007a).

In most countries, of course, reliance on unfettered market forces for the production and distribution of health care services and products is rare. Typically, governments intervene in health care markets to a far greater degree than for most other economic goods: regulating who may provide a given service, what they may charge and/or the profits they may earn; subsidising health care either partially or fully via a range of taxes; and in some cases, directly providing health care, especially public hospitals. In the UK, the government dominates the funding and provision of health care, so supply is largely fixed by political decisions. Most health care is fully subsidised – nothing is charged at the point of consumption – so, not surprisingly, demand is higher than it would be if patients had to pay. In practice, health care systems are a complex mix of private and public sector activities. The main question to be answered, however, is why health care should be considered different from any other economic good.

Arrow (1963) was the first to attempt an analysis of this question. He argued that special economic problems of medical care can be explained as adaptations of the existence of uncertainty in the incidence of disease and in efficacy of treatment. His key premise was that the principal characteristic of medical care is uncertainty because

demand, the incidence of illness and the efficacy of treatments are all uncertain. The demand for most goods is regular and predictable but ill health occurs randomly and its consequences can be severe. Moreover, there is uncertainty about how any given state of ill health will respond to health care. Recovery from a disease is as uncertain as its future incidence. The variable nature of risk-taking behaviour among health carers also makes this market different from those for economic goods. Arrow touched on two further main idiosyncrasies of consumer and provider behaviour in medical markets without asserting that they were unique and he also claimed that health care is an 'extreme' good. The first difference is that patients do not behave in the same way as consumers. They cannot 'test' the product before consuming it and it is difficult for them to obtain information about the most appropriate medical care for their condition. There are also external effects, because they tend to care about the health of each other consciously (Morris et al, 2007a) or unconsciously (i.e. herd-immunity effect) (Brisson and Edmunds, 2003). The second difference is that doctors do not behave in the same way as commercial decision makers. Arrow (1963) lists four ways in which the expected behaviour of the doctor is different from that of people in business: (a) advertising and overt competition are virtually non-existent among physicians; (b) advice given by physicians as to further treatment by themselves or others is supposed to be completely divorced from self-interest; (c) treatment administered by the physician is dictated by the objective needs of the patients and not limited by financial considerations; and (d) the physician is relied on as an expert in certifying the existence of illness and injuries for legal and other purposes. It is assumed that the need to convey accurate information will, when appropriate, outweigh the decision to please clients (Mooney, 1986b). Economic analysis of health care therefore requires specialised theoretical approaches that acknowledge these differences.

2.3 External effects: market failure in the provision of goods and services

'External effects', an abbreviation for 'external economies and diseconomies' – sometimes referred to as 'externalities', 'neighbourhood effects', 'side effects', 'spillover effects', or 'spillovers' – first appear as 'external economies' in Alfred Marshall's 'Principles' in the context of a competitive industry's downward-sloping supply curve. From now on, the term 'external effects' will be used to refer to those effects which necessarily accompany others that are unrelated to the economic activity

in question. In his introductory volume 'Principles of Economics' (1920), Marshall pointed out that we may divide the economies arising from an increase in the scale of production of any kind of goods, into two classes – those dependent on the general development of the industry (external economies); and those dependent on the resources of the individual houses of business engaged in it, their organization and the efficiency of their management (internal economies). Marshall's early argument about external effects, described by Mishan (1971), was that as an industry expands by, say, the inclusion of an additional firm, any resulting reduction in the average costs of production accrues to all the firms in the industry. The total reduction of costs experienced by all the intra-marginal firms is attributed to the entry of the additional one. The true or 'social' cost of the additional output produced by this marginal firm is not the total cost as calculated by that firm, but subtracting from this total cost the cost saved by all the intra-marginal firms. This proposition is important in determining the 'correct' or 'optimal' output of the industry. But the marginal cost, or total cost of the incremental firm, will be below the average cost by the amount of the total cost-savings it confers on the intra-marginal businesses. Therefore, marginal cost will be below the market price to the same extent and, following the marginal-cost pricing rule, output should be extended beyond the competitive equilibrium until marginal cost is equal to price. The existence of external economies in a competitive industry, Marshall concludes, entails an equilibrium output that is below optimal.

According to Mishan (1971), the 'ideal', or 'optimal', output is identified by the point at which the supply curve of the firm intersects its demand curve. This concept, and its corresponding construction, he extended in a symmetrical manner to external diseconomies, to reveal that the optimal output of a competitive industry was below the equilibrium output. These external effects were later shown by well-known economists (i.e. Buchanan, Fisher) to have wide applications to companies in determining the optimal size of an industry and also to industries themselves. Such effects, however, are not exclusive to industry.

Brent (1997) states that an external effect exists when there is interdependence between the utility (or production) function of individuals or firms: i.e. where an individual or firm B's consumption or production affects that of another person or firm A. This can be mathematically presented as equation 2.1 (E2.1):

$$UA = UA\,[X_A1, X_A2, \ldots, X_Am; Y_B1] \qquad \text{(E2.1)}$$

This illustrates that the utility of individual or firm A is dependent on the activities (X_A1, X_A2,…, X_Am) that are under his/her control but also on another Y_B1, which is under the control of a second individual or firm B. This outside activity Y_B1 can enhance A's utility (for example, if B is a gardener who grows beautiful flowers that decorate A's neighbourhood) or can detract from A's utility (for example, if B is a smoker who indirectly causes the non-smoking A to get lung cancer). In other words, external effects can enhance individuals' or firm's utility, or reduce it, depending on the type of external effects.

External effects appear in two forms (Feldstein, 1979). The first impacts on economic efficiency: it is only when all the marginal benefits (MSB) equal all the marginal costs (MSC) that the optimal level of output is determined. The second affects redistribution: some people receive an external benefit for which they do not compensate those providing them, or a cost is imposed on them for which they are not reimbursed.

There are many definitions of external economies. Arrow (1971) defined external effects as the consequences of an action by one individual or group that falls on others, and unintentionally alters the utility and/or the production functions of those individuals without compensating them for damage caused or their having to compensate for advantages that accrue to them from that economic activity. Sometimes it is difficult to distinguish the intentionality of such an action in the production side of the market but, it is normally assumed that these actions spring from unintentional behaviour.

2.3.1 The particular case of external effects in the health care markets

This section will explore the relevance of theories of market equilibrium to markets for health care. In a competitive market system, economic efficiency of both demand and supply cannot normally be achieved when common assumptions underlying that competitive markets are violated (Feldstein, 1979).

Health care markets, however, seem to operate rather differently because of their specific characteristics. The following important assumptions of perfect competition are unfulfilled in medical care: (a) that consumers have perfect information. Consumers lack information concerning their medical diagnosis, treatment needs, the quality of different providers and the prices charged by different providers (Feldstein, 1979); (b)

that there is complete mobility of resources and patients and providers have an incentive to minimize their costs of purchasing and providing medical treatment (Feldstein, 1979). Barriers to mobility of resources include restrictions on the tasks that various personnel are permitted to perform; limited entry into health professions and controlled entry by institutions into various institutional markets (Feldstein, 1979); and, (c) the presence of external effects. Arrow cites communicable disease in this context: an individual who refuses vaccination or diagnosis (e.g. HIV) not only risks his own health but that of others. This implies that the market price of a vaccine may not accurately capture all the benefits and costs of the market transaction and no feedback mechanism exists to reflect the value of the resources used in health care (Scott et al, 2001).

Health care markets will not lead to Pareto efficiency if external effects are present. In theory, individuals in a well-functioning, perfectly competitive market will use medical care until the marginal benefits, measured through the demand curve, equal marginal costs, which in equilibrium will equal the price. This leads to an efficient level of consumption in the absence of external effects but where external effects exist, the marginal external cost or benefit to people in society must be added to the marginal private cost or benefit, which is measured by the demand curve, leading to the marginal social cost or benefit. Therefore free health care markets do not provide optimal welfare.

2.3.2 Different ways of categorising external effects

There are two types of external effects: negative (social costs), and positive (social benefits). Negative external effects exist when the market quantity is greater than the equilibrium quantity. A clear example would be passive smoking, defined as the involuntary inhalation of cigarette smoke in closed spaces that have been contaminated by smokers and which is associated with a number of health consequences. Positive external effects exist when the market quantity produced is smaller than the equilibrium quantity, for example the case of immunization for contagious diseases. Here, people outside the market transaction – people who are not presently being immunized – are affected by the immunization because the immunized person is less likely to become a carrier of the disease.

Each type of external effect can occur on the production or consumption side. An external effect on the consumption side occurs if in an economic transaction, one consumer cares directly about another agent's production or consumption action (Varian, 1996). When the consumption of a good by one person affects the welfare of another person or an agent's production and that effect is not fully taken into account by the original person in making her/his decision to consume the good, there will be consequences. An example of a consumption external effect would be the adverse effect on their babies of women smoking during pregnancy.

A production external effect arises when the production possibilities of one firm are influenced by the choices of another firm or consumer (Varian, 1996). They occur when a firm, in producing a given good, affects other agents, firms or individuals but does not account for this effect in its production decisions. For instance, hospitals attempting to develop treatments for multi-resistant infections while caring for infected patients, and not compensating either the patient or society in general for the benefits they have obtained from the development of such a treatment.

One may also categorise external effects, according to their affect on output. The terms, 'technological' and 'pecuniary' are used to distinguish between external effects. They were first used by Scitovsky (1954), who defined technological external effects as those which occur when the production function of one firm is affected by the production of another. In other words, a technological external effect exists when actions taken by one firm affect the physical level of output of another, holding constant one firm's level of input (Holcombe and Sobel, 2001). It is important to hold one firm's level of input constant for purposes of comparison, because the actions of the other firm may affect the price that it must pay for its inputs, thus changing the input usage chosen to calculate its output. This would be a pecuniary external effect, not a technological one, because one firm could still produce the same level of physical output with the same level of physical inputs (Holcombe and Sobel, 2001). However, it would now be more costly for that firm to produce the same level of output using an unchanged input but this is a pecuniary effect that does not affect the technological relationship between inputs and outputs.

The distinction between technological and pecuniary external effects predates the use of the terminology. According to Holcombe and Sobel (2001), Pigou (1924) discussed external effects as a divergence between social and private net product: 'Here the

essence of the matter is that one person A, in the course of rendering some service for which payment is made to a second person B, incidentally also renders services or disservices to other persons C, D and E, of the sort that technical considerations prevent payment being extracted from the benefited parties or compensation being enforced on behalf of the injured parties'. According to Holcombe and Sobel (2001), Pigou referred to these services or disservices as third-party effects and noted that, unlike pecuniary external effects, not all third-party effects lead to inefficient resource allocation. The application of corrective taxes and subsidies has been suggested in cases where third-party effects cause a divergence between private and social costs but not every effect creates such a divergence and in such cases social welfare maximization requires that such third-party effects occur. Therefore, pecuniary external effects are an integral part of the market mechanism.

To summarize: on the production side, a technological external effect occurs when actions taken by one firm directly affect the physical level of output of other agents, holding constant the first firm's level of inputs. Pecuniary external effects occur when actions taken by one firm directly affect either the prices that other agents pay or receive for outputs, when the first firm's physical level of output is held constant. However, on the consumption side, technological external effects would occur when actions of one person directly affect the physical level of household production of others, and pecuniary external effects would appear when actions of one person directly either the price that other agents pay or receive for outputs.

2.3.2.1 Categories of external effects to health care

'Positive 'and 'negative' and 'technological' and 'pecuniary' economic nomenclature has been extensively applied in other sectors such as environment, transport, and innovation areas. In the health sector, however the process is comparatively new, though other categories, such as 'selfish' or 'caring' external effects, have been used and an early exploratory review of external effects within different sectors including health has been conducted to explore the categorisation and valuation of this term. (See Appendix 2.1).

Little evidence can be found on the identification of external effects in health care. Table 2.1 shows a possible grouping of the few examples located, using the categories

established in section 2.3.2 of this chapter. The main focus of attention for health care has been the 'technological' group. Applying the economic definition in the health context would identify technological external effects as those actions or activities which affect other people by unintentionally altering, their utilities, health and/or welfare, without providing them with compensation or compelling them to compensate others for the impact of their unintended actions. Support for the examples cited in Table 2.1 was found in the classification established by Mooney (1989) for health external effects: "those associated with infectious diseases and those arising because of concern for others". There is no evidence so far of pecuniary external effects in health care.

Table 2.1 Effects examples on health care classified according to type, category and market side

Market side	Category of external effect	Positive	Negative
Consumption	Technological	• associated with communicable diseases; • selfish, caring and altruistic; • intergenerational/intrageneracional • consumer protection/consumption	• associated with communicable diseases; • intergenerational/intrageneracional
	Pecuniary	-	-
Production	Technological	-	-
	Pecuniary	-	-

The first external effect to be analysed in health economics, according to Jacobsson et al (2005) was the herd-immunity effect associated with interventions targeted at communicable diseases by Weisbrod (1961) and Lees DS (1960), the focus later being defined as "caring external effects" when individuals were seen to benefit from knowing that other people were receiving medical treatment. Knowing that someone is in pain simply because they cannot afford medical treatment makes many people upset. People are affected by the health of others because they care about them (Culyer, 1976). Few economists distinguish Arrow's (1963) 'selfish' external effect from the 'caring' external effect. Although caring external effects are most probably of great significance

and are sometimes argued to be one of the most important characteristics of the Welfare State, current methods of resource allocation do not take them into account (Jacobsson, 2005).

It is important to understand that caring 'for' others and caring 'about' others are two distinct technological external effects (Wiseman, 1997). The first implies some form of positive action because it involves tending another person. The second is to do with feelings 'for' another person. Caring 'about' someone, in the sense of feeling affection for them, is based on feelings of affinity. The well-being of others has a positive weight in the individual's set of preferences. Caring 'for' someone may also be based on a sense of obligation, i.e. the carer may be paid for her services or provide them because she feels generally compassionate for all people in need. Caring in conventional economic terms only occurs because it is 'rational', in the sense that people derive benefit from it and that the benefit exceeds the opportunity cost. These theories can be categorised in general terms (Wiseman, 1997) that juxtapose selfish and unselfish behaviour and process and outcome utility. Both, selfish and caring behaviour can generate positive external effects, because individuals are obtaining benefits from the action of other people. A selfish motive refers simply to concern for one's own perceived needs – i.e., that referred to by Arrow. An unselfish motive involves a concern for the well-being of others, i.e. the well-being has a positive weight in an individual's utility function. It is also generally assumed that these individuals have, at the very least, a selfish component in their psyche. According to Labelle and Hurley (1992) selfish external effects are not very common but it is still necessary to measure and value their magnitude. Labelle and Hurley (1992) also affirm that if one admits to either paternalistic or altruistic interdependencies, then external effects exist for a broad array of health care interventions and must be potentially important when evaluating health-care programs. 'Process utility' is defined here as the satisfaction of happiness derived from the act of caring or the act of giving. 'Outcome utility' is the satisfaction derived from the consequences of caring or giving.

Kennedy and Welling (1997) identified two types of external effects stemming from the provision of parental childcare that could drive a wedge between the equilibrium and efficiency levels of parental childcare. The first is an inter-generational external effect that stems from the effect that childcare choice made by today's parents has on the productivity of the next generation of workers (Kennedy and Welling, 1997).

Depending on the time spent, it could be a positive or negative technological external effect. The second is an intra-generational external effect arising from the impact of time spent on child care by a working parent. The interaction between these external effects determines the efficiency properties of the equilibrium (Kennedy and Welling, 1997).

Feldstein (1979) described two positive technological types of external effects. The first is the "consumer protection" argument. Given the technical nature of medical care, the usual lack in patient's knowledge regarding diagnosis, treatment needs, and the provider's competence; consumers might benefit from the establishment of certain minimum standards and the provision of information. If the private market did not provide standards (possibly through the threat of malpractice actions) or the necessary information required by consumers, or if all consumers wanted the government to ensure some minimum standards, then consumer protection would become an external effect and hence a legitimate role for the government (Feldstein, 1979). The other external effect of personal medical services is what may be referred to as "external effects in consumption". If healthier and wealthier individuals do not want to see persons less fortunate than themselves go without necessary medical care and are willing to contribute to such care, then an external effect in consumption arises. This is because the utility of individuals depends not only upon the quantity of goods and services that wealthy people purchase but also upon the amount of goods and services (such as medical care) purchased by others. Under such circumstances, if a person or group contributes to the medical care of the less fortunate, then other persons, who would also have been willing to contribute, receive an external benefit. In addition, many other people will receive the benefit of seeing the less fortunate receive medical care, even if they did not contribute to this process.

This preliminary review has provided a few examples of studies of the external effects related to health care. Compared with other sectors such as environment or transport which have a long tradition of study in this field, health care has come recently to the discipline and is much in need of further exploration.

2.4 Methods of internalising the market failure of external effects

We have discussed why external effects lead markets to an inefficient allocation of resources but not how this inefficiency might be redressed. Examining possible solutions to this market failure, two main approaches appear to offer improve levels of efficiency: the private and the public solution. All proposed remedies share the same goal - to move the allocation of resources closer to the social optimum.

2.4.1 Private solutions for efficient provision

Although external effects tend to increase market inefficiency, government action is not always needed to solve the problem because people can develop private solutions (Mankiw, 2000) such as moral codes and social sanctions, charities, merging business, contracts and the enforcement of property rights. Each of these is discussed below.

Sometimes, external effects can be overcome by *moral codes and social sanctions* (Mankiw, 2000). For example, most people do not shout at others in the street, because it is the 'wrong' thing to do. Moral injunctions learnt from our parents cause us to take account of how our actions affect other people. In economic terms, it makes us 'internalize' external effects. C*harities* are another private solution to external effects (Mankiw, 2000), many being specifically established to deal with external effects. For example, museums and art galleries receive gifts in part because culture has positive external effects on society. *Integrating or merging different types of business* (Mankiw, 2000) is another solution. Consider, for example, an almond grower and a beekeeper located next to each other. Each business confers a positive external effect on the other: by pollinating the blossom on the trees, the bees help the farmer produce almonds. At the same time, the bees use the nectar they get from the almond trees to produce honey. However, when the almond grower is deciding how many trees to plant and the beekeeper is deciding how many bees to keep, they may fail to consider the positive mutual external effects. If so, the almond grower might plant too few trees and the beekeeper keep too few bees. On the other hand, these external effects would be internalized if the beekeeper bought the almond orchard or the almond grower the beehives. Both activities would then take place within the same organisation and the owner could choose the optimum number of trees and bees. Internalizing external

effects is one reason why some firms are involved in different types of business (Mankiw, 2000). Another way for the private market to deal with external effects is for the interested parties to enter into a *contract* (Mankiw, 2000). In the example above, a contract between the almond grower and the beekeeper could solve the problem of too few trees and bees. The contract would simply specify the number of each, and perhaps involve a payment from one party to the other. Such a contract would solve the inefficiency that normally arises from these external effects and make both parties more successful.

The establishment and enforcement of private *property rights* could provide an alternate framework for the resolution of unacceptable external effects. According to Mankiw (2000), "A private property right is a legally established title to the sole ownership of a scarce resource that is enforceable in the courts". When property rights exist, and only a small number of individuals are involved, the parties can get together to consider and internalize the external effects (Brent, 1997). The establishment of property rights, thus, creates a framework which allows bargaining and the achievement of a socially optimal outcome. However, unacceptable [or negative] external effects persist in situations where property rights are poorly defined, have not been secured, or accrue only at prohibitive cost (i.e. environmental damage caused by company waste being discharged into rivers). Furthermore, satisfying the requirements of a transaction can be costly. Valuable resources may have to be used to locate potential trading partners, negotiate with them, and enforce an agreement. Economists refer to these costs as *transaction costs* and when they are higher than the gains to be realized from an exchange of contract, no exchange will occur. But transaction costs are never zero (Glahe and Lee, 1981). In some cases, property rights cannot be effectively enforced because transaction costs are prohibitive. When this occurs, productive exchanges do not take place and resources are not employed in the most effective way, thereby facilitating negative external effects (Glahe and Lee, 1981).

Varian (2006), described a special case in which external effects are independent of the assignment of property rights. This is known as the Coase Theorem. According to Ronald Coase (1959), whatever the initial distribution of rights may be, if private parties can bargain without cost over the allocation of resources, then the private market will always solve the problem of external effects and allocate resources efficiently (Mankiw, 2000). Despite the appealing logic of the Coase theorem, private actors on their own

often fail to resolve the problems caused by external effects (Mankiw, 2000) and it is the State which has to protect the property rights and ensure the completion of contracts. The Coase theorem applies only when the interested parties have no trouble reaching and enforcing an agreement. In the real world, however, bargaining does not always work, even when a mutually beneficial agreement is possible. Sometimes the interested parties fail to avoid an unwanted external effect because of transaction costs. In a recent example, the transaction costs were not the expenses of the negotiators but of the lawyers required to draft and enforce the contracts (Mankiw, 2000). Reaching an efficient bargain is especially difficult when the number of interested parties is large because coordinating the negotiations can be costly (Mankiw, 2000). However, if private parties are able to bargain over the allocation of resources with little or no cost, they can solve the problem of external effects on their own.

2.4.2 Public solutions: regulation, finance, and optimum provision

To avoid the inefficiency of market equilibrium when private solutions do not work, the government can attempt to remedy the problem of external effects (Samuelson and Nordhans, 1992). The existence of external effects means that prevailing market prices do not always reflect the true social cost of resources and this justifies the involvement of the public sector. Policy makers can respond in three main different ways (Barr, 1987): by regulation, finance or public production.

2.4.2.1 Regulation policies and finance

The State may try to correct external effects by making regulations. This would be an indirect remedy to correct external effects created by market failure. At its most simple, regulation is a legislative intervention which modifies individual or company behaviour in the context of the legal framework of property rights and contract law that underpins the workings of markets (McDowell et al, 2009).

Alternatively, when an external effect exists (and the conditions of the Coase theorem do not hold) a price instrument might be used to set the social optimum. This could be Pigovian taxes or subsidies (Brent, 1997). Pigou (1932) suggested that when there is an

external diseconomy, taxes should be introduced proportionate to the value of the damage done. If external economies exist, then subsidies should be applied (Brent, 1997). Therefore, the government can internalize [plan to avoid] external effects by regulating or taxing activities that have negative external effects and subsidizing those that have positive external effects. Taxes enacted to correct the effects of negative external effects are called Pigovian taxes, after economist Arthur Pigou (1877-1959), an early advocate of their use.

Economists (Dunnet, 1998; Varian, 1992) usually prefer Pigovian taxes over regulations as a way to deal with pollution, for example, because they can reduce it at a lower cost to society. A tax is just as effective as a regulation in reducing the overall level of pollution. The reason why economists prefer use of the tax is that it reduces costs more efficiently. Regulation requires each individual to reduce negative external effects by the same amount but an equal reduction is not necessarily the least expensive way to clean up the pollution. The Pigovian tax places a price on the 'right' to pollute. Just as markets allocate goods to those buyers who value them most highly, a Pigovian tax allocates the highest price for pollution to those factories that face the highest level of pollution.

Pigovian taxes are unlike most other taxes. Most distort incentives and move allocation of resources away from the social optimum. Pigovian taxes correct incentives for the presence of external effects and thereby move the allocation of resources closer to the social optimum when damages are observable. But this is not the most common case. Thus, while Pigovian taxes raise revenue for the government, they also enhance economic efficiency. Although it is not an easy task, one must still evaluate external effects in order to inform policy makers about the "market price" of these external effects and to compensate individuals affected by them.

2.4.2.2 Provision of health care as a "public good"

The second option would be for the government activity to become a producer of intermediate or final goods and services (McDowell et al, 2009). The term 'public goods' is used to describe certain outputs, which for technical reasons simply cannot be produced efficiently if production is left to the interaction of market forces (McDowell

et al, 2009). For this reason, although health care could be provided privately, there are some cases (e.g. as where external effects exist), when public provision is more efficient.

The interest in public health amongst politicians, the media and public has never been greater. Promoting health and preventing diseases are major items on the agenda of many governments. The UK Government's increasing emphasis on quality standards, outcomes and choice highlights the need for informed health service planning (Griffiths et al, 2005). Public health is defined as "the science and art of preventing disease, prolonging life, and promoting health through the organized efforts of society" (Department of Health, 1988). Among other tasks, public health professionals work with other professional groups to plan and carefully evaluate the provision of health care.

The government is able to remedy inefficiencies through the provision of health care. However, most health care products and services are not public goods because they are both: 'rival' (i.e. one person will usually prevent another person from consuming that same health care), and 'excludable' (i.e. individuals could usually be excluded from consuming it). Nevertheless, like public health interventions, some health care programmes do have public good properties, non-rivalry and non-excludability. To design good public provision schemes, government regulators need to know and access information about the range of alternatives available if they are to attain maximum efficiency.

Economic evaluation of public health interventions offers a tool to assess the efficiency of the different interventions that might be offered to the population. Evaluation is essential and should be a routine part of all public health intervention programs, despite the problems of applying economic evaluation in the public health context (Kelly et al, 2005).

2.5 Discussion and conclusions

Market failure could result from the existence of negative or positive external effects. There are two types of external effects: positive, and negative. External effects could

appear on both consumption and production sides of the market. Two main categories of external effects were studied: technological external effects, which have a direct impact on resources and pecuniary, which have an impact on prices. There is little evidence of the identification of external effects in health care. Most of the reviewed literature examined caring externalities.

External effects could arise because individuals may choose to consume levels of public health interventions based on the costs and benefits to themselves (private costs and benefits), and these may be different from the costs and benefits to society (social costs and benefit). Therefore, the evaluation of many public health interventions raises methodological challenges, because these interventions generate very broad costs and benefits and are often directed at populations or communities rather than specific individuals (Kelly et al, 2005). However, the external effects of public health interventions could be internalised through government provision to increase the quantity provided in the market (i.e. herd-immunity generated by a public vaccination program). This provision could compensate those affected by negative external effects or charge those who receive extra benefit from positive external effects.

The existence of external effects legitimizes a role for government in health care but the nature of that role is undefined. It is not sufficient merely to claim that external effects exist and that government should therefore intervene in the market. Where external effects exist, there are two pre-requisites before intervention (Feldstein, 1979). First, the government must determine the exact nature and size of the external benefits and costs. Second, it must discuss how these external effects should be financed. No further details will be provided on the latter role, since it is not within the scope of this thesis.

Inadequate consideration of external effects in policy making does not imply that external effects are non-existent in the health area. Appendix 2.2-2.4 provides several examples of technological, positive and negative, external effects raised by different public health interventions. For instance, there is a wide range of evidence of the relevance of the positive external effect of herd-immunity effect, within vaccination programs (Trotter and Edmunds, 2006). Some examples of technological negative external effects occur due to hospital infections (Cooper et al, 2004); alcohol habits; or smoking cessation though, there is no known prioritisation criteria for ranking them according to their importance.

There are a number of different ways to incorporate external effects in the economic evaluation of public health interventions: cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and cost-utility analysis (CUA) (Drummond, 2007). Currently, CEA and CUA dominate and CBA is used relatively infrequently (Labelle and Hurley, 1992). An important question to answer, therefore, is whether the existing CEA-CUA methodology can be adapted to measure external effects. There is no evidence so far of the most effective way to include external effects in the evaluation of public health interventions.

The importance of external effects in resource allocation is best seen by studying all costs and benefits associated with public health interventions. We need to calculate their magnitude in public programs to ascertain how and in which ways the decisions of policy makers might change if they were to account for external effects but this constitutes a major challenge because we are still unsure how to accurately measure and value external effects (Kehoe and Freshman, 1994). There is, therefore, no alternative but to use economic evaluation in order to understand the impact of external effects in health care. So far, however, they have rarely been considered in this context. Now, they must be acknowledged and incorporated into analyses by considering the existing information, making the assumptions explicit and building them into the analysis in order to better inform decisions made in connection with both intersectoral and intrasectoral costs and consequences (Drummond et al, 2007). To incorporate and internalise external effects, one might understand and use the approaches long established in other sectors.

There is a need to review the literature, consider how external effects have been measured and valued in other sectors and investigate this gap in the measurement and valuation of external effects in health care. It is also important to review other sectors, with long traditions in accounting for external effects, to determine the criteria used to identify the effects that are most relevant to health care, categorise those most studied and explain why, and decide whether they are capable of being conceptually homogenized.

The next chapter of this thesis presents a literature review of different sectors of types, categories, market sides and measurement and valuation approaches to external effects. This literature review provides limited evidence to illustrate what could be a relevant external effect to incorporate into the evaluation of a public health program.

CHAPTER 3 Exploring taxonomies to measure and value external effects from other sectors that apply to health

3.1 Introduction

Chapter 3 aims to review methods of measuring and valuing external effects in different sectors of economic evaluation in order to identify possible ways of incorporating external effects into the evaluation of public health programmes. A preliminary review was undertaken in order to identify those sectors which have been successfully measuring and valuing external effects historically. The search was conducted between October and December 2006, using the electronic library databases of Brunel University and London School of Economics and one on-line database (Google scholar). The free text search terms used were "externalit*, "spillover*" and, "economic*". This review identified relevant studies in the following sectors: agriculture, environment, innovation, technology, telecommunications, network, transport and education (see Appendix 3.1). The objectives of chapter 3 are therefore: (a) to assess the most studied types and categories of external effect and side of market which uses them; (b) to identify which external effects are of greatest importance; (c) to explore the impact of external effects; (d) to review approaches used in valuing external effects; and (e) to explore the use of these valuation methods in economic evaluations. Because originally, external effects tended to be studied in different sectors, it is important to discuss the application of these methods to health care in order to be able to use the results to inform the operationalisation of methods for the economic evaluation of public health interventions in the context of NICE. The subsequent sections of this chapter cover methods of review, results and discussion.

3.2 Methods

This section describes the search strategy used, and how studies were selected and reviewed.

3.2.1 Search strategy

A literature search was conducted between March and June 2007, using two electronic databases (Web of Science[2] and Econlit), with an iterative review of references. The free text terms are presented in Appendix 3.2 and included three different types of search terms: (a) one for each particular sector; (b) one referring to type of valuation approach used; and (c) one referring to external effects. Search terms were chosen to enable retrieval of papers on valuation approaches to external effects in nine[3] different sectors: agriculture, environment, innovation, technology, telecommunications, network, transport, education and health. Due to an unmanageable number of hits reached by Web of Science (13546 papers) and Econlit (12856 papers), a limitation was placed on the search criteria. As search terms were already restricting the search in each sector, different combinations of search terms and language restrictions were tried but none achieved an acceptable reduction in the number of hits received. The search for literature was therefore limited to the last ten years for each sector (Web of Science, 47 hits; Econlit, 49 hits). Once papers were retrieved and downloaded to a file, they were screened for duplicate and irrelevant records.

3.2.2 Selection criteria

Each selected paper had to satisfy all of the following criteria.

1. It measured and/or valued an external effect (according to the definition in section 2.3).
2. The approach which it used had been tested empirically and details of this process were shown.
3. It was written in English, [There were no resources for translation].
4. It was published during the last ten years, [to increase the likelihood of reflecting current valuation approaches].

[2] ISI Proceedings and External collections produced no additional papers and were therefore not included in the search.
[3] See appendix 2.1 for details

3.2.3 Review questions

Selected papers were reviewed against a set of 40 questions designed to extract data in five main areas: the background to external effects; specification of the impact measurement; valuation approach; main findings and given criticism. [See Appendix 3.3] The potential contribution of each paper, to the evaluation of external effects in public health interventions was also considered.

The questions related to the background data of external effects were designed to identify the types, categories and side of the market most studied in the context of external effects, according to the definitions of section 2.3.2 of this thesis.

Knowledge of impact measurement helps to identify which proxies to use such as measures of external effects and whether there are any established criteria for the prioritization of external effects. Examination of valuation approaches highlighted the methodologies most frequently used to incorporate external effects in other sectors, and served as a pointer to possible ways of incorporating external effects into health sector valuations. Collection of information about ways of measuring and valuing external effects on health care was of great relevance to this review of the literature.

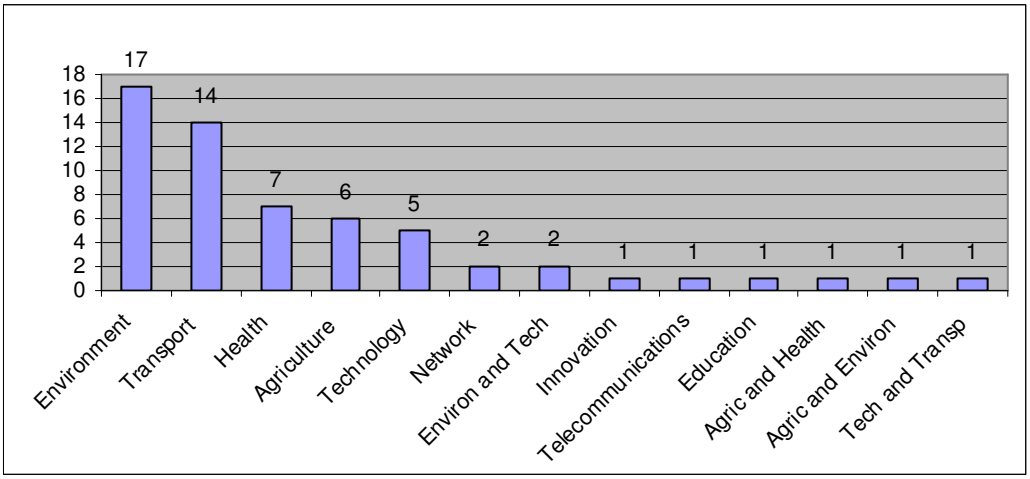
3.3 Results

This section outlines the search results and provides a description of reviewed papers, methods used to measure external effects and a summary of the main findings.

3.3.1 Description of studies

A total of 103 papers produced by the search were screened or duplicated and a shortlist of 66 was identified for further examination using the selection criteria. [See Appendix 3.4] Seven of these papers did not merit inclusion, leading to the selection of 59 papers. See Appendix 3.5 for a list of included papers, and Appendix 3.6 for details of the papers reviewed. 46% of papers were found in the 'Web of Science' and 48% in the 'Econlit' database, searching by title. See Figure 3.1 for distribution of papers across sectors.

Figure 3.1 Distribution of studies across sectors



Six papers were found using "agriculture" as a search term. Two studies were found under "network". Although strictly, they did not belong to this area, it was decided to keep strict with the findings by search term, and include them. Both studies were from the transport field and dealt with the external costs of Belgian inter-urban freight traffic and a cost-benefit analysis of walking and cycling track networks. The environment and transport sectors produced more evidence than others because they have a tradition of valuing external effects. Papers on these sectors represented 29% and 24%, of the total, respectively.

More than 50% of publications reviewed were published between 2003 and 2007. About 44% (n=26) of the papers stated that their aim was to estimate and quantify external effects. The rest sought to: (a) compare and analyse external effects of different public interventions; (b) develop models to examine the impact of external effects; (c) discuss different methods used to measure external effects; (d) evaluate different accounting systems for external effects; (e) discuss and calculate approaches to internalize external effects; and (f) explore how assignment of property rights affect social efficiency.

The importance of studying external effects was raised in 54% (n=32) of papers. A wide variety of justifications of importance were used including the need to: (a) base choice among interventions on true cost; (b) reduce uncertainty about costs in cost-

benefit results; (c) estimate all the costs reflected in common decisions; (d) avoid a non-optimal allocation of resources that leads to welfare losses when making decisions; (e) be more aware of damage caused and its associated financial effects; (f) provide better estimates as a guiding principle for the agreement of further policy; (g) calculate how much benefit an intervention could add to the country; (h) identify alternative interventions from the current ones in order to become more competitive in the market; and, (i) include external effects when calculating prices to increase the precision of assessment of national revenues generated in different sectors.

When specifying the type of external effects, most papers concentrated on *negative* external effects (n=36). Only 14% of the papers measured and valued positive and negative external effects in the same paper (see Graph 3.1).

Graph 3.1 Types of external effects

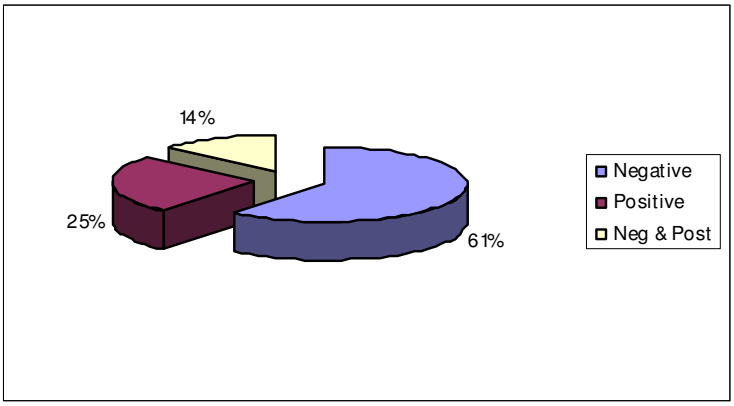


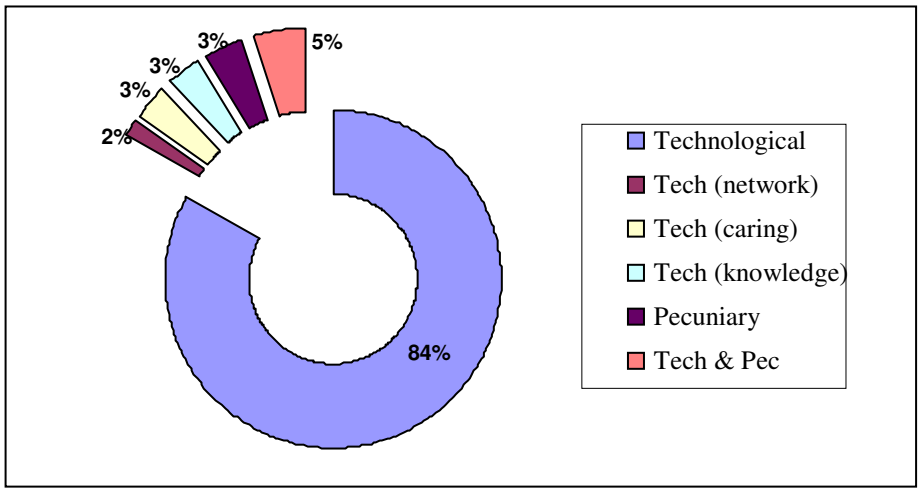
Table 3.1 shows that 25% (n=15) of the papers reviewed studied negative external effects and that they concentrated in the *consumption* side. Only 8% (n=5) of papers studying positive external effects were focused on the *production* side. There were no differences in the number of papers dealing with the consumption and production sides of the market. Indeed, 12% (n=7) of the papers examined measured and valued external effects on both sides of the market in the same papers.

Table 3.1 Type of external effects by market side

Effects Side	Negative	Positive	Both	TOTAL
Consumption	15	10	1	26
Production	14	5	7	26
Both	7	-	-	7
TOTAL	36	15	8	59

The importance of focusing on the production side of the market was explained in 9 papers (15%). These reasons included: (a) an awareness of increasing costs due to a tendency towards increasing production; (b) difficulty in comparing the impact of global and regional technologies in terms of monetary damage; (c) the tendency to look forward with technology but backwards to environmental costs; (d) the need for a tool to evaluate the convenience of a project. Of the 5 papers (8%) on the consumption side, the most common reason given for focusing on external effects was the need to carry out a societal impact assessment.

Graph 3.2 Categories of external effects



Graph 3.2 shows the wide range of categories of external effects studied. These categories were not established uniformly accepted in 86% (n=51) of the papers. Of those, 88% (45/51) were concerned with technological external effects, 2% (n=1) with caring external effects, 2% (n=1) with knowledge, 4% (2/51) with pecuniary external effects, and 4% (2/51) with both technological and pecuniary external effects. Of the

papers using categories, there was a marked consistency between the categories established by the papers' authors and those which I have used for this study (see section 2.3.2.1 for definition of external effects categories).

On the consumption side of the market, technological external effects were the focus of 88% (n=23) of the papers examined; caring external effects were studied by 8% (n=2); and one paper reported on both technological and pecuniary external effects. Papers focusing on production external effects used an extended number of categories compared with those on the consumption side. 77% (n=20) of the papers were concentrated on technological external effects but only 4% (n=1) on pecuniary external effects. Two studies looked at knowledge external effects, and one at network external effects. Two papers considered pecuniary and technological external effects at the same time. Of those studying external effects on both consumption and production sides at the same time, technological and pecuniary external effects accounted for 86% (n=6) and 14% (n=1) respectively.

3.3.2 Identification of external effects impacts and their importance

The impact of external effects is often wide-ranging and positive and negative external effects may occur at the same time (see Appendix 3.7 to Appendix.3.10). The most commonly identified negative external effects (81%, 29/36) were environmental and/or health losses. However, of the 15 papers looking at positive external effects, 47% (n=7) studied only their impact on the environment and/or health. The remaining 53% (n=8) papers studied impacts on education, infrastructure, welfare, knowledge, innovation and employment, competition between firms, industrial development, and investment.

Of the eight papers looking at positive and negative external effects, five papers were concerned with their environmental impact. Other papers (n=3) focused on impacts relating to insecurity, health, reforestation, productivity and labour.

There were no selection criteria established in any paper to lead decisions about which external effect impact could or should be measured and why.

3.3.3 Measurement of the impact of external effects

Table 3.2 shows that reduction of air pollution and noise were the measures most frequently used to evaluate environmental impacts on the consumption side, whereas reduction in accidents was the measure most used to evaluate impacts on health. On the production side, increases and reductions in natural resources were the most common measure used in studies of environmental impact. Beyond these, there is a great variety of measures used within different impacts studied (See appendix 3.7 and 3.10). The impact of negative external effects on both consumption and production sides of the market include environment, health, infrastructure and real money trade. The most common measures used to assess environmental impact were: CO2 emissions, air pollution, greenhouse gases, climate change, ecological damage, global warming, noise and eutrophication. Impact on health was assessed on the incidence of methemoglobinemia (a fatal illness for children), acute and chronic effects, accidents injuries and mortality. Measures used to study impacts on the infrastructure included materials (i.e. loss of mechanical strength; leakage and failure of protective coatings due to degradation of materials).

Table 3.2 Measures to value negative external effects

Impact	Consumption (n=15/26)	Production (n=14/26)
Environment	Air pollution (11/15); noise (10/15); congestion (5/15); emissions (2/15); climate changes (1/15); ecosystem (2/15); resources (1/15); livestock (1/15); agriculture (1/15); destruction of obsolete pesticides (1/15); land use (1/15); and, barrier effects (1/15);	Natural resources (4/14); wildlife, ecosystem and biodiversity (2/14); shrimp farming (1/14); intense fusion economy (1/14); forest and soil (1/14);
Health	Accidents (9/15); respiratory effects (1/15); pesticide use (1/15); airbone pollutants (1/15);	Illnesses related to pesticides (2/14); emissions (1/14)
Infrastructure	Motorway costs (1/15); road damage (1/15);	Unrecovered costs on provision, operation and maintenance of public facilities, primarily roads and bridges (1/14)
Environment and Health	-	Plant construction (2/14); normal operation (2/14); decommissioning and recycling (2/14); site restoration (1/14); municipal solid waste incinerator (1/14); emissions (2/14);

Positive external effects were measured via a heterogeneous range of measures (see Table 3.3, or Appendix 3.9). Studies of the consumption side of positive external effects concentrated on their positive impact on environment and health, whereas the production side of the market focused on their impact on factors such as knowledge transmission and/or industrial development. This suggests that the production side of the market does not have a positive impact on, for example, environment or health.

Table 3.3 Measures to value positive external effects

Impact	Consumption (n=10/26)	Production (n=5/26)
Environment	Make unsightly a favourite view (1/10); tropical forest (1/10); air pollution (1/10); noise (1/10); crops (1/10);	-
Health	Reduction on the CHD incidence (1/10); accidents (1/10); herd-immunity (1/10); mortality (1/10); morbidity (1/10);	-
Infrastructure	Materials (1/10);	-
Education	Arts festival (1/10)	-
Welfare	Altruism (1/10); health and safety risk (1/10);	-
Knowledge	-	Innovation and employment (1/5);
Innovation	-	Research and development (1/5);
Competition between firms	-	Interactions between firms (1/5);
Industrial development	-	Employment (1/5);
Investment	-	Infrastructure investment (1/5);

Table 3.4 shows that equally heterogeneous impacts may be measured for positive and negative external effects. However, the mix of impacts measured varies substantially. Only one paper measured the same impact (on welfare) using different proxy measures. [See Appendix 3.10].

Table 3.4 Measures used to value negative and positive external effects

Impact	Consumption (n=1/26)	Production (n=7/26)
Environment	-	Water control structure (1/7); reforestation (1/7); landfill disposal and incineration of waste (1/7); resources, natural patrimony, climate and natural hazards (1/7); water pollution (1/7);
Health	Accidents (1/1); severe diseases and short-term absence (1/1); severe diseases and long-term absence/disability (1/1);	-
Infrastructure	-	Societal and spatial infrastructure (1/7);
Welfare	Insecurity (1/1);	Landscape image recreation, education, well-being, health and animal well-being (1/7);
Transport	Travel time (1/1); emissions (1/1); noise (1/1); congestion;	-
Traffic	Wear infrastructure (1/1); parking costs (1/1);	-
Technology	-	Diffusion of information and communications (1/7);
Traded goods	-	Environmental degradation, resource exhaustion, habitat destruction and positive cultural external effects (1/7);

3.3.4 Methods of valuing external effects

Most papers (53/59) made an assessment of the value of the impact of an external effect, but 25% (13/53) did not specify how this was done. Indeed, the majority of papers examined failed to specify either a formula or form of calculation for their valuation method (46/53). Of those papers not indicating a value for external effects (6/59), four were concerned with positive external effects, one with negative external effects and, one reported to measure both positive and negative external effects. A small majority of these papers (4/6) related to the production side and 50% (3/6) concentrated on technological external effects.

Table 3.5 provides a summary of the valuation techniques used to assess negative external effects, positive external effects and both types together. Those papers reporting negative external effects on the *consumption* side used the widest variety of valuation methods across the study as a whole. Contingent valuation of the external effect was the method most used on the *market* side. The next four sections detail the methods used for the evaluation of external effects according to type or market side.

Table 3.5 Different valuation approaches used across types of external effects

Valuation Approaches	Negative EE			Positive EE		Negative & Positive EE	
	Consumption (n=15)	Production (n=14)	Both (n=7)	Consumption (n=10)	Production (n=5)	Consumption (n=1)	Production (n=7)
Contingent Valuation	x	x	x	x			x
Hedonic pricing	x						x
Discrete Choice Modelling	x			x			
Human capital approach	x		x				
Treatment costs		x					
Replacement / restoring costs	x	x					x
Travel cost	x						x
Clean-up costs	x	x					x

Section 1 Negative external effects: consumption side

The valuation methods referred to in this section will be described according to Table 3.2. For further details on these methods, see Appendix 3.7. The majority of studies (9/11) using air pollution as a measure to value the environmental impact of external effects employed the willingness to pay (WTP) approach which utilised concepts such as value of life, risk of death, mortality and morbidity. This involved multiplication of *emission* factors per gram of pollutant by the *damage* cost per gram of pollutant, and by value of life in case of death. The remaining studies (2/11) did not specify valuation methods or value external effects.

Of the studies using noise as a measure of environmental impact, 40% (4/10) multiplied a price per decibel by noise levels above the threshold (already set by the government), and by the length of road on which the external effect was generated. Observed monetary values were obtained from the literature. The remaining papers (5/10) used a hedonic (the price of a good changes as the characteristics embodied in the good change) housing price market approach to value this negative external effect. In one notable case, the authors quantified damage to the neighbourhood using a hedonic price based on monetary values calculated using contingent valuation (Mayeres and Van

Dender, 2001). Another study used disability adjusted life years (DALYs) to measure health changes and mortality risks to value the impact on health of the level of exposure to noise (Torfs, 2007). The required data components were the exposure-response function, the frequency of the health outcome and the level of exposure. The response function or unit risk factor was calculated by contingent valuation.

The third most used measure to study environmental impact was congestion. Five studies, 80% (4/5) of the total, valued the impact of external effects by multiplying the loss of time suffered at peak hours by traffic flow (number of km in a period cover by a particular mode of transport multiplied by value of time). Speed on roads during peak and outside peak hours were computed using a flow speed relationship. The difference between these speeds was translated into a loss of time. The value of time was defined as 'all costs linked to particular form of transport' (e.g. fuel, insurance, maintenance and vehicle cost plus the inventory cost of the goods transported). One paper valued this impact as the delays imposed on other vehicles.

Impacts on health were mainly valued in terms of the risk of accidents. Five studies (56%) valued reduction of the risk of having an accident through WTP studies. One study valued accidents using Choice Modelling. In that study, respondents were invited to choose between two alternative states of the highway on the basis on three attributes: travel time, accident risk and toll charge. In one study, the human capital approach was used to value the impairment of life and health as a result of an accident. The health impairment element included the costs of rehabilitation and lost production associated with injury and death. Rehabilitation costs included the average cost of medical treatment, emergency, police and legal services per fatal and non-fatal injury. The estimated costs of lost production were based on national income per person of employable age for each financial year. Two other studies contained no explanation of the evaluation methods used.

Respiratory effects were also used in one paper as a means of evaluating the impact of external effects on health (Rey et al, 2004). This paper linked health effects to DALYs, using estimates of the number of Years Lived Disabled and Years of Life Lost. One study valued health through the cost of pesticide use as an expense of medical services plus loss of productive work time. WTP for reduced mortality risk was also used in one study to value the impact on health of airborne pollutants (De Nocker et al, 1999).

Two papers measured impact on the infrastructure. (Mayeres and Van Dender, 2001; Baublys and Isoraite, 2005) and another measured the infrastructure costs of a heavy vehicle moving along a motorway (Baublys and Isoraite, 2005) but the valuation method was not specified. Another study (Mayeres and Van Dender, 2001) used road damage repair costs as a measure to value impact on the infrastructure.

Section 2 Negative external effects: production side

Five of fourteen studies used contingent valuation to study negative external effects on the production side of the market. Specifically, one study valued air pollution using WTP estimates to value life lost; one study used the WTP method to value human life by calculating the reduction in death risk; two studies used contingent valuation to value human life as a dose-response function; and, one paper used WTP to avoid damage to health and the environment arising from the emission. Contingent valuation was mainly used in papers attempting to value the impact of negative external effects on both health and environment (See Appendix 3.8).

Environmental impacts were essentially valued by treatment cost methods (e.g. the expense of cleaning up a pesticide contaminated river), replacement costs[4] (e.g. lost input to reservoirs) or restoration costs (e.g. species in rivers and clean-up costs (e.g. removing pathogens from water). In one study, the value of reduced honey production was used to measure the environmental impact of external effects on wildlife and ecosystem biodiversity. Other valuation methods to measure impact on environment were the cost of additional applications of pesticide due to drops in the population of beneficial insects, crop losses associated with a secondary pest; the value of animals' lives and the shadow price of the shrimp farming stock.

The impact on health of the negative external effects of production was measured using agriculture (i.e. effects of pesticides) and emissions related measures, though five studies gave no information on valuation methods used and one paper did not value the impact of external effects. Of those papers valuing external effects, one used agriculture measures to value them [pesticides poisonings and related illnesses]. The costs of accidental pesticide poisonings and deaths were calculated using the expenses of

[4] Replacement cost method uses the cost of replacing or restoring a damaged asset to its original state as the proxy value of the damage (Pearce & Howarth, 2000).

hospitalizations, outpatient treatment, treatment costs for pesticide-induced cancers, fatalities and loss of work. The same study examined acute effects caused by pesticides using the following formula: value of a symptom-day multiplied by the number of farmers off work for one day plus those off for half a day multiplied by the GP consultation cost.

Section 3 Positive external effects: consumption and production sides

On the consumption side, forty per cent (4/10) of the studies used contingent valuation to study a variety of impacts including education' health and welfare [See Appendix 3.9]. Of these, one study asked the respondents whether they would be willing to pay an extra monthly tax to support an Arts Festival. Another study asked the respondents to state a WTP value for the avoidance of health and safety risks from transport and analysed household relocation preferences by willingness to accept an increase in the level of neighbourhood health risks from the transport of nuclear-waste. One study calculated a morbidity measure by asking people to state a WTP value and the overall related damage costs of illness. Another paper asked respondents to state their WTP for the possibility of someone else being cured from a variety of health conditions. One study (1/10) did not specify any valuation method (Brisson and Edmunds, 2003). Another paper valued emissions in order to explore the impact of a reduction in the incidence of Coronary Heart Diseases (CHD) on health using annual savings from CHD reduction multiplied by the percentage of costs external to the individual. One paper valued the impact on health through the number of fatal accidents - a relative preference value - and noise was measured using Discrete Choice Modelling (DCM). To obtain a value for travel time and a subjective value for accident and noise level reduction, multinomial logit and mixed logit models were used. One paper valued the environment impact using answers to questionnaires about the impact of making a favourite view unsightly. Two papers used market prices to value external effects. One valued impacts on the infrastructure as measured by materials (such as zinc, galvanised steel, limestone, etc), and one focused on valuing environmental impact using crop yield and the costs of liming and the benefits of oxidation.

On the production side, only one paper reported a valuation approach: it attempted to capture the impact of research and development (R&D) on innovation using regression

modelling. The potential external effect pool was constructed using proximities as weights in a summation of all other firms' R&D spending.

Section 4 *Negative and positive external effects: consumption and production sides*

On the consumption side, only one paper studied negative and positive external effects at the same time and it did not specify the methods used to value the impact of external effects. On the production side, however four out of seven papers used the contingent valuation method to value negative and positive effects at the same time (see Appendix 3.10). Of those four papers, two reported using Hedonic Pricing at the same time as contingent valuation. Just one of the seven papers used the replacement cost technique to value the environmental impact of reforestation and two papers made no mention of the valuation method used.

3.3.4.1 Nature of data sources

When valuing the impact of external effects only 15% of papers (9/59) used primary data sources, 66% (39/59) used exclusively secondary data, five others used mixed [primary and secondary] sources and the rest (n=6) did not value either negative or positive external effects, so no information on type of data used was provided.

Studies of *negative* external effects were based mainly on secondary data (29/36). However, 47% (7/15) of the papers which valued *positive* external effects used primary data. Studies valuing both negative *and* positive external effects employed mainly secondary data (7/8).

Table 3.6 shows that primary data has been used principally on the consumption side. The production side used mainly secondary data. 86% (n=6) of the papers using primary data to study external effects on the consumption side used contingent valuation for this purpose. Two of those papers (29%) employed Discrete Choice Modelling and five (5/7) studied technological external effects. Approximately 49% (19/39) of the papers using secondary data sources valued external effects using Contingent Valuation. Two

papers (2/39) on the production side employed Hedonic Pricing, Treatment Cost or Clean-up Cost approaches and, 90% of all the papers (35/39) studied technological external effects.

Table 3.6 Type of data used according market side and external effect category

External effects categories	Primary			Secondary			Mixed			Not valued			Total
	C	P	C+P	C	P	C+P	C	P	C+P	C	P	C+P	
Technological	5	1		13	16	6	3	2		1	2		49
Tech (caring)	2												2
Tech (network)											1		1
Tech (knowledge)		1									1		2
Pecuniary					1	1							2
Tech & Pec				2							1		3
Total	7	2	0	15	17	7	3	2	0	1	5	0	59

C: Consumption
P: Production
C+P: Consumption and Production

3.3.5 Economic evaluation analysis of external effects

7 out of 59 papers (12%) carried out a cost-benefit analysis after the valuation of external effects; three papers measured negative external effects; one paper measured positive external effects and three measured negative and positive external effects at the same time. 57% of papers (4/7) focused on the production market side.

3.4 Discussion

The majority of studies valued negative external effects and they were equally divided between the consumption and production sides. Studies of positive external effects largely concentrated on consumption. Technological external effects were the most studied category which makes them, prima facie, the most relevant external effects to consider for the empirical work of this thesis. Unfortunately, however, the findings of this chapter indicate that no established criteria exist on which one can rely for the identification the relative importance of particular external effects. Decisions about which external effects to choose depend on the reason for making them. Should they be analysed in order (a) to establish the full social costs and benefits as a basis for efficient pricing and allocation of resources and to extend the scope of social cost or benefit (De

Dios Ortuzar et al, 2000; Pretty et al, 2000; Wattage and Soussan, 2003; Lechon et al, 2003); (b) to study the implications for economic evaluation of, for example, agricultural and food policy (Gray and Malla, 1998) and (c) to value Pigovian taxes to internalise external effects on market prices (i.e internalisation of external effects) (Gibbons and O'Mahony, 2002). There are alternative ways to decide which external effects are relevant for the society to be modelled in economic evaluation. In 2004, a generic methodology of health impact assessment (HIA) was established for use in EU policy development (Wismar et al, 2007). This indicated that systematic reviews of available research are a particularly useful way of gathering evidence.

Findings from this chapter indicate that there is neither particular criteria to which particular measure nor valuation approach to use for incorporating external effects into economic evaluation. The most studied impacts of external effects over time were those affecting health and/or the environment. However, transport and environment were the two fields in which the greatest numbers of publications were found. A wide range of measures have been used to value external effects but no generally agreed criterion exists as to which particular measure should be applied. For instance, air pollution and noise were the most frequently used measures for environmental impact on consumption side, while natural resources was the main focus on the production side. On the consumption side, the most common measure for the study of health impacts was accidents. Although it was comparatively easy to assess the value of negative external effects, there was little consistent patterning of measures to assess positive or both, negative and positive, external effects. For example, the impact of positive external effects on the environment was only studied on the consumption side and five different papers used a range of measurements for this purpose. Interestingly, there was no consensus as to how to measure a particular type of external effect on both sides of the market. The methodology of these studies is an important consideration. All study designs used were vulnerable to a number of potentially important confounders, yet many of these were not recorded or, if recorded, were not used as adjusters in any analyses (i.e. acceptability of death when measuring road accidents). Furthermore, the studies did not describe any measures taken to prevent bias. Recommending a single 'best value' for each external effect and for the total external cost is, therefore, not feasible because of the high level of uncertainty of these measurements. Instead, displaying recommended values in intervals is more appropriate for use in policy

decisions (Eshet et al, 2005). Sensitivity analysis of some parameters might also be a solution to this limitation.

A notable percentage of papers (22%) did not specify which valuation methods were used to measure the impact of external effects. This may be due to the predominant use of secondary data and inadequate descriptions of methods. Having said that, contingent valuation, replacement and/or clean-up costs, in this order, seem to be the most frequently used approaches to the valuation of external effects regardless of the type of data used. Of the studies which used primary data for the consumption side or secondary data for the consumption and production sides, contingent valuation was the most used method. Clearly, contingent valuation is most frequently used to value external effects although no obvious criterion exists as to how it should be applied to the different categories of external effect (Brisson and Edmunds, 2004; Beuthe et al, 2002; De Dios Ortuzar, 2000). An earlier paper (Eshet et al, 2005) concluded that different valuation methods are appropriate for different types of external effect so recommendations of a 'best method' were unlikely to follow. As shown in this review, sometimes, a full valuation of the external costs of a specfic impact may employ a variety of techniques (Eshet et al, 2005). According to a report prepared in 1995 for the Department of Transport by Robert Tinch, hedonic pricing (HP) technique has a clear role to play in the valuation of negative external effects on transport (i.e. noise, air pollution, etc) but this does not necessarily imply that this valuation method would be the best way to measure the impacts on health of external effects stemming from public health interventions. Although, there is no agreed or best method for valuing external effects, this chapter indicates that contingent valuation is the most frequently used approach to the valuation of external effects in sectors other than health.

Technological negative external effects are easy to find in a public health context e.g. aggressions or crimes to family or friends due to alcohol intake; passive smoking; anxiety among family members due to bulimic or anorexic illness in a member of that family; etc. Health impacts have been generally studied on the consumption side and therefore it is more common to find examples on the consumption rather than the production side, as is the case for all examples cited in this paragraph. Depending on the external effects that would be valued in this thesis, measures found in this review, to estimate the health impacts, would be of help. Although this chapter has shown that contingent valuation is the most frequently used approach to valuation of external

effects in different sectors, only 12% of the studies examined conducted an economic evaluation. Apart from that, this method is always used to inform cost-benefit analysis, which is not generally used to inform public health decisions, particularly in NICE context, which uses cost-effectiveness analysis. This thesis aims to incorporate the impact of external effects into economic evaluations of public health interventions in a UK context. NICE recommends the use of cost-effectiveness analysis as the first approach for economic evaluation of public health interventions. Therefore, this is the approach that will be used to value and incorporate external effects into a public health programme.

Incorporating external effects in an economic evaluation may involve the adaptation of an existing model or the development of a new one. Because the aim of this thesis is to study the impact of the inclusion of external effects on current decision making by NICE, it is replicating a model used to inform current NICE decision making.

To do this, it will be necessary to find a cost-effectiveness analysis of a particular public health intervention which is being used to inform policy making but does not incorporate external effects. There should exists documented epidemiological data, clinical evidence, and policy interest of those particular external effects to be incorporated in economic evaluation of a particular public health programme. As shown in this chapter, no agreed criteria exist about which external effects should be valued in a health context or how. Therefore, the incorporation of external effects into a cost-effectiveness analysis of a particular public health programme will steer subsequent chapters.

CHAPTER 4 Economic evaluation of smoking cessation interventions: replication case study

Chapter one identified smoking as a good example of a health behaviour that produces external effects to society but also indicates that, to date, economic evaluation of smoking cessation programmes informing policy making has tended not to include external effects. Chapter 4 develops a model to allow for inclusion of external effects, using smoking as a case study. The chapter is divided into three main sections. This chapter presents the first three models of this thesis: model 1 (M1) (Flack et al (2007a) model); model 2 (M2) (replication of Flack et al (2007a) model); and, model 3 (M3) (replication of Flack et al (2007a) model with relevant changes considered). Section 4.1 describes evidence about the degree to which external effects have been incorporated into economic evaluation of smoking cessation programmes and justifies the selection of a model for replication in the empirical analysis. Section 4.2 replicates the selected model from section 4.1, and demonstrates how this is done appropriately and adds some data and calculations changes which are thought to be appropriate. Section 4.3 discusses and incorporates potential changes to the model that allows the incorporation of external effects. The discussion considers the procedures of model replication and offers some recommendations.

4.1 Description of economic evaluation of smoking cessation programmes and selection of a particular case

4.1.1 Literature reviews

A systematic review was conducted to ascertain whether previous incorporation of external effects was conducted in economic evaluation of smoking cessation programs. The search was conducted in the Centre of Reviews and Dissemination (CRD) NHS EED and HTA, and Web of Knowledge databases during September 2010. The search term used in NHS EED and HTA databases was “smoking cessation”, whereas in the Web of Knowledge a combination between “smoking cessation” and “cost-benefit or costbenefit or cost benefit or cost-effectiveness or costeffectiveness or cost effectiveness

or economic evaluation or cost* or valu* or critical appraisal or model" was used. A full description of the review is given in Appendix 4.1. Although some papers[5] (Andrews and Tingen, 2006; Rasmussen et al, 2005; Feenstra et al, 2005; Pollack, 2001; Cohen and Barton, 1998) studied external effects, no economic evaluations of smoking cessation interventions were found incorporating external effects of smoking.

A second literature review was conducted to identify economic evaluation of smoking cessation programmes currently used to inform policy making in England. A review of Centre of Reviews and Dissemination (CRD – NHS EED), the National Institute for Clinical Excellence (NICE) or Health Technology Assessment (HTA) of economic evaluation of smoking cessation programmes was carried. A description of the review is given in Appendix 4.2. Economic evaluations of smoking cessation interventions were found. Among those was a report, (Flack et al, 2007a) undertaken by the York Health Economics Consortium, which informs policy making on the cost-effectiveness of interventions for smoking cessation. Therefore it was considered appropriate to replicate this models as base model to incorporate external effects rather than developing a new model because this thesis primarily aims at the incorporation of external effects and not developing an economic evaluation of smoking cessation programmes per se. The model used in (Flack et al, 2007a) is described below.

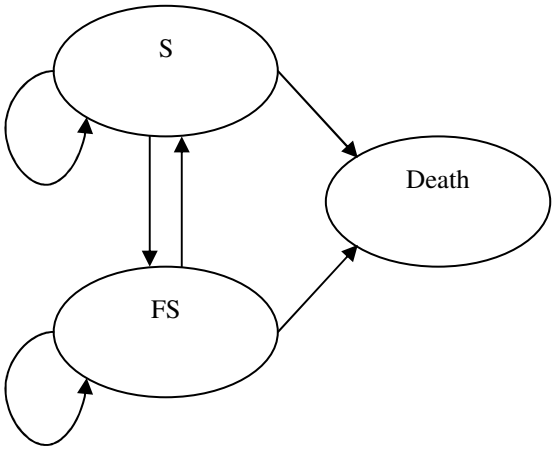
4.1.2 Model structure

The Markov model developed by Flack et al (2007a), referred in this thesis as model 1 (M1) calculated costs and QALYs of eleven different smoking cessation interventions, from the perspective of the National Health Service (NHS). The 'patient' group was modelled as a cohort over their lifetime, 100 years of life, in six-monthly cycles. Six months was chosen by Flack et al (2007a) because it allowed the model to consider the natural progression and resolution of the disease. Choosing a longer period such as 12 or 24 months would have been too long to allow differences in the probabilities. In each

[5] Andrews JO, Tingen MS. The effect of smoking, smoking cessation, and passive smoke exposure on common laboratory values in clinical settings: a review of the evidence. Critical Care Nursing Clinics of North America, 2006; 18(1):63-9.
Rasmussen SR, Prescott SR, Sorensen TIA,et al. The total lifetime health cost savings of smoking cessation to society. European Journal of Public Health, 2005; 15(6):601-6.
Feenstra TL, Hamberg-van Reenen HH, Hoogenveen RT, et al. Cost-effectiveness of face-to-face smoking cessation interventions: A dynamic modelling study. Value in Health, 2005; 8(3):178-90.
Pollack HA. Sudden infant death syndrome, maternal smoking during pregnancy, and the cost-effectiveness of smoking cessation intervention. American Journal of Public Health, 2001; 91(3):432-36.
Cohen D, Barton G. The cost to society of smoking cessation. Thorax, 1998; 53:S38-S42.

cycle, smokers could either remain smoker (S), quit (become former smokers) or die. Former smokers (FS) could either remain former smokers, relapse (become smokers) or die. Figure 4.1 shows the overall structure of the model.

Figure 4.1 Natural history of smoking



Transition probabilities used in the model comprised cessation and relapse rates of smoking and mortality rates according to smoking status. Table 4.1 shows the data used to estimate transition probabilities.

Table 4.1 Transition probabilities used as input parameters

Transition probabilities	Without intervention	Interventions	Source
Background probability of quitting smoking	2%	2%	Stapleton (1998) and West (2006)
Probability of quitting smoking	2% (background probability)	Intervention-dependent	Stapleton (1998) and West (2006)
Probability of relapse after quitting	0	21%	McGhan and Dix Smith (1996)
Mortality rate for smokers	Age-dependent	Age-dependent	Derived (see Appendix 4.3)
Mortality rate for former smokers	Age-dependent	Age-dependent	Derived (see Appendix 4.3)

Source: Flack et al (2007a)

In each cycle, S and FS from the cohort model have a chance of getting five conditions including: Lung cancer (LC); Coronary Heart Disease (CHD); Chronic Obstructive Pulmonary Diseases (COPD); Myocardial Infarction (MI); Stroke (ST). The possibility

of multiple conditions was excluded. The costs and QALYs generated by these conditions were not included in the Markov model but were generated outside of it. To calculate the number of people with each condition in each cycle, the number of S and FS was multiplied by smoking status related prevalence. Prevalence of each condition was assumed to be dependent on age and sex. Each condition has an associated cost and utility. To enable the total costs and utilities of the interventions to be compared with 'no intervention', the number of people with each condition was multiplied by the associated cost/utility of that condition in each cycle. This resulted in a total cost/utility for each condition. To calculate an overall total cost/utility, these were summed.

4.1.3 Study population

The hypothetical cohort of 1,000 smokers was representative of all smoking adults in the general population, and worked through the model from 16 until the age of 100 years, when it was assumed that everyone dies. No new entrants were considered in the model. Population weights, by sex and age, were derived from population estimates provided by the Office for National Statistics and applied to costs and QALYs to ensure that the cohort was representative of the whole population. See Appendix 4.4 for the specific weights used. The costs and QALY outcomes for each age-gender group were then multiplied by these weights to provide total outcomes that were representative of the chosen population.

4.1.4 Data

Several sources of evidence were used by Flack et al (2007a) to inform their analysis. The data required for the model were: background smoking cessation rate; relapse smoking rate; mortality by gender, smoking status and age; prevalence of each condition by age, gender and smoking status; utilities and costs by condition and; annual smoking cessation rates and costs by intervention. Flack et al (2007a) conducted literature reviews in the Centre for Reviews and Dissemination to get data for those parameters.

4.1.4.1 Mortality of each condition by smoking status

Flack et al (2007a) used actual mortality rates: for smokers (mS) and former smokers (mFS). However, to allow a similar calculation in this thesis data on non-smokers mortality (mNS) is also needed. The authors developed an equation to calculate this mortality data. Variables of the equation are described in Appendix 4.5.

The mortality equation, reproduced from Flack et al (2007a), described as follows:

$$(mS * D1) + (mFS * D2) + (mNS * D3) = C \quad \text{(E4.1)}$$

$mFS/mS = A$; $mNS/mS = B$;

$$(mS * D1) + (mS * D2 * A) + (mS * D3 * B) = C \quad \text{(E4.2)}$$

This allows the Equation 2 to be solved as follows:

$$mS = C / ((D1 + (D2 * A) + (D3 * B)); \quad \text{(E4.3)}$$

$$mFS = E * A; \quad \text{(E4.4)}$$

$$mNS = E * B; \quad \text{(E4.5)}$$

Equations 3, 4 and 5 were repeated for all ages and gender. The mortality rates by age and gender, the actuary life tables and the prevalence of smoking are given in Appendix 4.6, 4.7 and 4.8. The actuarial method (Briggs et al, 2006) was used by Flack et al (2007a) to convert this data into transition probabilities and adjust them to 6 month cycles. Refer to Appendix 4.3 for transition probabilities used by Flack et al (2007a) model.

4.1.4.2 Prevalence of each condition by smoking status

Data for Flack et al (2007a) model was the prevalence of: smokers (pS), and former smokers (pFS), though as well as for mortality data, the estimate for never-smokers (pNS) was also needed. To calculate prevalence, similar approach was used. Variables of the prevalence equation are described in Appendix 4.9.

The prevalence equation was described as follows:

$$(pS * D1) + (pFS * D2) + (pNS * D3) = H \quad \text{(E4.6)}$$

$pFS/pS = I$; $pNS/pS = J$;

$$(pS * D1) + (pS * D2 * I) + (pS * D3 * J) = H \quad \text{(E4.7)}$$

This allows the Equation 7 to be solved as follows:

$$pS = H / ((D1 + (D2 * I) + (D3 * J)); \quad \text{(E4.8)}$$

$$pFS = pS * I; \quad \text{(E4.9)}$$

$$pNS = pS * J; \quad \text{(E4.10)}$$

This process was repeated, by age and gender, for all conditions. The prevalence for each condition, relative risk by smoking status, and resulting prevalence by age, gender and smoking status are given in Appendix 4.10. The annual prevalence was used for the 6-month prevalence.

4.1.4.3 Utility scores

Each condition has an associated utility for the time-period spent in the health state. In every cycle the number of people having each condition was multiplied by the associated utility.

The values used in the model by Flack et al (2007a) were provided by secondary data sources. Flack et al (2007a) searched the Tengs and Wallace[6] database (Health Priority Database), Medline, articles cited by others and the National Health Service Economic Evaluation Database. Flack et al (2007a) stated that whilst Tengs and Wallace (2000) provide utility scores for different severity levels of the conditions, in order for this to be reflected in the model there was the need to know how many smokers, former smokers and non-smokers are in each of these states at any given time. Averages were

[6] Tengs and Wallace (2000) gathered from publicly available source documents a review of 1,000 health related quality-of-life estimates.

calculated, according to authors, for the relevant conditions and used for lung cancer, coronary heart disease, myocardial infarction and stroke.

Flack et al (2007a) stated that Rutten-van Molken et al (2006) carried out a study to assess the association between country of recruitment and COPD utility. Data were taken from a subset of 1,235 patients from 13 countries that completed an EQ-5D questionnaire at the baseline of the 'Understanding the Potential Long-Term Implementation on Function with Tiotropim' (UPLIFT) trial. The UPLIFT trial was a four-year randomised, double-blind, placebo-controlled, parallel group trial designed to determine whether dopropium reduces the rate of decline of FEV over time. Six thousand COPD patients were included in the trial and the EQ-5D utility score was 0.76 at baseline. The EQ-5D scores were split into six groups based on the severity of COPD (moderate, severe and very severe) and whether patients were in the UK or the United States. The model used an average of the UK scores for all severities of COPD.

Tillmann and Silcock (1997) assessed the difference in health status between current and former smokers (who have not smoked for five years or more), according to Flack et al (2007a). To elicit smokers' and former smokers' health status, a questionnaire was sent to patients of nine general medical practices in Aberdeen, Scotland. The questions comprised SF-36, EuroQol, nine condition-specific questions selected from the MRC Questionnaire on Respiratory Symptoms and a range of socioeconomic details. Five hundred thousand questionnaires were sent out to former smokers and a further 1,494 were sent to smokers. Of the respondents, 778 former smokers and 887 smokers had valid responses to the questionnaires. The results show that the mean EuroQol score was 0.75 for smokers and 0.78 for former smokers, with no differences regarding age and gender observed. A summary of data used in the model by Flack et al (2007a) is displayed in Table 4.2. The assumptions from this model considered that a person with CHD had higher utility than a smoker with no associated diseases.

Table 4.2 Health-related quality of life parameters used in the model

Utility	Value	Source
Utility associated with LC	0.58	Tengs and Wallace (2000)
Utility associated with CHD	0.80	Tengs and Wallace (2000)
Utility associated with COPD	0.73	Rutten-van et al (2006)
Utility associated with MI	0.80	Tengs and Wallace (2000)
Utility associated with ST	0.48	Tengs and Wallace (2000)
Utility associated with smokers with no comorbidities	0.75	Tillmann and Silcock (1997)
Utility associated with former smokers with no comorbidities	0.78	Tillmann and Silcock (1997)

Source: Flack et al (2007a)

When an individual had co-morbidities, the criteria of lowest utility was applied (an assumption used to overcome concerns of double counting in multiplicative or additive assumptions) by Flack et al (2007a). This enabled the total Quality Adjusted Life Years (QALYs) of the interventions to be compared to the base case ('no intervention'). Outcomes were discounted at 3.5% per year.

4.1.4.4 Costs

Flack et al (2007a) used cost data associated with each condition and costs. All costs were presented in UK pounds (January 2006 prices). Costs were inflated using the Retail Prices Index (monthly index number of retail prices) published by the UK National Statistics.

The lifetime costs included all medical costs that are incorporated in Flack et al (2007a) model. As such, they included not only the cost of the intervention, but other costs such as treatment of different conditions. Therefore, the cost of 'no intervention' was expected to be quite substantial, since rates of complications were likely to be high.

The lung cancer costs were obtained, by authors, from the Health Care Needs Assessment (Sanderson and Spiro, 2006). Sanderson and Spiro (2006) acknowledge uncertainty surrounding the cost of palliative and terminal care but estimate it to be around £2,000 to £7,000 per person (1998 UK sterling). The average of these two figures (£4,550) was used in the model (£5,501 at current prices) by authors.

The British Heart Foundation (Petersen et al, 2003) estimated the total cost of coronary heart disease per year. This cost was divided by the number of people with coronary heart disease in the UK to get the total cost per person, according to authors.

The annual cost of COPD was taken from the National Clinical Guideline on Management of Chronic Obstructive Pulmonary Disease in Adults in Primary and Secondary Care (2004). This cost included GP visits, medication, oxygen, inpatient stay and emergency admission. It is unclear whether the reported figure took account of gender differences in the number of people with chronic obstructive pulmonary disease.

The cost of myocardial infarction, described by Flack et al (2007a), had two components: the cost of an event and the ongoing yearly cost. The first was taken from reference costs while the latter was based on monthly general practitioner (GP) visits, a follow-up cardiology visit every three months and cholesterol lowing drugs (Department of Health 2005; Curtis and Netten, 2006; and Health & Social Care Information Centre, 2005).

The National Audit Office (NAO) (National Audit Office, 2006) estimated that the direct cost of stroke was 2.8 billion each year (£ 2005). The total cost per person was calculated, by authors, using the same approach used for coronary heart disease.

The annual costs of each health state used are shown in Table 4.3.

Table 4.3 Annual average costs of clinic health state (in 2006 £) parameters used in the model

Unit costs (£2006)	Value	Source
Annual cost for a LC episode	£5,501	Sanderson (2000)
Annual cost for a CHD episode	£1,063	Department of Health (2004), Government Actuary's Department (2006), Petersen et al (2003)
Annual cost for a COPD episode	£926	The National Collaborating Centre for Chronic Conditions (2004)
Annual cost for a MI episode	£2,175	Department of Health (2005), Curtis and Netten (2006), Health and Social Care Information Centre (2006)
Annual cost for a ST episode	£2,061	Department of Health (2004), National Audit Office (2006), Government Actuary's Department (2006)

Source: Flack et al (2007a)

The number of people with each condition was multiplied by the NHS cost generated by each condition in each cycle. This resulted in a total cost for each condition, which were summed up to get the overall total cost. Costs were discounted at 3.5% per year, the same as outcomes.

4.1.5 No Intervention

The background quit rate assumed by authors for the no intervention case was 2%, which adjusted for the possibility of relapse smoking. This rate was converted into a transition probability with the actuarial method and therefore adjusted to 6 months cycles according to authors.

4.1.6 Interventions

The data in Flack et al (2007a) were derived from rapid reviews, where possible, and from studies identified by NICE. The required data for each of the interventions investigated were: six-monthly cost of intervention, the duration of intervention and the annual cessation rates for smoking due to the intervention. The smoking cessation interventions described in Flack's et al (2007a) report were categorised into three types of interventions: NHS and workplace, only workplace, and pharmacist-based.

According to Flack et al (2007a), the interventions related to the NHS and workplaces were described by Parrot et al (1998), and included the one-year cessation rates and cost per smoker associated with: (a) brief advice (BA); (b) brief advice plus self-help material (BAS); (c) brief advice plus self-help material plus nicotine replacement therapy (BASNRT); and, (d) brief advice plus self-help material plus nicotine replacement therapy plus specialist clinic (BASNRTS). Information regarding the cost components of the intervention was provided in Parrott et al (1998). This was used, by authors, to calculate the costs of the interventions using the British National Formulary (British Medical Association and Royal Pharmaceutical Society of Great Britain, 2006) and Curtis and Netten (2005).

Regarding specific smoking cessation interventions for the workplace, Javitz et al (2004) identified four different smoking cessation programmes: two different bupropion regimes crossed with two different counselling approaches (less, LICB, and more, MICB, intensive counselling). The British National Formulary recommends those ones involving 150mg of bupropion.

Several interventions using pharmacy-based methods to aid smoking cessation were identified by McGhan and Smith (1996) according to Flack et al (2007a). These included: (a) nicotine patch and weekly group counselling (NPGC); (b) nicotine patch and weekly individual counselling (NPIC); (c) nicotine patch and no counselling (NPNC); (d) nicotine patch and pharmacist consultation (NPPC); (e) nicotine patch and pharmacist consultation and comprehensive behavioural program (NPPCBP).

Table 4.4 summarises the costs and annual cessation rates from the eleven different interventions studied by Flack et al (2007a). The first four interventions were delivered in the primary care setting and workplace; the two next only on the work place environment; and the last five were pharmacist-based interventions.

Table 4.4 Cessation rates and costs (£ 2006)

Intervention	Cessation rates		Costs	Source of costs
	1 year	6 month		
Brief advice (BA)	3%		£7.14	Parrott et al (1998), Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society of Great Britain (2006)
Brief advice plus self-help material (BAS)	4%		£10.67	Parrott et al (1998), Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society of Great Britain (2006)
Brief advice plus self-help material plus Nicotine Replacement Therapy (BASNRT)	6%		£111.10	Parrott et al (1998), Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society of Great Britain (2006)
Brief advice plus self-help material plus Nicotine Replacement Therapy plus specialist clinic (BASNRTS)	15%		£122.96	Parrott et al (1998), Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society of Great Britain (2006)
Less intensive counselling and bupropion (LICB)	23.6%		£80.21	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
More intensive counselling and bupropion (MICB)	31.4%		£120.21	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
Nicotine patch and weekly group counselling (NPGC)		26%	£142.78	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
Nicotine patch and weekly individual counselling (NPIC)		20%	£95.50	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
Nicotine patch and no counselling (NPNC)		15%	£45.50	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
Nicotine patch and pharmacist consultation (NPPC)		31%	£280.50	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)
Nicotine patch, pharmacist consultation and comprehensive behavioural program (NPPCBP)		44%	£377.78	Curtis and Netten (2005), British Medical Association and Royal Pharmaceutical Society o Great Britain (2006)

Source: Flack et al (2007a)

The costs were also reported by Curtis and Netten (2005) and the Health and Social Care Information Centre (2006).

Flack et al (2007a) assumed that all intervention-related quitting occurred in the first 6 months (months 6-12 relapse rate), with some people relapsing at a rate of 21%, until the first year. Moreover, they assumed that after one year, the quit rate becomes the same as the background cessation rate (2%). Flack et al (2007a) indicated that to make possible the comparison among interventions, it was assumed thatthe relapse rate occurred at the same time between the sixth and twelfth month. Therefore, the annual quit rates for the interventions accounted for relapse in the first 6 months.

4.1.7 Economic evaluation

A cost-effectiveness analysis[7] (CEA) was undertaken by Flack et al (2007a) to assess the relative benefits of a given treatment using patient outcomes and the costs incurred in achieving those outcomes.

Incremental costs[8] per QALY gained were estimated by authors for all interventions modelled using the following formula:

Box 4.1 Formula to calculate incremental cost-effetiveness ratio

$$\text{Incremental cost-effectiveness ratio (ICER)} = \frac{\text{(Cost intervention – Cost no intervention)}}{\text{(Effects intervention – Effects no intervention)}}$$

The comparator for the CEA was assumed to be the no intervention option. The results refer to the 'average' smoker included in the model. The results are, therefore, a weighted average cost and QALYs for each patient in the cohort according to authors. Model 1 (M1) was the nomenclature used to refer to results in terms of costs per person and QALY gained by Flack et al (2007a).

4.1.8 Uncertainty

Flack et al (2007a) carried out a univariate deterministic sensitivity analysis to examine the impact on cost-effectiveness of reducing the background quit rate to 1.2%[9] and reducing the costs of the interventions to zero.

[7] Economic evaluation techniques can be used to examine not only the costs of the interventions in relationship to health or smoking outcomes, but also the monetary values of many of the individual conditions associated with smoking problems.
[8] The calculation of the additional unit gain of benefit is known as the incremental analysis and results are presented as incremental cost-effectiveness ratios (ICERs).
[9] Stapleton (1998) suggested a background long-term quit rate of just under 1% per year of those who ever smoked. This figure will slightly overestimate the quit rate after middle age because of deaths from continuing smokers. The background quit rate over this period as a proportion of those who were current smokers *in any given year* will be higher because over time, as smokers quit, the denominator reduces. Applying this correction to the above figures gives an average quit rate of 1.2%.

4.1.9 Results

Average lifetime costs in £2006, QALY gained per person and ICER per intervention are shown in Table 4.5.

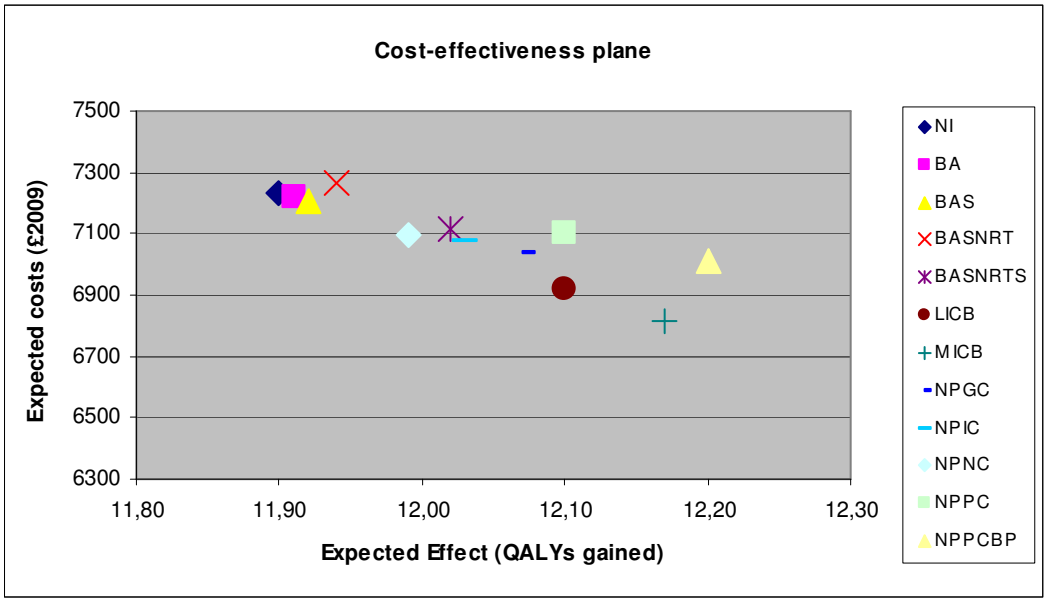
Table 4.5 Model estimates (M1) of average lifetime costs per smoker and QALYs lifetime gained per smoker (cohort of 1000 smokers; > 16 years; lifetime period reaching 100 years; starting distribution: 100% smokers; health states: smokers; former smokers; death)

Interventions	Average cost (£ 2006)	QALYs gained	ICER for M1	NMB M1
NI	7232.00	11.9000	-	
BA	7221.00	11.9100	Dominant	211,00
BAS	7206.00	11.9200	Dominant	426,00
BASNRT	7268.00	11.9400	£984	764,00
BASNRTS	7118.00	12.0200	Dominant	2514,00
LICB	6920.00	12.1000	Dominant	4312,00
MICB	6818.00	12.1700	Dominant	5814,00
NPGC	7037.00	12.0700	Dominant	3595,00
NPIC	7076.00	12.0300	Dominant	2756,00
NPNC	7098.00	11.9900	Dominant	1934,00
NPPC	7100.00	12.1000	Dominant	4132,00
NPPCBP	7010.00	12.2000	Dominant	6222,00

Source: Flack et al (2007a)

NPPCBP was the most cost-effective strategy, followed by MICB. Graph 4.1 shows the different expected costs and QALYs for different smoking cessation interventions.

Graph 4.1 Expected costs and effects for M1



4.1.10 Sensitivity analysis

Univariate sensitivity analyses were made by Flack et al (2007a) in order to capture parameter uncertainty. For M1, Flack et al (2007a) reported that reducing the background cessation rate to 1.2%, but keeping everything else the same, led to similar results. All interventions apart from the BASNRT intervention dominate 'no intervention'. BASNRT had an ICER of £226. Compared with BA, less cost-effective interventions, the results followed the same pattern as comparing smoking cessation programmes with no intervention. When the costs of the interventions were assumed to be zero, all the interventions were dominant when compared with 'no intervention' or 'BA' (the interventions are less costly and result in more QALYs).

4.2 Description of methods used in replication of Flack et al (2007a) model

For the model replication in this thesis, model 2 (M2), the model structure, and parameters from Flack et al (2007a) were used.

There is no evidence on how to best replicate a published economic evaluation. Therefore, the quality of this replication could not be formally assessed. However, the results generated from the analysis in this chapter are compared with those from Flack et al (2007a), and percentage of differences between lifetime costs and QALYs gained are calculated to assess the quality of the model replication. The replication process lasted from July 2008 till April 2009. The first step included an exhaustive reading of the NICE report, and a close examination of the model structure presented in the report. After this, concept of the model was graphically built, before the model was built in Excel. To resolve some doubts about data and structure of the model, Matthew Taylor, one of the authors of the NICE report, was contacted via email. After some clarifications from him, two visits were made to York to see the authors and: double check the model, clarify some aspects of the model structure and data, as well as compare outputs(in terms of costs and QALYs) between Flack et al (2007a) model and the replicatedmodel. Apart from that, expert modellers[10] at the Health Economics

[10] Dr.Gethin Griffith and Mrs. Edit Remark.

Research Group (HERG) conducted a verification process to match the concept of the model with the spreadsheet built in excel[11].

4.2.1 Model structure

To ensure that the Markov model used in the replicated model had the same structure as the one built by Flack et al (2007a), the authors were contacted. This was necessary because a clear diagram of the natural history of smoking was not provided in Flack et al (2007a).

4.2.2 Study population

The replicated model used the same cohort and starting population as Flack et al (2007a).

4.2.3 Data

In some cases, data reported on Flack et al (2007a) report, such as mortality, prevalence according to smoking status, or prevalence of diseases, gave some problems in terms of replication. Mortality data by sex was used by Flack et al (2007a) to calculate the mortality rate for each condition, whereas only a table with male mortality data was attached in the final report. Therefore, data sources referenced in the report were consulted. In this particular case, the information used on mortality was not the data detailed by the source, and therefore, the complete female mortality table used in the model was obtained directly from the authors of NICE report (Flack et al., 2007a). Doll et at (1994) observed no death in men under 25 years of age and the total number observed at 25-34 years of age was so small (67 out of 2115) that mortality rates in different smoking categories were subject to large random variation. Doll et al (1994) specified that usefully compared age specific mortality in detailed smoking categories only from about 35 years of age upwards. Although Doll et al (1994) also stated that under 35 years of age the mortality was higher in current smokers (1.5 per 100,000 per

[11] Particularly, Edit Remark conducted a validation and verification of the model.

year, based on 35 deaths) than in non-smokers (1.1 per 100,000 per year, based on 17 deaths). Doll et al (1994) did not give further comments or details on former smoker mortality rates. One of the authors of Flack et al (2007a), Matthew Taylor, said that the mortality for <35 years of age (in smokers) was calculated by using a regression technique based on the differences between smokers and never-smokers of other ages. Specifically, a non-linear (polynomial) regression was used based on the ratios for the other age bands and this was extrapolated to the <35 year age bands. Due to the inaccessibility of the data, the differences were calculated between current smokers' and former smokers' mortality rates for each age interval. Then, the average decrease of all these differences (29.96%) across ages for smokers was applied to calculate the former smokers death rate aged under 35, which was 0.1050.

Prevalence data of each condition by smoking status gave also some problems. Although the report contained complete tables of prevalence rates by age and sex, zero values were specified for young ages on lung cancer, coronary heart disease and myocardial infarction. To avoid using zero values for few ages, data sources were consulted to find out the correct prevalence rates and tables were reconstructed. Same utility and costs values reported in Flack et al. (2007a) were used in the replicated model.

The prevalence rate for Lung Cancer, Coronary Heart Disease and Myocardial Infarction for the first age intervals was reported as 0 due to the large number of decimals (five decimals). This was assumed to be zero to obtain closer results to Flack et al (2007a).

4.2.4 Interventions

The replication modelled the same interventions as Flack et al. (2007a) and used effectiveness data contained in the report. However, there was some unclear information on adjustment of six-month quitting rate by the relapse rate. Although intervention quit rates were supposed to be adjusted by relapse rate, there was no information available in the report about whether these rates were finally transformed to transition probabilities. Therefore, no transformation was adopted in the replication exercise.

4.2.5 Economic evaluation

Cost-effectiveness analysis was conducted to assess the costs and benefits from the smoking cessation programmes. The comparator was 'no intervention' as in Flack et al. (2007a), Moreover, the results referred to the 'average' smoker included in the model in terms of costs per person and QALY gained by the replication model.

4.2.6 Results of replication

Average lifetime costs in £2006, QALYs gained per person and ICER per intervention are shown in Table 4.6 for M2.

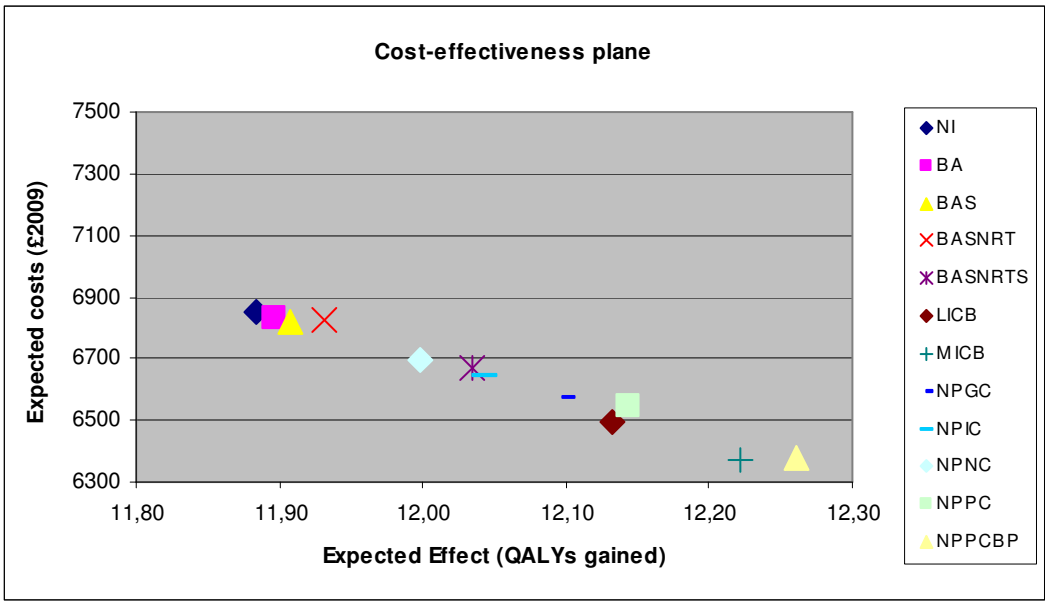
Table 4.6 Model estimates (M2) of average lifetime costs per smoker and QALYs lifetime gained per smoker (cohort of 1000 smokers; > 16 years; lifetime period reaching 100 years; starting distribution: 100% smokers; health states: smokers; former smokers; death)

Interventions	Average cost (£ 2006)	QALYs gained	ICER for M2	NMB M2
NI	6849.15	11.8842	-	
BA	6833.95	11.8964	Dominant	259,79
BAS	6818.05	11.9079	Dominant	505,10
BASNRT	6828.09	11.9309	Dominant	953,86
BASNRTS	6669.18	12.0341	Dominant	3177,38
LICB	6497.65	12.1327	Dominant	5321,77
MICB	6369.08	12.2222	Dominant	7239,67
NPGC	6575.18	12.0976	Dominant	4541,68
NPIC	6643.89	12.0433	Dominant	3386,20
NPNC	6694.63	11.9980	Dominant	2429,32
NPPC	6548.89	12.1429	Dominant	5474,70
NPPCBP	6378.01	12.2607	Dominant	8001,53

In concordance with Flack et al (2007a), NPPCBP was the most cost-effective strategy compared with no intervention, followed by MICB. However, there were two important differences that need comment and questioning. First, the BASNRT, in the replication model (M2), appears to be dominant, but not in the original model (M1). Second, all interventions seem to have different expected costs, compared with those obtained in the original model. As part of the validation process, the results obtained in the replication model (M2) were shown to York authors for them to comment on. After Matthew Taylor checkboth spreadsheets (M1 and M2 spreadsheets), both differences were attributed to the cost of myocardial infarction. Details to follow in section 4.3.1.

Graph 4.2 shows the expected cost and QALYs for different smoking cessation interventions in M2.

Graph 4.2 Expected costs and effects for M2



Regarding sensitivity analysis, reducing the background cessation rate to 1.2% in M2, but keeping everything else the same, led to similar results. All interventions dominate 'no intervention'. When the costs of the interventions were assumed to be zero all the interventions were dominant when compared with 'no intervention'.

4.2.6.1 Quality assessment of replication and recommendations to facilitate replication of models

Table 4.7 shows the differences in lifetime costs and QALYs gained between M1 and M2. The differences in lifetime costs were calculated using the cost of myocardial infarction reported in Flack et al (2007a) report (£2175) and the cost used in the spreadsheet model to calculate results (£2750).

Table 4.7 Differences in lifetime costs and QALYs gained between M1 and M2

Interventions	% differences in lifetime costs (M1 vs M2)		% differences in lifetime QALYs gained (M1 vs M2)
	costs MI=2175	costs MI=2750	
NI	5,59%	-1,20%	0,13%
BA	5,66%	-1,13%	0,11%
BAS	5,69%	-1,10%	0,10%
BASNRT	6,44%	-0,35%	0,08%
BASNRTS	6,73%	-0,07%	-0,12%
LICB	6,50%	-0,28%	-0,27%
MICB	7,05%	0,25%	-0,43%
NPGC	7,02%	0,22%	-0,23%
NPIC	6,50%	-0,29%	-0,11%
NPNC	6,03%	-0,76%	-0,07%
NPPC	8,42%	1,58%	-0,35%
NPPCBP	9,91%	3,01%	-0,50%
Average	**6,80%**	**-0,01%**	**-0,14%**

There 0.14% difference between lifetime QALYs reported in Flack et al (2007a) and those in found in the current analysis. In terms of lifetime costs, the difference between my model and Flack et al (2007a) results amounted to 6.80%. Due to the magnitude of the difference, the replicated model was checked with, Matthew Taylor, one of the authors from Flack et al (2007a) report. It was then realised that a different figure for the cost of myocardial infarction in Flack et al (2007a) was used. Therefore, the report used a figure of £2175 for myocardial infarction, whereas the results reported in the published report (Flack et al (2007a) were obtained from using a figure of £2750 for that particular disease. Having changed the figure of £2175 to £2750 the actual difference between obtained costs in the model reduced to 0.01%. Analysis in this thesis from M2 onwards assumed the cost of myocardial infarction to be £2175 because this was the figure that Matthew Taylor confirmed Flack et al (2007a) used, and also give the closest results to Flack et al (2007a). Overall, given the small differences (less than 1%) between both studies in terms of the lifetime costs and QALYs gained, for costs (using cost of £2750) and QALYs gained, M2 was considered a good quality replication of M1.

There are no established rules for the replication of economic evaluation models. However, some could be established from the process followed in this chapter. First, it is important to follow the diagram reported in any economic evaluation to build the structure of the model and to make sure this follows the explanation detailed in the text. In Flack et al (2007a), the diagram was not the best representation of the model because

the health states described in the text were not fully represented in the diagram. Reporting the structure of the model must be accurate in terms of transmitting the correct scheme of analysis. In this case, the Markov model structure should only have reported health states actually modelled to avoid confusion. Second, it is also of importance to understand whether a population or a cohort model was modelled, and the time horizon of the model. Finally, it is important to verify all data reported with epidemiological sources, to make sure the data is fully understood and the correct data is used in the model.

Findings from this chapter outline the importance of reporting methods of economic evaluation analyses in a transparent way to allow replication. Some problems with adjustments of transition probabilities were encountered because of the lack of clear steps by Flack et al (2007a). It is also important to reference all data sources and to report tables with a sensible number of decimals for costs (at least two decimals) and QALYs (at least four decimals).

Some time could have been saved asking for the model spreadsheet to Flack et al (2007a) authors, but the replication of the model was considered a good practice in order to fully understand the spreadsheet, and allow the subsequent incorporation of external effects into the model.

4.2.6.2 Critique of Flack et al (2007a) model (M1)

Decision analytic models are necessary to inform decision making by bringing together existing evidence to assess the likely cost-effectiveness of competing forms of smoking cessation programs. The replicated model presented in this thesis incorporated the full range of assumptions used to assess the cost-effectiveness over the lifetime of the cohort by Flack et al (2007a). However, this implies that a number of limitations in Flack et al (2007a) model may also apply here.

First, due to the lack of data on the relative risk of having each condition by smoking status it was not possible to 'split' former smokers into 'recent' and 'long-term' categories. It is unclear what the impact of this simplification would have on the model's results. If the probability of developing some or all of the conditions returns to the level found in non-smokers after a certain period of time, the model have

overestimated the number of people with each condition. This in-turn may have resulted in an overestimation of the associated costs and an underestimation of the associated QALYs. Second, within the model it is assumed that smokers attempt one type of cessation intervention and only try it once. In real life, smokers who fail to quit smoking with one intervention may be more likely to repeat the same intervention or try a number of different interventions (Hajek et al., 2009). Third, the effectiveness of the interventions was taken from published studies and may not be generalisable to the population older than 16 years modelled in this economic evaluation. In relation to that, Parrot et al (1998), which described the interventions related to the NHS or primary care setting and workplaces, highlighted an issue of the generalisability of the interventions arguing that those interventions provided within the workplace were not specifically delivered within the workplace, though they were assumed to be provided in the workplace.

Regarding cost data, it is unclear whether lung cancer costs obtained from Sanderson and Spiro (2006) took account of gender differences in the number of people. Stabile and Siegfried (2003) raised the importance of accounting for these differences, which accrue in terms of different costs for lung cancer. In any case, all the issues bordering on all lack of data summarised in section 4.3.1 could be considered as a critique of the model.

4.2.6.3 Changes to Flack et al (2007a) replication model (M2)

The exercise of replicating Flack et al (2007a) model (M2) and knowing the details of the M1 model generated some uncertainty regarding the appropriate use of some data and correct methods of some parameters' calculation. Therefore, some changes were applied to M2 to improve the model in terms of using appropriate data and calculating some parameters correctly. These changes led to model 3 (M3).

Flack et al (2007a) reported the current smokers' mortality rate for people aged 75-84 as 106, whereas Doll et al (1994) reported in their paper a 106.4 annual mortality per 1000 men. Evidence reported in papers should be used in model 3 (M3).

The assumption about running the model for 100 years, not accounting for the real life expectancy, is considered unrealistic though it did not have much impact on the results.

Therefore, when any person in the model reached the age of 100 years he/she exits the model.

Regarding the intervention cessation rates, it seemed that Flack et al (2007a) were directly using the annual rates reported in their report in the Markov model instead of accounting for the rate/probability conversion. According to Briggs et al (2006) it is necessary to transform all rates into transition probabilities for use in a Markov model. Transformed rates (i.e. transition probabilities) were therefore used

The prevalence rate for Lung Cancer, Coronary Heart Disease and Myocardial Infarction for the first age intervals was reported as 0 due to the large number of decimals. In some cases this resulted in no difference in lung cancer cases according to being a smoker, former smoker or a never smoker. As the authors reported the data sources, it would have been appropriate to re-calculate all these prevalence rates and achieve a small distinction for the different smoking health status habits. Forman et al (2003) and Allender et al (2006) were consulted to extract the evidence needed to replace those zero values.

All costs and prices were updated to £ 2010 using the GDP deflactor, from the World Economic Outlook Database, and the exchange rates for 2010 from the European Central Bank.

To estimate incremental cost-effectiveness ratios (ICERs), the smoking cessation interventions in each patient group should be ranked according to effectiveness and, therefore, the ICERs calculated by dividing the incremental cost by the incremental effect for each successively more effective treatment (Karlsson and Johannesson, 1996; Glick et al, 2007). Flack et al (2007a) compared all interventions to 'No Intervention'. Although it was the costless and least effective option, not all the ICERs should be calculated using the no intervention as the comparator. The NICE Report 'Methods for the development of NICE public health guidance (2008)' states that "the cost per QALY gained should be calculated as the difference in mean cost divided by the difference in mean QALYs for one intervention compared with the next most effective alternative. Therefore, results should have been calculated using this alternative and appropriate way but, because of consistency reasons and to facilitate the comparison with published and reported results by the replicated economic evaluation in this thesis (Flack et al, 2007), the used procedure of using "No Intervention" in all cases as the comparator was

kept. The ICER for each smoking cessation intervention was compared with a threshold value of £20K to establish whether the intervention represents an efficient use of limited NHS resources (Devlin and Parkin, 2004).

Net monetary benefit was also constructed from model M3 onwards as a validation of the results, though it was not reported till model 4 (M4) to keep comprehensive comparisons with M1 and M2. According to the criteria for interventions choice by using cost-effectiveness ratios, to select therapies that have not quantified sampling uncertainty, the net monetary benefit was calculated when a therapy has a significantly larger cost and effect than the alternative. In this case, the intervention recommended was the one with the greatest Net Monetary Benefit (NMB).

Concluding, the incorporation of all these changes resulted in a new version of the model labelled model 3 (M3). Table 4.8 shows results from M3, where all the changes previously detailed in this section has been incorporated in M2.

Table 4.8 Model estimates (M3) of average lifetime costs per smoker and QALYs lifetime gained per smoker (cohort of 1000 smokers; > 16 years; lifetime period reaching 100 years; starting distribution: 100% smokers; health states: smokers; former smokers; death)

Interventions	Average cost (£ 2006)	QALYs gained	ICER for M3	NMB M3	% differences in lifetime costs (M2 vs M3)	% differences in lifetime QALYs gained (M2 vs M3)
NI	6839,91	11,8783	-		0,14%	0,05%
BA	6851,34	11,8731	Dominant	-114,93	-0,25%	0,20%
BAS	6844,45	11,8787	11269,24	3,52	-0,39%	0,25%
BASNRT	6874,69	11,8897	3033,09	194,55	-0,68%	0,35%
BASNRTS	6803,42	11,9380	Dominant	1231,67	-1,97%	0,80%
LICB	6715,24	11,9820	Dominant	2198,73	-3,24%	1,26%
MICB	6671,75	12,0200	Dominant	3003,85	-4,54%	1,68%
NPGC	6532,11	12,1130	Dominant	5003,33	0,66%	-0,13%
NPIC	6598,33	12,0602	Dominant	3879,66	0,69%	-0,14%
NPNC	6651,66	12,0133	Dominant	2889,66	0,65%	-0,13%
NPPC	6513,23	12,1545	Dominant	5851,14	0,55%	-0,10%
NPPCBP	6379,66	12,2521	Dominant	7936,37	-0,03%	0,07%
Average	**-**	**-**	**-**	**-**	**-0,70%**	**0,35%**

Even though that all these changes are relevant to get more appropriate results, no much impact, in terms of lifetime costs and QALYs gained, was observed (i.e. average

difference on lifetime costs of -0.70%, and average difference on lifetime QALYs gained of 0.35%).

Smoking cessation interventions have been shown to result in greater benefits at lower or marginally higher costs than 'no intervention', though some changes considered appropiate have been incorporated into M2. Therefore, M3 was taken forward in subsequent chapters to incorporate external effects. The next modellling exercise in this thesis involved the incorporation of the external effects of passive smoking on adults and children in an economic evaluation of smoking cessation interventions. The three external effects (i.e. passive smoking, smoking during pregnancy, and transmission of smoking behaviour) were not incorporated at the same time because there exist different interventions for smokers and for pregnant smokers. In addition, the incorporation of external effects and their impact would be easier to understand incorporating one external effect after the other one. This procedure also allows comparison of the magnitude of the impact of each external effect in order toassess the relative importance of each external effect.

4.3 Changes to allow incorporation of external effects

Whilst the Flack et al (2007a), model (M1), reported all data for never smokers, this information was never included in the Markov model. Since this thesis intends to include external effects of passive smoking and smoking transmission behaviour, it is important to include the never smokers population group. The reason is that passive smokers are part of the never smokers. Therefore, to include passive smokers in the model we would need to distinguish between 'passive never smokers' and 'non passive never smokers' in the model. Therefore, a key difference between the M3 and the models used to account for external effects (M4 to M11) is the incorporation of these two new groups of population in the latter models. In light of these, the next chapter will be based on M3. Keeping M3 separate from M4 allowed a comparison of models that did not include these two new groups of population, which were added because of the incorporation of external effects.

CHAPTER 5 Economic Evaluation of Smoking Cessation Interventions: accounting for passive smoking in adults and children

5.1 Introduction

Chapter 4 replicated an economic evaluation of smoking cessation interventions using no intervention as a comparator. In line with current practice, that model did not account for external effects. This chapter incorporates passive smoking (in both adults and children) in an economic evaluation of smoking cessation interventions, as this external effect has been extensively studied in the UK (SCOTH, 2004; RCP, 2010) and worldwide (WHO, 2007; Oberg et al., 2010; Wipfli and Samet, 2010) and relevant empirical evidence gathered. The approach taken in this thesis is to measure costs and health outcomes arising from external effects and to incorporate them into the economic evaluation tool, with the ultimate aim of influencing policy. The chapter is structured as follows. First, there is a discussion of the methodology through which passive smoking-related health effects can be incorporated into the economic evaluation of smoking cessation interventions. It is necessary to identify the health consequences and costs of passive smoking in order to decide which health outcomes, costs and extended impacts of passive smoking should be included in the economic evaluation model. Second, therefore, the health consequences of passive smoking for adults and children are presented prior to inclusion in the model. Third, a review is conducted of the literature relating to prevalence, costs, and utilities of the health effects of passive smoking for children and adults. In this way, the data required for the model is identified. The remaining part of this chapter presents and discusses the methods and results of incorporating passive smoking in an economic evaluation of smoking cessation interventions. The purpose of this is to measure the impact of the incorporation of passive smoking into the economic evaluation, and to identify any potential policy recommendations. The chapter also investigates whether there is any difference in the incremental cost effectiveness analysis (ICER) and decision making, and assesses the magnitude of this difference.

5.2 Methods

This section discusses the development of the economic model and how the two literature reviews were conducted, including the search strategy and selection criteria. It explains how the health effects of passive smoking were incorporated in the Markov model, and how data was gathered relating to prevalence, costs and QALYs to measure these effects.

5.2.1 Model parameters

In order to build the model, a number of key input parameters were required: health effects caused by passive smoking among adults and children; mortality due to passive smoking; and prevalence, costs and utilities related to passive smoking. Also required was information relating to incidence; prevalence of different smoking states; mortality; quit and relapse rates; and effectiveness. The data values for these parameters have been obtained from a variety of sources which are described in the following sections.

Regarding data on mortality and illness prevalence caused by passive smoking, same adjustments than previous models were needed (see Sections 4.1.4.1 and 4.1.4.2, in chapter 4, for further details).

Health effects and mortality associated with passive smoking according to age: systematic literature review

This question was addressed by systematically identifying and assessing all those papers describing health effects and mortality associated with passive smoking, and then summarising the evidence from the review of these studies. The search methods adopted are described in Appendix 5.1. Selected papers were then examined to check if they covered any of the data on health effects and mortality which were required for the model. Where potentially relevant data was identified in more than one source, preference was given to those studies which offered meta-analyses or pooled estimates for health effects and mortality data associated with passive smoking. This was done because meta-analyses offer a quantitative synthesis approach, combining results from a

number of studies to present the average effect. Meta-analysis carried out in the UK setting was prioritised above other settings because this is the context of our analysis.

The key methodological features of the reviewed studies are presented below, along with a summary of their empirical findings. The search strategy for epidemiological studies yielded 1619 papers. A review of their titles and abstracts indicated that 205 potentially met the review's inclusion criteria. A more detailed review of these papers revealed that only six met the inclusion criteria. Six more papers were produced by a review of references, and incorporated into the search results. Details of this systematic literature review are shown in Appendices 5.2 to 5.3.

The main findings of the studies are summarised in three parts: the clinical implications of passive smoking for adults; the implications for children; and the mortality risk for passive smokers.

Clinical implications of passive smoking for adults

The findings indicated that among adults, lung cancer and coronary heart disease are the medical side effects from passive smoking with the strongest supporting evidence (see Table 5.1 below for findings). In this context, the effect on coronary heart disease and ischemic heart disease were assumed to be the same.

Table 5.1 Summary of characteristics and data from included studies for adults

Author, year	Health effect	N studies	Type of data[12]	Estimated value	Adjusted[13] estimate	95% CI
Studies identified						
Barnoya and Glantz 2005	Coronary heart disease	29	RR	1.31	not stated	1.21 to 1.41
He et al. 1999	Coronary heart disease	18	RR	1.25	not stated	1.17 to 1.32
Law et al. 1997	Ischemic heart disease	19	RR	1.3	not stated	1.22 to 1.38
Thun et al. 1999	Ischemic heart disease	17	RR	1.25	not stated	1.17 to 1.33
SCOTH[14] 2004	Lung cancer	-	RR	1.24	not stated	-
	Ischemic heart disease	-	RR	1.25		-
Hackshaw et al.1997	Lung cancer	37	RR	1.24	unadjusted	1.13 to 1.36
Parameter value used in model						
SCOTH[15] 2004	Lung cancer	-	RR	1.24	not stated	-

RR: relative risk of health effect associated with exposure to environmental tobacco smoke due to living with a smoker compared to living with a lifelong non-smoker

Data relating to risk for adults in all six studies was reported in terms of relative risk. As shown in Table 5.1, five of the studies report 95% confidence intervals, but none of the five states whether or not their estimates were adjusted for potential confounding variables. In order to assess the relative risk of lung cancer and coronary heart disease, the estimates given by the Smoking Committee on Tobacco and Health (SCOTH, 2004) were used, as these represent pooled estimates for the UK. To assess the passive smoking relative risk for lung cancer, the SCOTH report (RR 1.24) adopted values from Hackshaw et al. (1997). Taylor et al. (2007) also calculated the relative risk for lung cancer, but as this was a pooled estimate for Europe, it was felt to be less suitable than SCOTH`s UK-specific data. The same criterion was applied for the ischemic or coronary heart disease estimate; although some of the literature points to a higher estimate (RR 1.30) than the one used (RR 1.25), the pooled estimate for the UK was preferred.

[12] RR: relative risk (defined as the ratio of the chance of a disease developing among members of a population exposed to a factor compared with a similar population not exposed to the factor (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>); OR: odds ratio (this ratio estimates the chances of a particular event occurring in one population in relation to its rate of occurrence in another population (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>).
[13] Adjustment for potential confounding variables
[14] Scientific Committee on Tobacco and Health
[15] Scientific Committee on Tobacco and Health

Clinical implications of passive smoking for children

The most relevant medical side effects of passive smoking on children reported in the literature were asthma, wheezing, coughing, phlegm, breathlessness, acute otitis media, recurrent otitis media, middle ear effusion, glue ear, sudden infant death, and low birth weight (refer to Table 5.2 for findings). For babies, increased risk of low birth weight and sudden infant death were also reported as clinical consequences of a parent's smoking.

Table 5.2 Summary of characteristics and data from included studies for children older than five years

Author, year	Health effect	N studies	Type of data[16]	Estimated value	Adjusted[17] estimate	95% CI
Studies identified						
Uhari et al. 1996	Acute otitis media	22	RR	1.66	not stated	1.33 to 2.06
Leonardi-Bee et al. 2008	Birth weight	26	OR[18]	1.32	not stated	1.07 to 1.63
			OR[19]	1.22		1.08 to 1.37
Cook and Strachan 1999[20]	Wheeze	30	OR	1.24	unadjusted	1.17 to 1.31
	Cough	30	OR	1.40	unadjusted	1.27 to 1.53
	Phlegm	6	OR	1.35	unadjusted	1.13 to 1.62
	Breathlessness	6	OR	1.31	unadjusted	1.08 to 1.59
	Asthma (cross sectional studies)	21	OR	1.21	unadjusted	1.10 to 1.34
	Acute otitis media	13	OR	1.0 to 1.6	unadjusted	
	Recurrent otitis media	9	OR	1.48	unadjusted	1.08 to 2.04
	Middle ear effusion	5	OR	1.38	unadjusted	1.23 to 1.55
	Glue ear	9	OR	1.21	unadjusted	0.95 to 1.53
	Sudden infant death	18	OR	2.13	adjusted	1.86 to 2.43
Li et al. 1999	Lower respiratory tract infection	13	OR	1.25[21]	unadjusted	0.88 to 1.78
Pattenden et al. 2006	*Smoking in pregnancy*					
	Wheeze	12	OR	1.12	adjusted	1.04 to 1.22
	Asthma	12	OR	1.17	adjusted	1.04 to 1.31
	Nocturnal dry cough	12	OR	1.15	adjusted	1.00 to 1.32
	Morning cough	12	OR	1.14	adjusted	0.94 to 1.39
	Smoking in first 2 years					
	Wheeze	12	OR	1.06	adjusted	0.95 to 1.19
	Asthma	12	OR	1.04	adjusted	0.94 to 1.14
	Nocturnal dry cough	12	OR	1.03	adjusted	0.94 to 1.18
	Morning cough	12	OR	1.05	adjusted	0.96 to 1.25
Parameter value used in model						
Cook and Strachan 1999[22]	Wheeze	30	OR	1.24	unadjusted	1.17 to 1.31
	Cough	30	OR	1.40	unadjusted	1.27 to 1.53
	Asthma (cross sectional studies)	21	OR	1.21	unadjusted	1.10 to 1.34
	Acute otitis media	13	OR	1.0 to 1.6	unadjusted	-
	Middle ear effusion	5	OR	1.38	unadjusted	1.23 to 1.55

RR/OR: relative risk/odds ratio of health effect associated with exposure to environmental tobacco smoke due to parental smoking compared to having non-smoking parents.

Children's risk is generally reported in the studies in terms of odds ratio measures, with the exception of Unhari et al. (1996), who use the relative risk measure. All of the studies report 95% confidence intervals; only two papers do not say whether their estimates were adjusted for potential confounding (see Table 5.2).

[16] RR: relative risk (defined as the ratio of the chance of a disease developing among members of a population exposed to a factor compared with a similar population not exposed to the factor (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>); OR: odds ratio (this ratio estimates the chances of a particular event occurring in one population in relation to its rate of occurrence in another population (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>).

[17] Adjustment for potential confounding variables

[18] Maternal exposure to ETS during pregnancy (birth weight <2500g; prospective studies).

[19] Maternal exposure to ETS during pregnancy (birth weight <2500g; retrospective studies).

[20] The ORs reported in this paper are calculated on the assumption that either parent smokes at home, except in the case of sudden infant death, when only the mother`s smoking is considered.

[21] Four figures were reported in the paper; only the most conservative is given here.

[22] The ORs reported in this paper are calculated on the assumption that either parent smokes at home, except in the case of sudden infant death, when only the mother`s smoking is considered.

Although there are more recent estimates regarding the clinical implications of passive smoking for children at home, the figures reported by Cook and Strachan (1999) were used in the model because they represent pooled estimates for children younger than 16 years old. Using these estimates also allows us to differentiate between the side effects of passive smoking on babies and children. Three experts[23] in the field were contacted by email, and they recommended that the effects of passive smoking on babies ought to be studied for the first five years after birth. Care has been taken to avoid an overlap between this chapter (which focuses on passive smoking-related health effects on children aged 0 to 15) and Chapter Six (which focuses on health effects on 0 to 1 year old of maternal smoking during pregnancy). Thus, sudden infant death and low birth weight are considered to be the clinical implications of smoking during pregnancy, and are discussed in Chapter 6, while this chapter follows Cook and Strachan (1999) and focuses on wheezing, asthma, morning and nocturnal cough among children aged 0 to 15. Two studies report the relative risk of acute otitis media, with the value estimated by Cook and Strachan (1999) lying at the highest edge of the 95% confidence interval. The pooled estimates of Cook and Strachan (1999) are therefore used in the model. These estimates have also been used in other studies to calculate health effects on children from passive smoking (Rushton et al., 2003).

Mortality risk for passive smokers

The systematic literature review found no articles giving passive smoking-related mortality data, so advice was sought from those with the relevant knowledge in the UK. These experts directed the researcher to Jamrozik's UK-based study (2005); however, when reporting by cause the deaths attributable to passive smoking, this study does not compare passive and non-passive never-smokers groups. Only one other data source was recommended (Hill et al., 2004). This study examined the association between passive smoking and mortality from all causes in New Zealand. The clinical trial was conducted among adults aged 45-74 who had responded to the 1981 and 1996 censuses identifying themselves as "non-smokers" and providing data on the smoking status of all household members. The data used in the model came from the most recent census (1996-1999). The adjusted relative risk for men who were passive compared to those who were non-passive was 1.16, with a 95% confidence interval between 1.04 and 1.30.

[23] Professor S Petrou, of NICE, Lesley Owen, and Hema Mistry.

For women, this relative risk was 1.28, with a 95% confidence interval between 1.16-1.42. Although these estimates were not pooled, lack of evidence meant that this was the only data we could use in the model.

The death rate for smokers, former smokers, passive and non-passive never smokers was calculated by age and gender, converted to a transition probability, and considered in the Markov model. Refer to Appendix 5.4 for further details.

Prevalence, costs and utilities of health effects associated with passive smoking among children aged 0 to 15: systematic literature review

The aim of this systematic review was to identify and critically appraise all published material relating to the prevalence, costs and utilities of the health effects associated with passive smoking among children. Refer to Appendix 5.5 for the search methods.

Once again, where relevant data was identified in more than one source, preference was given to meta-analyses or pooled estimates relating to the health effects and mortality data associated with passive smoking. Meta-analysis carried out in the UK was prioritised as this setting is the context of the current analysis. Estimates used in HTA or NICE reports, which inform NICE policy making, were also favoured, followed by estimates from credible sources such as national statistics institutions. Estimates calculated from populations with the widest possible age interval were favoured. Where age intervals were comparable, the study offering the most conservative estimate was preferred.

The search strategy for prevalence studies yielded 1649 papers. Following a review of their titles and abstracts, only 233 were felt to meet the inclusion criteria. Of these, only 37 reported data of interest (see Appendices 5.6 and 5.7 for more details). The findings are summarised below according to type of data.

Prevalence

19 out of 37 studies reported data on the prevalence of passive smoking-related illnesses. See Table 5.3 for more details.

Table 5.3 Summary of characteristics and data relating to *prevalence* of health effects caused by living with a smoking parent among children younger than 15 years

Author, year	Health effect	Sample	Children`s age	Country	Estimated annual prevalence	95% CI
Studies identified						
SIGN 2003	Acute otitis media	-	< 10	UK	25%	-
	Otitis media with effusion	-	< 4		80%	-
Asher et al. 2006	Asthma	1843	6-7	UK	20.9%	-
			13-14		24.7%	-
Kwong GNM et al. 2001	Asthma	4806	8-9	UK	29.7%	-
		4810			35.8%	-
Soriano et al. 2003	Asthma	15751	5-14	UK	9.08%	-
Anderson et al. 2004	Asthma[24]	15755	12-14	UK	25.9%	-
	Wheeze[25]				27.5%	-
Burr et al. 2006	Asthma	1148	12	UK	27.3%	-
	Wheeze[26]				28%	-
	Breathless Wheeze[27]				19.9%	-
Butland et al. 2006	Asthma or Wheeze	4246	7-8	UK	17.8%	
Kurukulaaratchy et al. 2002	Asthma	1456	10	UK	14.4%	-
	Wheeze				18.9%	-
McCann et al. 2002	Asthma	1732	7-9	UK	24.3%	-
	Wheeze[28]	328			18.9%	-
ONS 2004	Asthma	25507	12-14	UK	21.08%	-
	Wheeze				33.73%	-
Pearce et al. 2007	Asthma	-	6-7	UK	24.8%	-
		-	13-14		22.9%	-
	Wheeze	-	6-7		19.6%	-
		-	13-14		27.1%	-
Rizwan et al. 2004	Asthma	1964	5-11	UK	29.8%	-
	Wheeze				29.4%	-
	Breathlessness				19.8%	-
Shamssain and Shamsian 1999	Asthma	3000	6-7	UK	22.7%	-
	Wheeze				29.6%	-
Kuehni et al. 2001	Wheeze	2600	1-5	UK	26%[29]	
					29%[30]	
Kuehni et al. 2000	Wheeze	1422	8-13	UK	20.5%[31]	
Patel et al. 2008	Wheeze	35485	13-14	UK	32.2%[32]	
Duran-Tauleria and Rona 1999	Asthma	1028	5-11	UK	6.6%	-
	Wheeze	2196			14.1%	-
	Cough	1047			6.8%	-
Linehan et al. 2009	Asthma	2377	6-11	UK	9.3%	-
	Wheeze	2408			20.3%	-
	Cough (night)	2387			33.5%	
Shamssain 2007	Asthma	1843	6-7	UK	26.95%	-
		2195	13-14		25.8%	-
	Wheeze	1843	6-7		35.6%	-
		2195	13-14		30.55%	-
	Cough	1843	6-7		27.2%	-
		2195	13-14y		19.1%	-
Parameter value used in model						
ONS 2004	Asthma	25507	12-14	UK	21.08%	-
	Wheeze				33.73%	-
Shamssain 2007	Cough	1843	6-7	UK	27.2%	-
		2195	13-14y		19.1%	-

[24] lifetime prevalence
[25] 12 month prevalence
[26] have ever wheezed
[27] have ever been breathless or wheezed
[28] last 12 months
[29] wheezing in 1998
[30] wheezing in 1998
[31] wheezing in 1998
[32] This estimate taken from the International Study of Asthma and Allergies in Childhood (ISAAC) conducted in 1994-1995.

Author, year	Health effect	Sample	Children`s age	Country	Estimated annual prevalence	95% CI
SIGN 2003	Acute otitis media	-	< 10	UK	25%	-
	Otitis media with effusion	-	< 4		80%	-

With regard to asthma and wheezing, the prevalence data selected for the model was that reported by the Office for National Statistics (ONS) (2004). This was the best evidence source for this data as it met the criterion of coming from an established source – the National Statistics Institution. For cough, the estimate used was that provided by Shamssain (2007). Although Linehan's estimate is more recent (2009), a comparison of those papers containing estimates for cough shows that the prevalence rates for asthma and wheeze also reported by the studies were closest the ones reported by Shamssain than the others (Duran-Tauleria and Rona, 1999; Linehan et al. 2009). An average prevalence rate was calculated where two separate rates were reported for the 6-7 and 13-14 age groups. The unique estimates for acute otitis media and otitis media with effusion were used.

Costs

Only nine studies out of 40 reported data on costs related to passive smoking illnesses. Table 5.4 shows details of this data.

Table 5.4 Summary of characteristics and data relating to *costs* associated with passive smoking-related illnesses among children aged 0 to 15 years who live with smoking parents

Author, year	Health effect	Sample	Children`s age (years)	Country	Estimated annual cost	95% CI	Currency /year
Studies identified							
Alsarraf et al. 1999	Acute otitis media	25	1-3	US	137.94	133.74-142.14	$ 1996
Koskinen et al. 2006	Acute otitis media	369	0-6	Finland	123.55	-	€ 2002
Main et al. 2008	Asthma	3416	0-12	UK	79.83	-	£2006
Ungar et al. 2001	Asthma	339	4-14	Canada	663	630-701	$1995
Van der Akker-van Marle et al. 2005	Asthma	2000	6-7 and 13-14	UK	189	-	£2004
Wang et al. 2005	Asthma	2.52 million	5-17	USA	401		$2003
Weinmann et al. 2003	Asthma	145	0-8	Germany	627	157-1918	$1996
Stevens et al. 2003	Asthma or wheeze	90	1-5y	UK	428.51	34.07-1781.89	£1999
Hollinghurst et al. 2008	Cough	121	3-5	UK	27.43	24.38-30.49	£2006
Hartman et al. 2001	Otitis media with effusion	187	1.6	Netherlands	286	-	$ 1998
Plaza and de los Santos 2003	Otitis media with effusion	1000	2-6	Spain	146	-	€2003
Parameter value used in model							
Koskinen et al.2006	Acute otitis media	369	0-6	Finland	123.55	-	€ 2002
Plaza and de los Santos 2003	Otitis media with effusion	1000	2-6	Spain	146	-	€2003
Main et al. 2008	Asthma	3416	0-12	UK	79.83	-	£2006
Stevens et al. 2003	Asthma or wheeze	90	1-5y	UK	428.51	34.07-1781.89	£1999
Hollinghurst et al. 2008	Cough	121	3-5	UK	27.43	24.38-30.49	£2006

For acute otitis media (Koshinen et al., 2006) and otitis media with effusion (Plaza and de los Santos, 2003), the estimates were taken from those studies with the largest age intervals. Main et al's estimate of the cost of an asthma episode (2008) was taken for the model as it was derived from a recent HTA report. Only one paper supplied estimates for wheeze and cough. To aid comparability, cost values were converted to sterling using country-specific gross domestic product deflators (World Bank, 2009) and euro-pound sterling exchange rates (European Central Bank, 2009).

Utility

Twelve out of 40 studies reported utilities (see Table 5.5 for more details). Only one study reported utility estimates for cough and otitis media with effusion, while several gave estimates for asthma and wheezing. Main et al's (2008) utility estimate for asthma was taken for the model because it was used in an HTA report. Regarding acute otitis media, although Brouwer et al. (2005) supplied the most recent estimate, the age interval in Oh et al's (1999) study was larger; the latters' estimate was therefore considered more appropriate for the model. Mohangoo et al's (2007) utility estimate for wheezing was taken for the model was the most conservative estimate.

Table 5.5 Summary of characteristics and data relating to *utilities* of health effects caused by living with smoking parents among children aged 0 to 15 years

Author, year	Health effect	Sample	Children`s age (years)	Estimated utility	95% CI	Instrument
Studies identified						
Oh et al. 1996	Acute otitis media	10 physicians	2 months-18years	0.79[33]	0.713-0.867	Physician interviews (utilities)[34]
Brouwer et al. 2005	Acute otitis media	384 children	1-7	0.87	-	Dutch instrument on generic HRQoL
Main et al. 2008	Asthma	3416	0-12	0.85	-	HRQoL
Van der Akker-van Marle et al. 2005	Asthma	2000	6-7 and 13-14	0.73	-	HRQoL
Goldbeck et al. 2007	Asthma	81	7-18	0.77	-	Quality of life
Norrby et al. 2006	Asthma	53	9-16	0.82	-	CHQ-HRQoL
Sawyer et al. 2004	Asthma	123	10-14	0.69	-	PAQLQ-HRQoL[35]
Polley et al. 2008	Chronic cough	147	40-67	0.76	-	LCQ-CQLQ-HRQoL[36]
Tengs and Wallance 2000	Otitis media with effusion	-	children	0.7	-	Quality of life
Mohangoo et al. 2007	Wheeze	1071	15	0.75	-	CHQ-HRQoL[37]
Oostenbrink et al. 2006	Wheeze	500	0-4	0.76	-	ITQOL-HRQoL[38]
Mohangoo et al. 2005	Wheeze	500	0-3.3	0.86	-	TAPQOL-HRQoL[39]

[33] The value reported by the authors was 0.79 (utility per day) of AOM. This was transformed to a utility value according to the 6 months cycle of my model. The treatment length was assumed to be the same as the length of an AOM episode.
[34] A utility analysis was performed based on the physicians' responses to the AOM and adverse-event scenarios presented in the mail survey. Utility was defined as a preference for each given health state, rated on a scale of severity from 0 to 1.
[35] The Paediatric Asthma Quality of Life Questionnaire (PAQLQ) was utilised as the disease-specific HRQoL measure.
[36] The researchers undertook a cross-sectional comparison of scores from two cough-specific, health-related quality of life (HRQoL) questionnaires, the Leicester Cough Questionnaire (LCQ), and the Cough Quality of Life Questionnaire (CQLQ), together with a generic HRQoL measure, the EuroQol.
[37] The Child Health Questionnaire (CHQ) is a generic self-report questionnaire for measuring and comparing HRQoL.
[38] The Infant/Toddler Quality of Life Questionnaire (ITQOL) is a generic "profile measure" for HRQoL among children.
[39] This study evaluated the HRQoL using the TNOZAL Preschool Children Quality of Life (TAPQOL) questionnaire.

Author, year	Health effect	Sample	Children`s age (years)	Estimated utility	95% CI	Instrument
Parameter value used in model						
Polley et al. 2008	Chronic cough	147	40-67	0.76	-	LCQ-CQLQ-HRQoL[40]
Tengs and Wallance 2000	Otitis media with effusion	-	children	0.7	-	Quality of life
Main et al. 2008	Asthma	3416	0-12	0.85	-	HRQoL
Oh et al. 1996	Acute otitis media	10 physicians	2 months-18years	0.79[41]	0.713-0.867	Physician interviews (utilities)[42]
Mohangoo et al. 2007	Wheeze	1071	15	0.75	-	CHQ-HRQoL[43]

HRQoL: Health-related quality-of-life

Uptake of smoking (incidence)

At the start of the modelling process, age and gender-specific incidence rates were calculated for each of the two never-smoking categories (non-passive and passive). The data for the analysis was taken from the General Household Survey (GHS) of 2006 (see Appendix 5.8 for how this survey was selected). In each cycle, until reaching the age of 100 the transition from non-passive never-smoker, to passive smoker to smoking status was modelled. To calculate the incidence (uptake) of smoking from non-passive and passive never smokers two types of information were needed: (a) the incidence rate (new smokers/population) of smoking and the increase in the relative oddsof uptake of smoking if any household member was smoking in the household, which was calculated, from the Health Survey for England (HSE) (2006), as the quotient of odds of passive never-smokers and odds of non-passive never-smokers. It was assumed that this household data was representative of total passive smoking exposure. This data was adjusted by age, and gender.

[40] The researchers undertook a cross-sectional comparison of scores from two cough-specific, health-related quality of life (HRQoL) questionnaires, the Leicester Cough Questionnaire (LCQ), and the Cough Quality of Life Questionnaire (CQLQ), together with a generic HRQoL measure, the EuroQol.

[41] The value reported by the authors was 0.79 (utility per day) of AOM. This was transformed to a utility value according to the 6 months cycle of my model. The treatment length was assumed to be the same as the length of an AOM episode.

[42] A utility analysis was performed based on the physicians' responses to the AOM and adverse-event scenarios presented in the mail survey. Utility was defined as a preference for each given health state, rated on a scale of severity from 0 to 1.

[43] The Child Health Questionnaire (CHQ) is a generic self-report questionnaire for measuring and comparing HRQoL.

The incidence rate of smoking (rate at which never smokers start smoking) was adjusted using the (respective) increase in the odds ratio(s) of uptake of smoking if any household member was smoking, and therefore, increasing the risk of smoking if the household members were passive never smokers. This increased risk was also published by Leonardi-Bee et al (2011) for children, though not for adults. Therefore, this odds ratio was finally proxied using data from the HSE (2006). . Finally, this rate was converted to a transition probability value for use in the Markov model.

Detailed data on the incidence transition probability values used in the model is given in Appendix 5.9.

Quit and relapse rates

These were modelled exactly as in the M2 and M3 models (see Section 4.1.6, Chapter 4).

Prevalence

At the start of the modelling process, for each of the four smoking categories, the age and gender-specific prevalence of smoking status was applied to mirror the known prevalence of these states in the English population. The prevalence rates for adults and children were taken from the Health Survey for England (2006) (see Appendix 5.10 for how the survey was selected). This survey represents the most up to date information we have about people`s smoking at home, but the fact that it also includes non-household members (i.e. visitors) who smoke makes it impossible to calculate exactly how many passive smokers there are in a given household. Separate information was calculated for adults (defined as anyone over16) and children in the HSE survey. The variable used to derive the adult number of passive smokers was generated by asking household members if they were often near people who smoke at home; this data was broken down according to cigarette smoking status, age and sex. It was assumed that smokers smoke inside and not outside of the house/flat in the HSE survey. This variable was used to calculate the number of passive smokers inside the Markov model. This

cohort of people was used to measure the impact of passive smoking in the cost-utility analysis of smoking cessation interventions.

Those whose cigarette smoking status was: "never smoked cigarettes at all" were considered non-smokers, whereas those who said they "used to smoke cigarettes occasionally" and "used to smoke cigarettes regularly" were classified as former smokers.

The data relating to adults which was used in the model is reported in Table 5.7. More detailed data extracted from the HSE 2006 can be seen in Appendix 5.11.

Table 5.7 Prevalence of smoking status among the adult population (aged 16 onwards)

Age	Current smoker (S)		Former (F)		Non-passive never-smokers		Passive never-smokers	
	men	women	men	women	men	women	men	women
16-24	0.28	0.28	0.10	0.10	0.51	0.52	0.12	0.09
25-34	0.34	0.25	0.22	0.25	0.41	0.47	0.03	0.03
35-44	0.28	0.23	0.24	0.24	0.46	0.48	0.02	0.04
45-54	0.24	0.24	0.30	0.27	0.43	0.46	0.03	0.03
55-64	0.19	0.20	0.46	0.34	0.33	0.44	0.02	0.02
65-74	0.14	0.13	0.55	0.34	0.30	0.51	0.01	0.02
75 and over	0.09	0.08	0.60	0.41	0.30	0.47	0.01	0.03
All ages	0.23	0.21	0.35	0.28	0.39	0.47	0.03	0.04

Because passive smokers are assumed to be generated by adult smokers, the prevalence of passive smokers was adjusted to account for this. The steps followed were: (a) take prevalence rates among current smokers by age and sex (from the HSE 2006) and multiply them by the average prevalence of passive smokers; and (b) divide the resulting numbers by the average prevalence of current smokers (i.e. for men of 16-24 years: 0.28 * (0.035/0.22)). To capture an average for female and male passive smokers combined, the average figure for passive smokers of all ages (0.035) was calculated. This proxy was necessary because of the lack of data on the number of passive smokers caused by the current number of smokers. It was the only possibility with the available data.

The impact on child passive smokers was also considered. In order to keep the structure of the model comparable with previous versions, the effect of passive smoking on children was calculated outside the Markov model, but using the output for smokers

generated in the model. The population used in the model was a cohort of 1000 adults aged 16 upwards; introducing children would have changed the whole structure of the model cohort.

The only available data relating to the prevalence of passive smoking among children is in the HSE 2006, but this is limited to children aged between 8 and 15. It was assumed that rates among children aged 0 to 7 would be similar to those among 8 to 15 year olds. With this assumption, it was possible to calculate the prevalence of smoking status among children aged 0 to 15 (see Table 5.8 for details).

Table 5.8 Prevalence of smoking status among children aged 0 to 15

Age	Ever smoked	Non-passive never-smoker	Passive never-smoker
0-15	0,15	0,63	0,22

Although, children who ever smoke may have tried once, and refused to try again, and therefore they could have been affected by passive smoking, the 15% of children who had ever tried cigarettes were not included in the model. The figures used in the model may therefore be conservative. The same method as was used for adults – multiplying by the average prevalence of passive smokers and dividing by the average prevalence of current smokers – was adopted for children. The prevalence rate for child passive smokers (0.22 according to Table 5.8) was divided by the overall average smoking prevalence rate for adults (i.e. the average of 0.23 and 0.21 from Table 5.7) to obtain the rate of passive smoking children generated by smokers. The result accords with the findings of Jarvis et al. (2000) on the prevalence of passive smoking as reported by schoolchildren aged 11-15 in England. Jarvis`s study was a cross-sectional survey of data from nationally representative samples of secondary school children, collected by the Office for National Statistics between 1988 and 1998. Although offering similar results, the more recent data has been taken for use in the model. It suggests that 96.5% of children living with a smoker are passive smokers.

The average number of children living in a household was calculated by dividing the total population under 15 years by the total population aged between 15 and 59. (Further details are given in Appendix 5.12.) The model assumes a maximum age of 59 for

parents of children aged 15 or under (taking 45 as the maximum age for getting pregnant). An average number of 0.63 dependent children is assumed for every two adult members in each household. Although recent evidence from Smallwood and Wilson (2007) claimed that the average number of dependent children per family was 1.8 in 2006, this estimate has not been used here because it only covers families with dependent children, and does not take into account families with any dependants.

Multiplying the number of adult smokers (aged 16-100) in each model cycle by the average number of children by person, the average number of children living with each smoker was obtained. This number was then multiplied by the prevalence of passive smoking children in the total child population to arrive at the average number of children passive smokers per existing number of smokers in the population.

Sources of effectiveness

The same effectiveness studies were used in this economic model as before (see Section 4.1.6, Chapter 4). However, because Model M3 incorporated the transformation of these effectiveness rates to transition probabilities, Brief Advice resulted in a lower effectiveness rate than the comparator. Therefore, to ensure "face validity" the intervention was assumed to be minimally more effective (0.05) than non-intervention. This figure (0.05) was chosen to ensure that this assumption did not affect the cost-effectiveness of this intervention.

5.2.2 Economic model

The aim of this analysis is to determine, using a Markov decision model, the relative cost-utility of the different smoking cessation interventions identified in NICE`s report (Flack et al., 2007a) on the health effects of passive smoking. The population examined is a cohort of 1000 adults, who, as in M2 and M3, are divided according to their smoking status. When passive smoking among children is incorporated into the model (M5), the cohort of 1000 adults increases by the number of passive children generated by smokers in the population (96.5% of adult smokers' children). In this way, the

population of M4 and M5 (the models being developed in this chapter) differs from that of M3.

A Markov (state transition) model was developed in Microsoft EXCEL (Microsoft Corporation). The structure of the model was adapted from that of M3. The models used in this chapter (M4 and M5) differ from M3 in the addition of two new groups to the population: non-passive never-smokers and passive never-smokers (M3 considered smokers, former smokers and death health states only). M4 and M5 differ in their incorporation of external effects: M4 does not consider the effects of passive smoking, while M5 does. See Table 5.9 for details.

Table 5.9 Summary of differences between M3, M4 and M5

Model	Starting population in Markov Model					Incorporation of passive smoking on adults and children
	Smokers	Former smokers	Non-passive never-smokers	Passive never-smokers	Death	
M3	√	x	x	x	x	x
M4	√	√	√	√	x	x
M5	√	√	√	√	x	√

√≡ included in the model
x≡ not included in the model

To assess the impact of passive smoking, the number of passive smokers was calculated from the number of smokers by age and gender from the Markov model. As in M2 and M3, the analysis adopts the National Health Service`s preferred cycle length of six months.

The model estimates[44]: (a) impact on average lifetime costs due to passive smoking (£ 2010); and (b) quality-adjusted life-years (QALYs) lost to adults and children due to passive smoking. The effectiveness outputs differ from those calculated and obtained in M2 and M3, which were lifetime QALYs gained. This change was made because it seems to be conceptually easier to understand the impact of negative external effects

[44] To facilitate the presentation and interpretation of results, only those lifetime costs and QALYs lost associated with the least and most cost-effective smoking cessation programmes are presented.

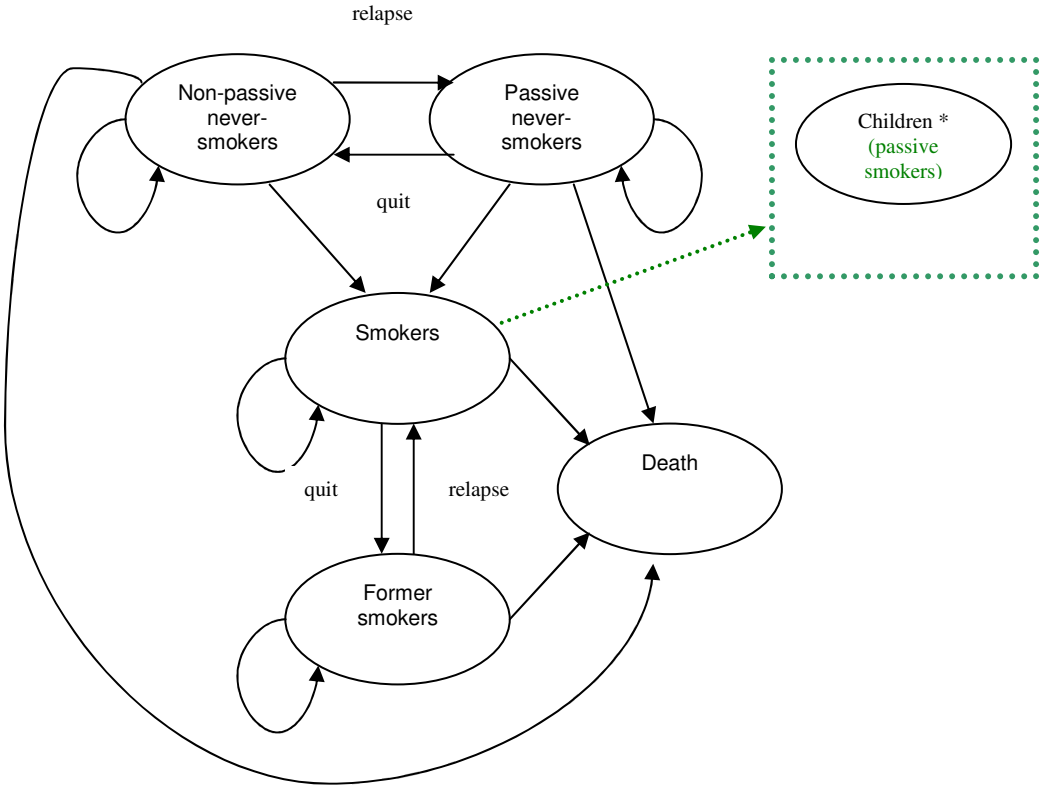
introduced in the model when the effects are calculated as QALYs lost. However, it would also have been possible to calculate QALYs gained.

Model structure

Within the Markov state transition model, adults reside in one of five discrete health states. The model starts with a fixed distribution of the population according to their smoking habits. At regular time intervals (the model cycle), adults make at most one transition between states. During each cycle, all adults must be in one of the health states in the model. The probabilities attached to each transition between model cycles were based on the data used in the Flack et al (2007) report and, when new data was needed (e.g. regarding costs or utilities of the health effects of passive smoking on adults and children), systematic literature reviews were carried out. Some of the model states therefore have an associated utility and cost, and some of the model transitions have a cost. Transition probabilities were assigned to each of the transitions (indicated by the arrows in Figure 5.1). The model was run for the lifetime of the population modelled (with a convenience cut off at 100 years).

The structure of the model is shown in Figure 5.1.

Figure 5.1 Structure of the smoking cessation model accounting for passive smoking



* Children who are passive smokers generated by the smokers in the adult population modelled

The passive smokers' cohort is a function of the smokers' cohort. Smokers and former smokers are linked through their quit and relapse rates, as are passive and non-passive never-smokers. Adults might remain in a given state at the end of each cycle or could transition to death. The model assumes that passive smoking is irrelevant to smokers and former smokers; it does not materially increase the already high risk faced by these groups. This assumption also enables a clearer distinction to be made between active (smokers and former smokers) and passive smoking (never smokers). Passive smoking does increase the risk faced by non-smokers, however. Although the model is built separately by gender, female smokers generate female and male passive smokers of any age, and male smokers generate male and female passive smokers of any age, and then results are adjusted according to the population weights.

5.2.3 Time horizon

The time horizon of the model was set for a maximum lifespan of 100 years, as before.

5.2.4 Discount rate

Both costs and benefits (QALYS) in the model have been discounted at an annual rate of 3.5%, as before.

5.2.5 Cost-effectiveness ratios and net monetary benefit

Mutually exclusive treatment options were adopted as for M2 and M3. Net monetary benefit (NMB) was constructed following the same criteria as before, adopting a threshold value of £20,000.

5.2.6 Uncertainty

Uncertainty about estimates of costs, effectiveness, and the cost-effectiveness ratio or NMB can arise in a number of ways. There are two major sources of uncertainty: parameter and model uncertainty (Manning et al., 1996). Only parameter uncertainty has been studied in this case. In an attempt to deal with parameter uncertainty in the input parameters of the decision model, univariate and probabilistic sensitivity analyses were conducted after the economic evaluation. Univariate sensitivity analysis only was conducted by Flack et al. (2007a) in M1 (see Section 4.1.10, Chapter 4). Their analysis addressed the background cessation rate and the cost of interventions. For consistency`s sake, therefore, univariate sensitivity analysis was also conducted here.

Although univariate sensitivity analysis remains the most popular technique to account for uncertainty, the analysis of M4 and M5 demonstrates that it gives insufficient insight into the scale of decision uncertainty (Claxton et al., 2005). Probabilistic sensitivity analysis (PSA) is an alternative approach that involves specifying distributions for input parameters in the model and employing Monte Carlo simulation to sample from these distributions, allowing the joint effect of parameter uncertainty to be assessed (Briggs et

al., 2002). Probabilistic sensitivity analysis involves specifying distributions for model parameters to represent parameter uncertainty in their estimation and employing Monte Carlo simulation to select values at random from those distributions (Briggs et al., 2002). Variables can take a range of values described by the specified distribution (Briggs et al., 2002). This type of sensitivity analysis was also employed in M4 and M5.

There was uncertainty about the true numerical variables of the parameters used as inputs in the model, such as the incidence rates of starting smoking, effectiveness of smoking cessation programmes, relative risk of getting a particular disease due to passive smoking, utility values and costs. Therefore, having specified distributions for all these parameters of the model, probabilistic analysis was undertaken by randomly sampling from each of the parameter distributions and calculating the expected costs and expected QALYs for that combination of parameter values. This process formed a single replication of the model results, and a total of 1000 iterations were performed in order to examine the distribution of the resulting cost and outcomes for each smoking intervention. The cumulative NMB for the most cost-effective intervention was calculated to see whether the number of iterations was enough to produce stable results.

5.2.6.1 Choosing distributions for the parameters

Care was taken to choose the distribution which was most appropriate to the nature of the data; different distributions were deployed for the four different types of parameters employed in this cost-effectiveness model. Distributions for estimation of parameters were selected according to the recommendations of Briggs et al. (2002; 2006, pp108). For probability parameters such as quit and relapse rates and smoking incidence rates, the beta distribution was selected. The utilities parameters was also based on a beta distribution. Gamma distribution was considered more appropriate for the unit cost parameters. Finally, for the relative risk parameters regarding the five different diseases (LC, CHD, COPD, MI, ST) and diseases associated with passive smoking, and the relative risk of mortality for passive and non-passive never-smokers, the lognormal distrubution was considered. Beta and gamma parameters were calculated differently depending on the distribution. The formulas for making these calculations have been fully described by Briggs et al. (2006, pp.87, 91,90). There was little data available to provide information on 95% Confident Intervals (CI) and standard deviation of all

parameters to use in the PSA. Therefore, when reported, 95% CI and standard deviation, was used. However, in cases where only the CI was reported, the standard deviation was calculated from the difference range from the interval estimates divided by 2 * 1.96. This formula should theoretically be used only for normal distributions, but it has also been applied here for non-normal distributions (Briggs et al., 2006). Where data on standard deviations or confidence intervals is not available, the common practice in regard to the standard deviation is to substitute 1/10th of the mean value for any missing value (Fox et al., 2007). Refer to Appendix 5.13 for more details.

5.2.6.2 Cost-effectiveness acceptability curves

In the updated NICE methods guidance, the use of cost-effectiveness acceptability curves (CEACs) is recommended (Claxton, 2005). Therefore, cost-effectiveness acceptability curves (CEACs) were derived from the joint distribution of incremental costs and incremental effects resulting from comparing each intervention with the base case (no intervention). The most common technique for estimating these joint distributions is nonparametric bootstrapping of the observed data, although other methods are available (Fenwick and Byforf, 2005). In this case, we used the bootstrapping technique. CEACs were constructed by recording the number of times each alternative was cost effective or calculating the highest Net Benefit from the simulated output of a model (Claxton, 2008) for M4 and M5. They show the probability that an intervention is likely to be cost-effective compared with the alternative, given the observed data, for a range of maximum monetary values that a decision-maker might be willing to pay for a particular unit change in outcome (Fenwick and Byforf, 2005). For each specified value of this “acceptable” cost-effectiveness ratio (a point on the x-axis), the CEAC shows the probability that the data is consistent with a true cost-effectiveness ratio falling below that value (read off the y-axis) (Fenwick and Byforf, 2005). However, it is important to note that the alternative with the highest probability of being cost-effective may not be the most cost-effective alternative (having the highest expected net-benefit) (Claxton, 2008). To facilitate the presentation and interpretation of the results, only CEACs of the least and most cost-effective smoking cessation programmes are presented. In order to facilitate comparison with the results of Flack et al. (2007a), the CEACs need to be calculated comparing each alternative with no intervention. If the same intervention comes out on top for any simulation, the CEACs

will be meaningful. Therefore, to study the probability of NMB having a point estimate below a threshold was studied through histograms of NMB.

5.3 Results

The Markov model outlined in this chapter was evaluated to estimate average lifetime costs and QALYs lost. The results are first presented for an adult passive population only, and then for a population including both passive adults and children. Table 5.10 distinguishes between the results generated by M4 (excluding external effects) and M5 (including external effects). Because the inclusion of external effects does not alter policy decisions in regard to the ranking of cost-effectiveness of interventions, the results are only presented for no intervention (NI), for an intervention falling in the middle of the cost-effectiveness scale (LICB), and for the most cost-effective intervention (NPPCBP). The initial intention was to present the results for the least cost-effective intervention (BA), but because these results were so similar to those for no intervention, it was decided that selecting an intervention which fell in the middle of the cost-effectiveness ranking (LICB) would better facilitate the presentation of the results.

Table 5.10 M4 and M5 estimates of average lifetime costs and QALYs lost per adult (cohort of 1000 adults; > 16 years; lifetime period reaching 100 years; starting distribution: according to prevalence; health states: smokers; former smokers; non-passive never-smokers; passive smokers; and death)

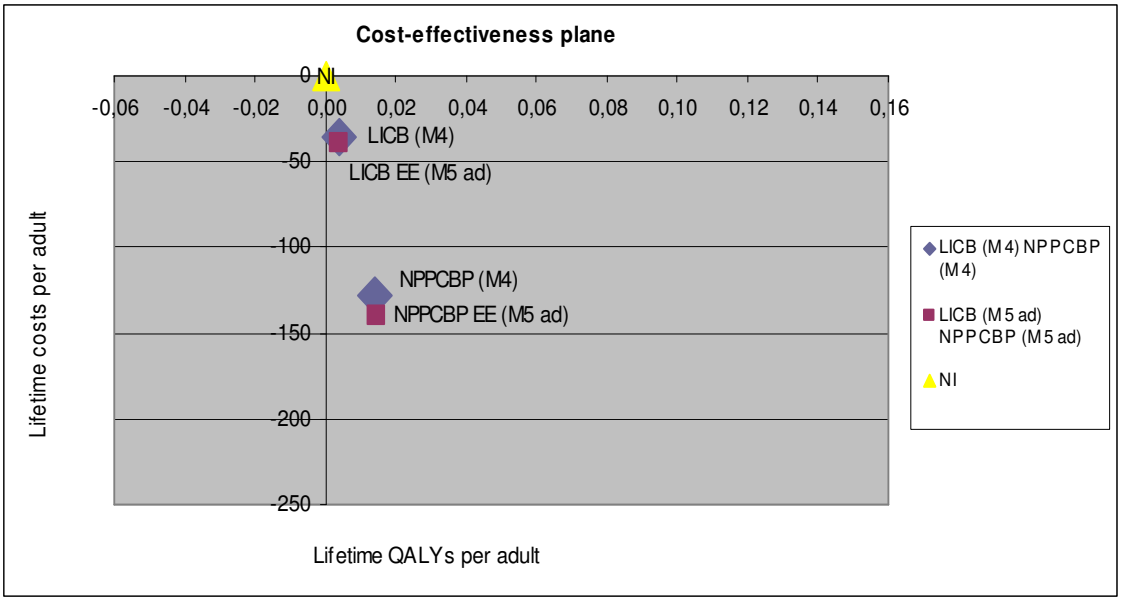
Interventions	Discounted average COST per adult (M4)	Discounted average COST per adult (M5)	Discounted QALYs lost per adult (M4)	Discounted QALYs lost per adult (M5)	NMB per adult (M4)	NMB per adult (M5)
NI	3676.48	3708.68	3.3159	3.3165		
LICB	3640.46	3669.19	3.3118	3.3123	117.79	122.49
NPPCBP	3549.00	3569.19	3.3018	3.3021	409.76	426.04

M4=M3 incorporating non-smokers in the Markov model, but excluding passive smoking
M5=M3 incorporating non-smokers in the Markov model, but including passive smoking

In both M4 and M5, NPPCBP, with the highest NMB, is the most cost-effective intervention. It is therefore the recommended intervention, whether or not passive smoking is included. Model M5 (which includes adult passive smokers) shows that external effects are responsible for an extra lifetime cost of £20.19 per adult and 0.0004 extra lifetime QALYs lost. When external effects are excluded, the NMB value of the

most cost-effective intervention is £409.76; when external effects (i.e. passive smoking) are included, this figure rises to £426.04 – a difference of £16.28. Graph 5.1 compares the differences in lifetime costs and QALYs when external effects are included and excluded. To facilitate the interpretation of the graphical results, QALYs lost were converted to lifetime QALYs adjusting for the negative sign.

Graph 5.1 Lifetime costs and lifetime QALYs per adult (M4) and per adult including adult passive smokers (M5)



When child passive smokers are included, the most cost-effective smoking cessation intervention remains unchanged (refer to Table 5.11). Comparing the results from M4 and M5 (and including both adult and children passive smokers), it emerges that external effects are responsible for an extra lifetime cost of £154.08 per adult and 0.0999 extra lifetime QALYs lost. In this case, when passive smoking among both adults and children is taken into account, the NMB of NPPCBP is £2460.12. When passive smoking is not accounted for, the NMB for the most cost-effective intervention (NPPCBP) drops by £1192.46.

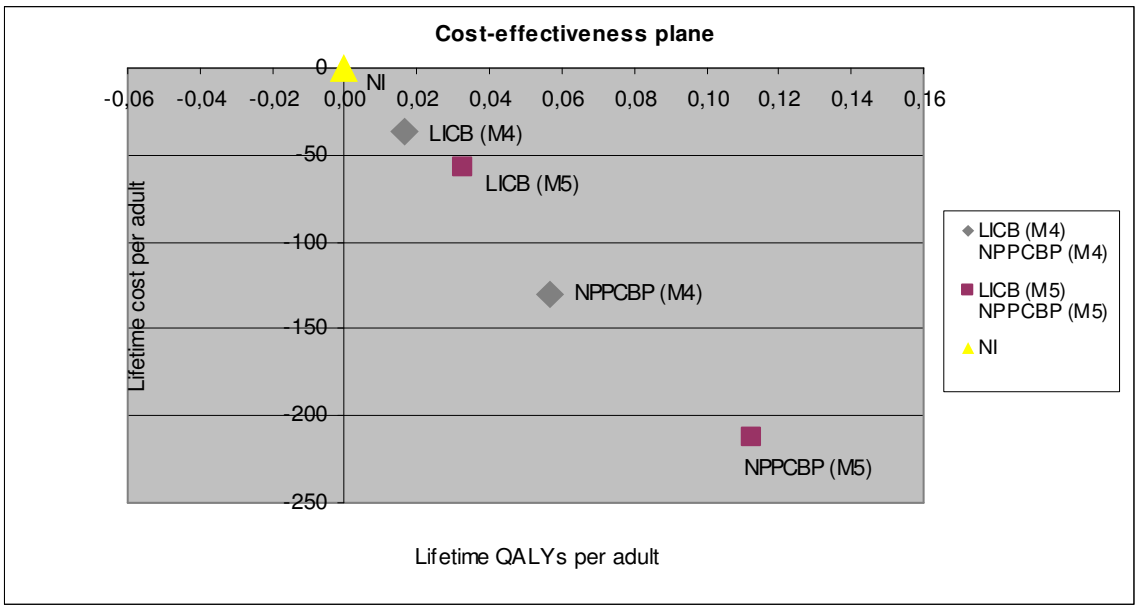
Table 5.11 M4 and M5 estimates of average lifetime costs and QALYs lost per adult (cohort of 1000 adults which includes 96.5% of adult smokers' children considered as passive smokers; > 16 years + 0-15 years; lifetime period reaching 100 years; starting distribution: according to prevalence; health states: smokers; former smokers; non-passive never-smokers; passive smokers; and death)

Interventions	Discounted average COST per adult (M4)	Discounted average COST per adult (M5)	Discounted QALYs lost per adult (M4)	Discounted QALYs lost per adult (M5)	NMB per adult (M4)	NMB per adult (M5)
NI	3713.13	3949.41	3.4592	3.6146		
LICB	3676.16	3892.08	3.4427	3.5820	366.65	708.43
NPPCBP	3582.76	3736.83	3.4024	3.5022	1267.66	2460.12

M4=M3 incorporating non-smokers in the Markov model, but excluding passive smoking
M5=M3 incorporating non-smokers in the Markov model, but including passive smoking

The impact of incorporating child passive smokers is seen by comparing Graph 5.1 with Graph 5.2. The difference between the least and the most cost-effective interventions is much greater when external effects are included.

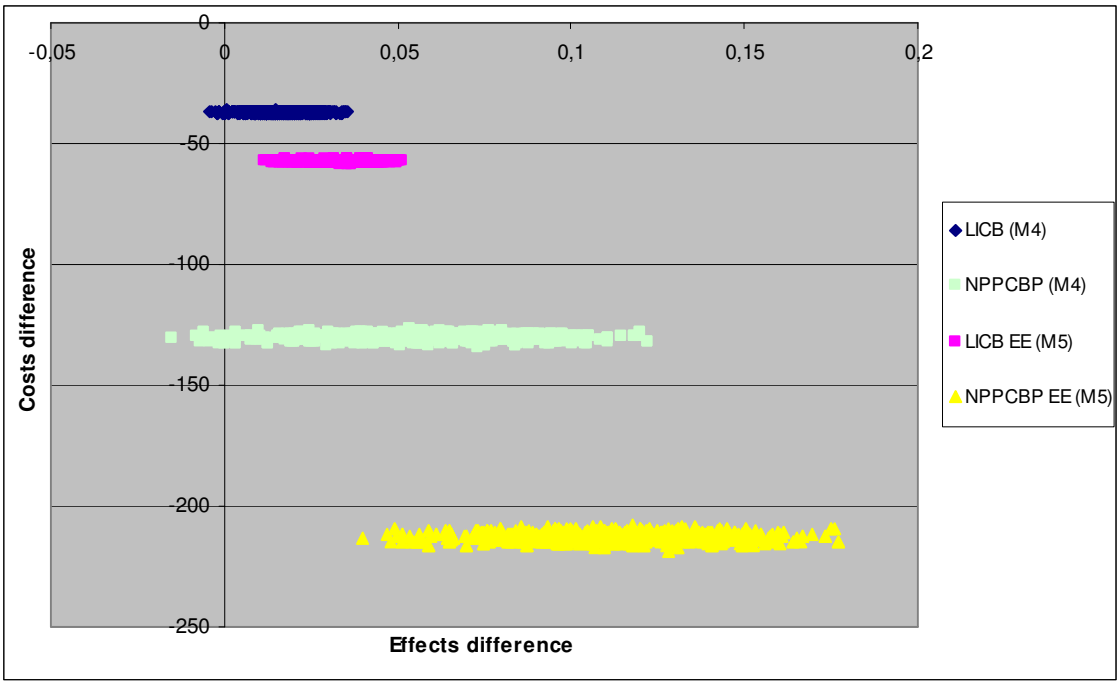
Graph 5.2 Lifetime costs and lifetime QALYs per adult (M4) and per adult including adult and children passive smokers (M5)



A univariate sensitivity analysis, consisting on a decrease of background cessation rate to 1.2% and costs of interventions equal to zero, was conducted for coherence with the sensitivity analysis carried forward by Flack et al. (2007a). In both M4 and M5, these assumptions led to the same conclusions as were obtained by the main analysis in both adult-only and adult and child scenarios – NPPCBP remained the dominant strategy in both cases. Having specified distributions for all the relevant parameters of the model, probabilistic analysis was undertaken by randomly sampling from each of the parameters` distributions and calculating the expected costs and expected QALYs for that combination of parameter values. This process formed a single replication of the model results; a total of 1000 replications from the model are presented on the cost-effectiveness plane in Graph 5.3 (for the model excluding external effects) and Graph 5.4 (for the model including adult and child passive smokers). Both graphs indicate that higher uncertainty exists around the most cost-effective interventions.

Graph 5.3 shows the net incremental costs and net incremental effectiveness of LICB and NPPCBP compared to no intervention when external effects are included and not included. The graph suggests no significant uncertainty associated with the incremental cost-effectiveness ratio for LICB (M4), the middle ranking cost-effective intervention, whereas for NPPCBP (M4), the most cost-effective intervention, it appears to suggest more uncertainty around the cost-effectiveness ratio. This higher uncertainty might be explained by the higher effectiveness rate from NPPCBP (M4) and, therefore, higher uncertainty introduced in the model, because the standard deviation for the PSA is calculated from 10% of the estimated value. For the most cost-effective intervention (NPPCBP (M4)), the 95% confident interval (CI) in terms of costs is (-132.70,-128.12), whereas for QALYs lost, the 95% CI is (0.0048, 0.1022).

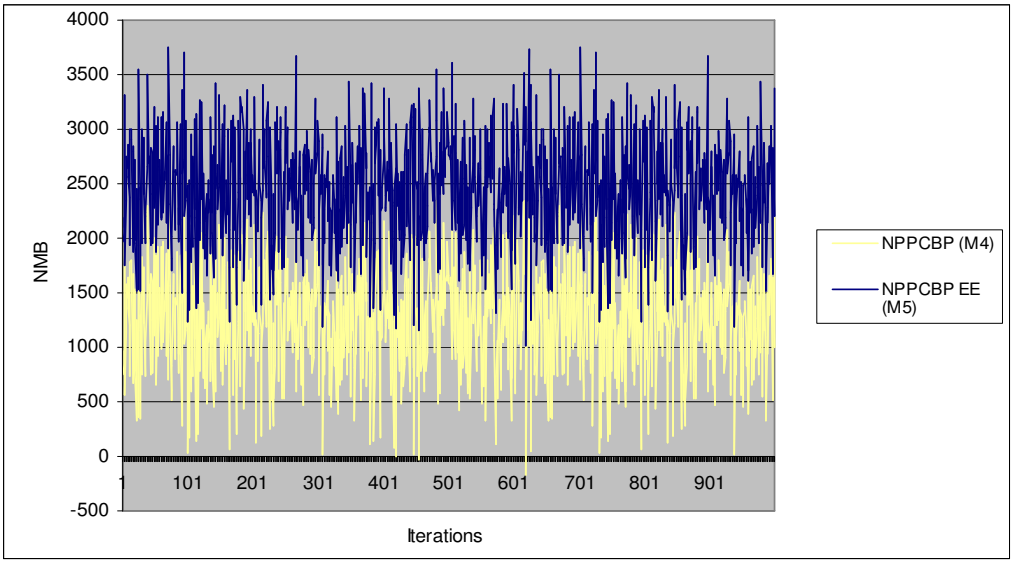
Graph 5.3 Monte Carlo simulation results on the cost-effectiveness plane for M4 and M5



When adult and children passive smokers are included, the scatter plot of net incremental costs and net incremental effectiveness compared to no intervention shows a similar level of uncertainty, though the uncertainty around costs slightly increases. This might be explained as the result of the incorporation of external effects. Not much uncertainty is suggested for LICB EE (M5), but it is for NPPCBP EE (M5) (see Graph 5.3 for details). In this case, for the most cost-effective intervention, the 95% CI for costs is (-215.82, -209.28) and the 95% CI for QALYs lost is (0.0602, 0.1577). The pattern of uncertainty around the incremental costs and effects and the level of uncertainty seem to be similar whether external effects are included or not, though there are differences in terms of both costs and QALYs. The findings suggest that uncertainty does not increase massively with the inclusion of external effects.

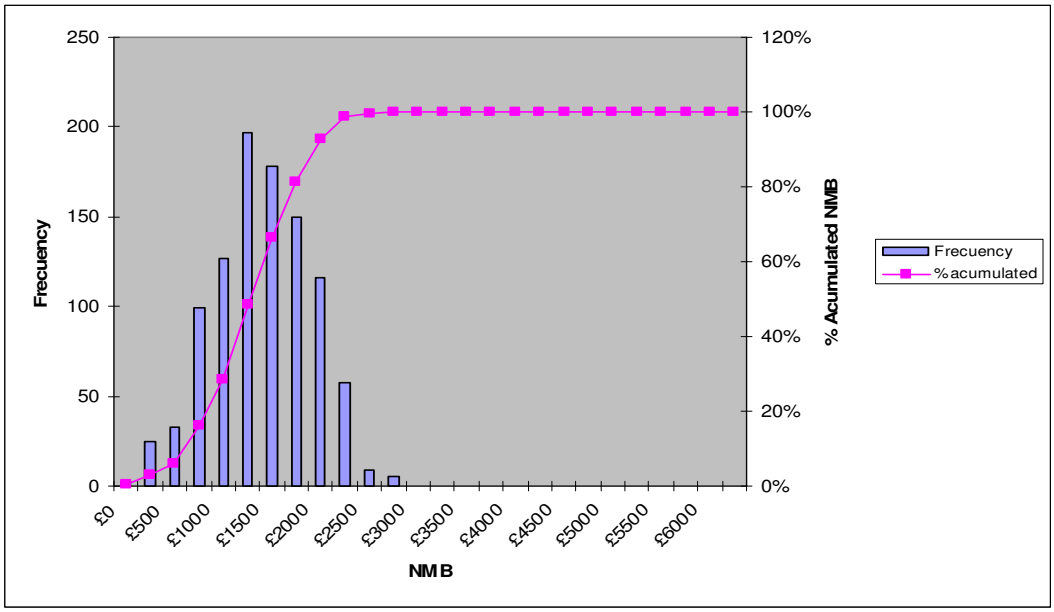
Graph 5.4 shows the uncertainty around the NMB of the most cost-effective intervention (NPPCBP) with and without passive smoking. Higher uncertainty around the NMB estimates is observed in the simulations calculated by the PSA.

Graph 5.4 Uncertainty surrounding the NMB of the most cost-effective intervention when impact of passive smoking on adults and children is taken into account (NPPCBP EE; M5) and when it is not (NPPCBP; M4)



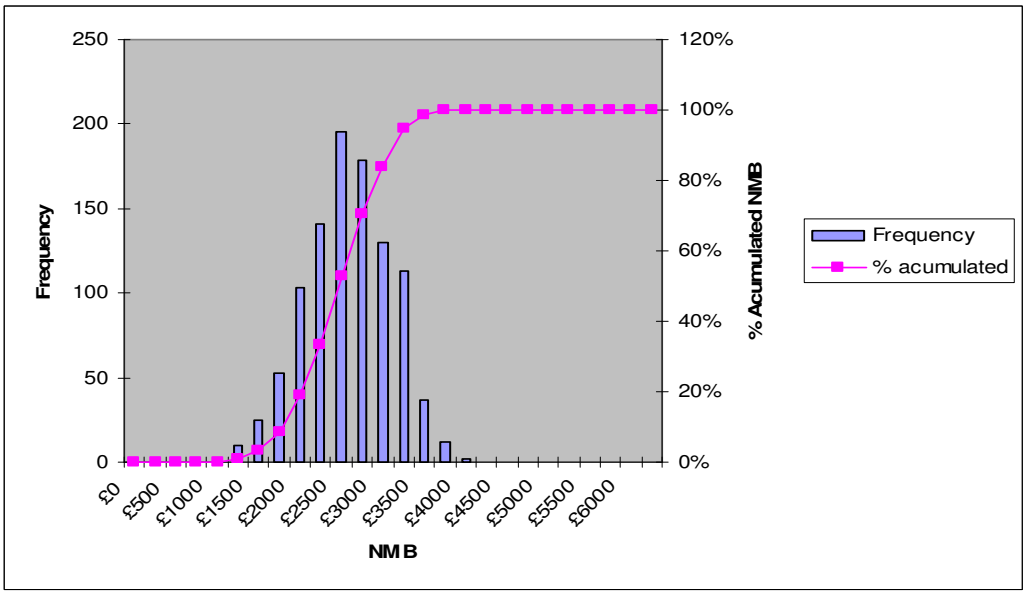
Cost-effectiveness acceptability curves (CEAC) were calculated for M4 – excluding external effects – and M5 – including them (see Appendix 5.14 for details). However, as NPPCBP is so cost-effective and the dominant strategy, these CEACs did not tell us much information, so the decision was made to present histograms showing the NMB for the most cost-effective intervention instead. Graph 5.5 presents a histogram of the distribution of predicted NMB results. The median (IQ range) NMB was estimated at around £1250 per QALY. Overall, 90% of the NMB estimates have a point estimate below £2000.

Graph 5.5 Distribution of predicted NMB for NPPCBP at M4



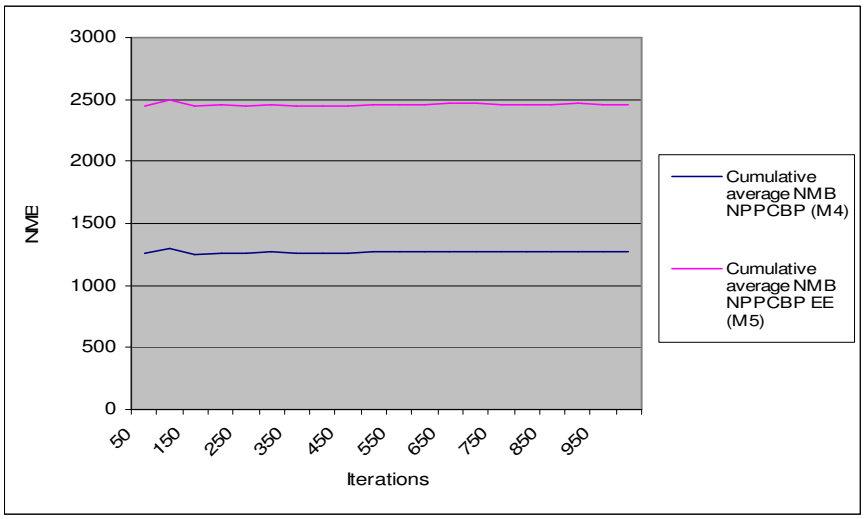
However, when the impact of passive smoking on adults and children is incorporated into the economic evaluation (see Graph 5.6), the median (IQ range) NMB increases to approximately £2500. 90% of the estimates were estimated to have a point estimate of NMB below £3250. Thus, the NMB rises when external effects are included.

Graph 5.6 Distribution of predicted NMB for NPPCBP EE at M5



Graph 5.7 shows that, as far as the most cost-effective intervention was concerned, around 250 iterations were required to achieve stable results from the model when external effects were excluded. When external effects were included, results became stable after about same iterations. The results in both scenarios may therefore be considered robust.

Graph 5.7 Cumulative average NMB for LICB and NPPCBP in M4 and M5



5.4 Discussion

This chapter incorporates passive smoking into the economic evaluation of smoking cessation interventions. Attempts in previous studies have been made to value passive smoking, but none of this work has so far been incorporated into economic evaluation modelling (Sloan et al., 2004). The findings of this chapter, apart from the methods to incorporate of external effects, are of value - assessing whether the incorporation of external effects into cost-effectiveness of interventions might change policy decisions. This chapter also provides insights into the uncertainty which surrounds the parameters driving the model, and the difficulty of estimating the impact of passive smoking on society.

The systematic literature reviews show that passive smoking can be measured in adults by the occurrence of episodes of lung cancer and coronary heart disease, and in children

by episodes of asthma, wheeze, cough, otitis media with effusion, and acute otitis media. Other health effects caused by passive smoking which are cited in the literature, such as increased risk among children of pulmonary tuberculosis, are not yet supported by epidemiological evidence.

In terms of results, the changes made to the model (see Chapter 4, Section 3) mean a straightforward comparison with Flack's results (2007) is not possible. However, notwithstanding these changes, the results do accord with those of Flack et al.: the intervention composed of nicotine patch, pharmacist consultation and comprehensive behavioural programme (NPPCBP) is the most cost-effective smoking cessation intervention. Other barriers to direct comparison are the change in result unit from total lifetime QALYs to total QALYs lost; and the change in population (the addition of 96.5% of adult smokers' children to account for child passive smokers in the model). When the economic evaluations of the chosen public smoking interventions were compared, the inclusion or otherwise of external effects made no difference to the cost-effectiveness rankings. This was to be expected, since the incorporation of external effects introduces a multiplicative effect on costs and QALYs. Although a difference exists in terms of the magnitude of the ICER, the incremental cost-effectiveness ratios generated by smoking cessation interventions are typically well below the sort of thresholds used by NICE for technology appraisals. It is thus almost axiomatic that all the interventions people consider are cost-effective.

Adult passive smokers are responsible for an extra lifetime cost of £20.19 per adult and 0.0004 extra lifetime QALYs lost in the model, whereas adult and child passive smokers combined are responsible for an extra lifetime cost of £154.08 and 0.0999 extra lifetime QALYs lost per adult. In other words, the biggest impact into economic evaluation, in terms of costs and QALYs lost, relies on children passive smoking.

Univariate and probabilistic sensitivity analyses were conducted to study the robustness of the results. The areas of uncertainty in this assessment were background cessation rates and the cost of interventions; for consistency`s sake, these were examined according to Flack's (2007a) criteria. No differences were noted when the uncertainty around these parameters was studied. Other uncertainties noted in relation to the model presented in this chapter were: intervention quit rate; relative risk of different illnesses for passive smokers; incidence of smoking; and cost and utilities of illness episodes. Although uncertainty was present, the probabilistic sensitivity analysis strongly

supports the results derived from the base model, although the level of uncertainty appears to be wider, the more cost-effective the intervention. This seems to be coherent, because the probabilistic analysis is based on the standard deviations calculated from a 10% of the effectiveness rate. It appears that the more effective the intervention, the higher the effectiveness rate and the higher the standard deviation, leading to higher variability in the model. When external effects are incorporated, costs and health effects shift down and to the right on the graph as additional costs and QALYs lost are incurred. Therefore there is a movement in costs and QALYs lost across the graph. The size of these differences could be due to the uncertainty surrounding the incidence rate. This is an important parameter as it significantly influences the number of smokers in the model. Additional checks were conducted on the variability of this parameter, and results were highly sensible to its variability. Cost-effectiveness acceptability curves show that when external effects are incorporated into the economic evaluation, the least cost-effective interventions become even less so, while the most cost-effective programmes seem to become more cost-effective. In smoking cessation programmes does not change policy making decision, but in other scenarios, with less cost-effective programmes, this could potentially change all policy decisions taken so far.

Regarding the data on prevalence used in the model, self reported measures of second-hand exposure have several important limitations – i.e living with a smoker captures less than half of the variation in nicotine concentration in never-smokers (Breteler et al., 1994) and does not take into account exposure in workplaces and public places (Llewellyn et al., 2009).

One of the most relevant parameters of this model, as discussed, is the incidence or uptake rate of smoking. This parameter was a proxy, constructed from data drawn from the General Household Survey (2006). The most important assumption made was that this database was based on a consistent population and that across the years the smoking uptake rates have not varied. In the survey, people were asked at what age they started smoking. The problem, however, is that uptake rates and patterns are likely to have changed since NHS smoking cessation interventions began. Moreover, the population itself may have changed over time: the number of missing observations may have gone up or down, and the starting age for smoking may have altered. It was intended to track individuals across time, but no data was available for doing so. Household identification

codes were different for each survey wave. The validity and generalisability of the quitting and relapse rate in the model are also a limitation.

Changes in effectiveness rates could be discussed in terms of the different nature of the trials, related to the different structure of the randomised controlled trials or on the design of the trial, in calculating varying effectiveness for each different intervention. But this is outside the scope of this thesis.

Indirect benefits to the family members of successful quitters, especially children, are widely accepted as probable outcomes of individuals quitting. However, these potential benefits are somewhat difficult to quantify (Wang et al., 2008). Similarly, potential benefits for society in general through avoidance of passive smoking and unwelcome exposure to cigarette smoke may also accrue (Wang et al., 2008), but this is out of the scope of this thesis.

An additional question to better explore uncertainty would be whether further evidence is required to support decision-making about smoking interventions in the future. Decisions based on existing information will be uncertain, and there will always be a chance of making the "wrong" decision (Briggs et al., 2006). Although we may make the correct decision now based on our current estimate of expected net-benefit, there is a chance that another alternative might have higher net-benefit once our current uncertainties are resolved (Briggs et al., 2006). If a decision based on current information turns out to be "wrong", there will be costs in terms of health benefits and resources forgone (Briggs et al., 2006). Although this is beyond the scope of this thesis, further research into the Value of Information would be useful; such analysis might make it possible to calculate the maximum that the health care system should be willing to pay for additional evidence to inform decisions about smoking interventions in the future, and it would place an upper bound on the value of conducting further research. However, my figures suggest that the Value of Information (VOI) may in practice be low; uncertainty does not significantly alter policy as most smoking cessation programmes are recognised as generally cost-effective.

One important limitation of this analysis is that current smokers and former smokers who also consider themselves to be passive smokers are not considered. On the other hand, this avoids the misclassification of current smokers as non-smokers; only those who have never smoked are classified as passive smokers. This avoids any confusion

between active and passive smoking. Further research could explore the impact of incorporating into the model all those people who consider themselves passive smokers. The study only counts those children exposed to ETS at home as passive smokers. This seems to be an appropriate assumption in current times, given that it has been forbidden to smoke in public places since July 1st 2007, and the home is the site where young children are most exposed to ETS (Brown, 2001). However, as the data source is the HSE of 2006, the burden of passive smokers may have been underestimated.

The next chapter incorporates into the model the effects on babies of smoking during pregnancy. It will illustrate the importance of including a second external effect in the economic evaluation of smoking cessation programmes.

CHAPTER 6 Economic Evaluation of Smoking Cessation Interventions: accounting for smoking during pregnancy

6.1 Introduction

Chapter 5 evaluated the introduction of passive smoking into an economic evaluation of smoking cessation interventions. The aim of this chapter is to incorporate the impact of smoking during pregnancy on babies' first year of life. The specific objectives are: (a) by means of a systematic literature review, to identify the main health effects in babies' first year of life caused by mothers smoking during pregnancy; (b) by means of a systematic literature review, to explore the prevalence, costs, and utilities for babies' first year of life; (c) to explore the incidence, mortality, prevalence and sources of effectiveness used in this particular model; (d) to take an existing economic evaluation tool, designed to assess the cost effectiveness of interventions for reducing smoking during pregnancy, and adapt it to calculate the average extra lifetime costs and QALYs lost in babies' first year of life as a result of smoking during pregnancy; (e) to present and discuss the results produced by the model; and (f) to demonstrate the differences in lifetime costs and QALYs lost when this external effect is incorporated, considering the reasons for these differences.

6.2 Methods

This section discusses: (a) how the two literature reviews on health effects and prevalence, costs and utilities were conducted, including the search strategy, selection criteria, and data extraction strategy; (b) the parameters used in the model; and (c) how the structure of the existing economic evaluation tool (assessing smoking cessation programmes for pregnant women) was adapted to incorporate the health effects of smoking during pregnancy.

6.2.1 Model parameters

In order to run the model a number of key input parameters were required: incidence; mortality; quit and relapse rates; prevalence of different smoking states; effectiveness; and prevalence, costs and QALYs associated with passive smoking. These relate primarily to the transition probabilities, and the costs and utilities required to calculate the model cost-utility outputs. Some of the model states (smokers, former smokers, non-passive never-smokers and passive smokers) have an associated utility and cost, and some of the model transitions have a cost. Transition probabilities were assigned to each of the transitions (indicated by the arrows in Figure 6.1). The data values for these parameters were obtained from a variety of sources which are described in the following sections.

Systematic reviews investigating health effects due to smoking during pregnancy

The aim of these systematic literature reviews was to ascertain from the perspective of the UK NHS which health effects experienced by pregnant women and babies in their first year are most likely to be associated with smoking during pregnancy. This question was addressed by systematically identifying those papers which describe the health effects on pregnant women and babies in their first year associated with smoking during pregnancy, assessing the quality of these papers and reviewing and summarising the relevant evidence. Two discrete reviews were undertaken; one focused on health effects on babies in their first year, and the other focused on health effects on women.

The first literature review formed part of the systematic literature review which investigated the health effects of passive smoking on children (see *Clinical implications of passive smoking for children,* Section 5.2.1; Chapter 5). The literature review indicated that, according to existing evidence, the only health effects of smoking during pregnancy on babies' first year of life are low birth weight and sudden infant death (see Table 6.1 below for findings). For the odds ratio of low birth weight, the lowest differential effect (i.e. estimate with lower confident interval) was adopted, introducing in the model the estimate with lower uncertainty.

Table 6.1 Summary of characteristics, data and odds ratios presented in included studies investigating health effects for babies in their first year of life associated with smoking during pregnancy

Author, year	Health effect	N studies	Type of data[45]	Estimated value	Adjusted estimate	95% CI
Studies identified						
Leonardi-Bee et al. 2008	Low birth weight	26	OR[46] OR[47]	1.32 1.22	not stated	1.07 to 1.63 1.08 to 1.37
Cook and Strachan 1999[48]	Sudden infant death	18	OR	2.13	adjusted	1.86 to 2.43
Parameter value used in model						
Leonardi-Bee et al. 2008	Low birth weight	26	OR[49]	1.22	not stated	1.08 to 1.37
Cook and Strachan 1999[50]	Sudden infant death	18	OR	2.13	adjusted	1.86 to 2.43

OR: odds ratio of health effect associated with exposure to environmental tobacco smoke due to maternal smoking during pregnancy compared to having non-smoking mother.

The second literature review, exploring the clinical implications of smoking during pregnancy for women, yielded 4051 "hits". Details of this systematic literature review are shown in Appendices 6.1 and 6.2. Two studies were excluded for reasons of duplication. After a detailed review of titles and abstracts, only one paper met the inclusion criteria (US Department of Health, 2004).

The aim of this report, from the Surgeon General's Advisory Committee on Smoking and Health in the USA, was to evaluate all available scientific evidence to determine whether smoking causes disease. The report identified all the relevant data, evaluated and summarised the evidence and applied the criteria for causal inference to determine whether the weight of the evidence supported a definitive conclusion. Chapter 5 of the report reviews the evidence for a relationship between smoking and adverse reproductive effects. In particular, it examines the associations between smoking and fertility, smoking and pregnancy complications, and the health of children born to smokers. The 1978 Surgeon General's report (US Department of Health and Human Services, 1978) introduced new findings concerning smoking and pregnancy complications including placental abruption, placenta praevia, and the premature

[45] RR: relative risk (defined as the ratio of the chance of a disease developing among members of a population exposed to a factor compared with a similar population not exposed to the factor (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>); OR: odds ratio (this ratio estimates the chances of a particular event occurring in one population in relation to its rate of occurrence in another population (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>).
[46] Maternal exposure to ETS during pregnancy (birth weight <2500g; prospective studies).
[47] Maternal exposure to ETS during pregnancy (birth weight <2500g; retrospective studies).
[48] The ORs reported in this paper are calculated on the assumption that either parent smokes at home, except in the case of sudden infant death, when only the mother`s smoking is considered.
[49] Maternal exposure to ETS during pregnancy (birth weight <2500g; retrospective studies).
[50] The ORs reported in this paper are calculated on the assumption that either parent smokes at home, except in the case of sudden infant death, when only the mother`s smoking is considered.

rupture of membranes. The 1980 report on the health consequences of smoking for women (US Department of Health and Human Services, 1980) went further in its assertion of the effects of smoking on the placenta. This report also introduced new information on smoking risks. It found the evidence to be suggestive but not sufficient to infer a causal relationship between maternal active smoking and ectopic pregnancy. However, for placenta praevia[51], placental abruption[52] and pre-eclampsia[53] it found there was sufficient evidence to infer a causal relationship (see Table 6.2). Flack et al. (2007a) did additional analysis to investigate the impact of smoking cessation interventions on pregnant women in terms of the costs and QALY implications, using the economic model in Flack et al. (2007). In their report (2007a), they identified the same clinical implications for women of smoking during pregnancy, apart from ectopic pregnancy.

Table 6.2 Summary of risk data for pregnant women who smoke

Author (year)	Health effect	N studies	Type of data[54]	Estimated value	Adjusted estimate	95% CI
Studies identified						
US Department of Health (2004)	Placenta praevia	-	OR	2.3	-	1.3 to 4.4
US Department of Health (2004)	Placenta abruption	-	OR		-	1.4 to 2.4
US Department of Health (2004)	Pre-eclampsia	-	OR		-	0.45 to 0.71
Parameter value used in model						
-	-	-	-	-	-	-

Placenta praevia has been consistently found to occur more frequently in smokers than in non-smokers, with one report estimating an odds ratio value of around 2.3. Only a pooled estimate value was encountered for placenta praevia. The other health effects were reported by means of adjusted odds ratios. Although this made it possible to calculate a mid-point estimate which would have enabled these health effects to be

[51] Placenta praevia occurs when the maturing placenta is close to the cervical os or completely obstructs the os (US Department of Health, 2004).

[52] Placental abruption occurs when the normally implanted placenta prematurely separates from the wall of the uterus. It is associated with high rates of preterm deliveries, stillbirths, and early infant deaths.

[53] Pre-eclampsia is a hypertensive disorder developed during pregnancy with proteinuria and edema.

[54] RR: relative risk (defined as the ratio of the chance of a disease developing among members of a population exposed to a factor compared with a similar population not exposed to the factor (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>); OR: odds ratio (this ratio estimates the chances of a particular event occurring in one population in relation to its rate of occurrence in another population (medical dictionary, 2011 <http://medical-dictionary.thefreedictionary.com>).

incorporated into the model, they were ultimately excluded because of the lack of data on the costs and utilities of these health effects on women.

Systematic review investigating prevalence, costs and utilities of health effects associated with passive smoking on infants in their first year of life

In order to incorporate the external effect smoking during pregnancy into the model, prevalence, cost and utility data were required. Each disease associated with women and first year babies (i.e. ectopic pregnancy, low birth weight, etc.) has an associated utility, cost and prevalence. The prevalence data was adjusted according to the procedure detailed in Sections 4.1.4.1 and 4.1.4.2, in chapter 4, of this thesis.

A number of criteria were applied where potentially useful data was identified in multiple sources. First, consistent with the previous systematic literature reviews, meta-analyses or pooled estimates for health effects and mortality data associated with passive smoking were given preference. Meta-analysis carried out in the UK setting was prioritised over other settings as this is the context of the current analysis. Second, priority was given to estimates used in HTA or NICE reports, as these inform NICE policy making. Third, estimates from credible sources such as national statistics institutions were preferred, followed by estimates calculated for the UK setting. However, for data on the costs associated with low birth weight, the most important consideration was to find estimates which were appropriate to child weight. Mrs Hema Mistry, author of one of the papers on the costs associated with low birth weight first year babies, suggested that it was appropriate to look for cost estimates from the European context[55] for first year babies weighing between 2250 and 2500 grams. Anything below this is now considered extremely low weight, and cost estimates in this bracket are generally less realistic than those calculated for average cases of low birth weight. Finally, preference was given to the most conservative estimate.

The search strategy for prevalence studies yielded 300 citations. Following a review of the titles and abstracts, 281 potentially met the review's inclusion criteria. Of these, 21 reported data of interest (see Appendices 6.3, 6.4 and 6.5 for more details on the study selection process and included references). The findings are summarised below.

[55] All US estimates are in a very different context.

Prevalence

Six studies out of 21 reported data on the prevalence of illnesses related to smoking during pregnancy (see Table 6.3).

Table 6.3 Summary of characteristics and data related to *prevalence* of health effects caused by smoking during pregnancy on the health of women and infants in their first year

Author, year	Health effect	Sample	Country	Estimated annual prevalence[56]	95% CI
Studies identified					
Petrou (2003)	LBW (<2500grams)	-	UK	7.28%	-
Walker (2000)	Pre-eclampsia	-	UK	40%[57]	-
Meads et al. (2008)	Pre-eclampsia	-	-	4.7%[58]	4.3-5.3
Simon et al. (2005)	Pre-eclampsia	-	-	2-8%	-
Dattani and Cooper (2000)	SIDS	-	UK	3.7%	-
Messer (2009)	SIDS (under one year after live birth)	-	UK	2.8%[59]	-
Parameter value used in the model					
Petrou (2003)	LBW (<2500grams)	-	UK	7.28%	-
Messer (2009)	SIDS (under one year after live birth)	-	UK	2.8%	-

No data was found on placenta praevia or placental abruption. There was only one estimate for prevalence of low birth weight. For SIDS, the estimate of 2.8% was selected because, in accordance with the selection criteria, it was the most conservative estimate. Also in line with the selection criteria, the estimate chosen for prevalence of pre-eclampsia was the one from the UK (Walker, 2000).

[56] Estimated annual prevalence of liveborn babies
[57] This estimate is reported by the author referencing one study from 1982.
[58] Considering medium risk women.
[59] In terms of infants deaths, the estimate includes both neonatal and post-neonatal deaths.

Costs

Fifteen studies out of 21 reported data on the costs of treatment of illnesses related to smoking during pregnancy. Table 6.4 shows details of this data.

Table 6.4 Summary of characteristics and data related to *costs* of treatment of pregnant women and first year babies

Author, year	Health effect	Sample	Country	Annual cost	95% CI	Currency/ year
Studies identified						
Boyle et al. (1983)	LBW (500-999 grams) (1000-1499 grams)	265 98	Canada	13600 14200	-	Canadian $/1978
Gorsky and Colby (1984)	LBW (1500-2499grams)	-	US	19671[60]	-	$/1984
Herdman et al. (1987)	LBW (<2500grams)	-	US	31000-71000	-	$/1987[61]
Lewit et al. (1995)	LBW (1000-2500grams)	-	US	11900	-	$/1988
McCormick et al. (1991)	LBW (< 1500 grams)	32	US	10139	-	$/1984
Mistry et al. (2009)	LBW (1000-1499grams) (<1000grams)	199	UK	18817 26815[62]	-	£/2004-2005
Orme et al. (2000)	LBW	-	UK	14790.52[63]	-	£/1999
Petrou (2003)	LBW (<1500 grams) (1000-1499 grams) (<1000 grams)	- - -	UK	9207 22541 39483	4295-14119 14780-30302 30466-48500	£/1998
Ringborg et al. (2006)	LBW (2250-2499 grams) (2000-2249 grams) (1750-1999 grams) (1500-1749 grams) (1250-1499 grams) (1000-1249 grams) (750-999 grams) (500-749 grams) (<500 grams)	1529 1247 790 577 459 338 303 140 13	Sweden	12900 14463 17330 21501 25838 38190 58959 74264 77677	- - - - - - - - -	€/2000
Rogowski (1998)	LBW		US		-	$/1987

[60] This cost comprised: initial hospitalisation costs, rehospitalisation costs and long-term morbidity costs.
[61] Publication year
[62] Both costs are calculated for Level 3 care, including ambulance transfers. Excluding ambulance transfers, the cost would be £12325 for first year babies 1000-1400grams, and £19558 for first year babies <1000grams.
[63] Total cost of treating smoking-related disease in the first year (health care cost).

Author, year	Health effect	Sample	Country	Annual cost	95% CI	Currency/ year
	(<1000 grams) (1000-1249 grams) (1250-1499 grams)	887		58900 55800 44100		
Russell et al. (2007a)	LBW	384200	US	15100[64]	13300-16800	$/2001
Schmitt et al. (2006)	LBW (2000-2499 grams) (1750-1999 grams) (1500-1749 grams) (1250-1499 grams) (1000-1249 grams) (750-999 grams) (500-749 grams) (<500 grams)	 16806 3117 1974 1352 1050 913 667 107	US	 8987 27545 44992 69799 118816 193833 220802 127785	 - - - - - - - -	$/2000
Walker et al. (1985)	LBW (<1500 grams)	273	Rhode Island	4092	-	$/1982
Wu et al. (2006)	placental abruption	-	-	659.24	-	£/2002
Meads et al. (2008)	pre-eclampsia	-	-	9009	-	£/2005[65]
Wu et al. (2006)	pre-eclampsia[66]	-	-	2211	-	£/2002
Parameter value used in the model						
Ringborg et al. (2006)	LBW (2250-2499 grams)	1529	Sweden	12900	-	€/2000

There were a number of estimates for LBW, most of them using different weights as benchmarks. Low birth weight is defined by the World Health Organisation as anything less than 2500 grams (NHS, 2008). As specified in the selection criteria discussed earlier, first year babies weighing less than 2250 grams are now generally considered severely low weight. As cost estimates calculated for children between 2250 grams and 2500 grams are more reliable than those for babies at the extreme low end of the weight scale, the decision was made to adopt the estimate given by Ringborg et al. (2006). No estimates for placenta praevia were found. Only one estimate for placental abruption was found, which was the one used. The most conservative estimate for pre-eclampsia was used, according to the selection criteria established. The annual cost assigned to SIDS was assumed to be zero, as the cost of an infant death to the NHS is very low.

[64] Preterm infant hospitalisation costs.
[65] This cost from Simon et al. (2006) was converted from US$ 2001 to UK£ inflated to 2004-5 costs.
[66] This cost includes all costs related to management of severe pre-eclampsia (inpatient stay, consultant visits, drugs, etc). The estimate for management costs for mild pre-eclampsia is taken as the lower limit for the confident interval.

This assumption is consistent with no NHS costs assumed for any death occurring in the Markov model due to smoking habits.

Utility

Of the 21 studies, three reported data on utilities (see Table 6.5 for details). In accordance with the selection criteria, the most conservative estimate for low birth weight was used (Moya and Goldberg, 2002). Table 6.5 shows that no estimates exist for health effects on pregnant smokers (i.e. placenta praevia, placental abruption and pre-eclampsia). Flack et al. (2007a) also found this. A value of full life (utility equal to one) was used when SIDS occurred, to calculate QALYs lost.

Table 6.5 Summary of characteristics and data relating to *utilities* of health effects on pregnant women and babies in their first year of life

Author, year	Health effect	Sample	Estimated value	95% CI	Instrument
Studies identified					
Tengs and Wallace (2000)	LWB	-	0.75	-	-
Petrou et al. 2009	LBW	190	0.789		Health Utilities Index Mark III
Moya and Goldberg (2002)	LBW (<1500grams)	-	0.85	-	Expert judgement
Parameter value used in the model					
Moya and Goldberg (2002)	LBW (<1500grams)	-	0.85	-	Expert judgement

In summary, the model could not ultimately include any health effect on pregnant women, given the lack of data on prevalence, costs or utilities. Only the external effects of maternal smoking on babies' first year of life were measured and included. The life expectancy of an infant under one year, 71.99 years, was used to estimate the lost lifetime from deaths of babies during the first year of life from smokers during pregnancy (ONS, 2010). This lost lifetime was discounted according to the six-month cycle used in the model.

Uptake of smoking (incidence)

Data on the incidence of smoking was assumed to be the same as that reported and calculated in M4 and M5 for women aged 16 to 44.5 years (see Section 5.2.1 in Chapter 5 for details).

Mortality

Mortality was handled as reported in Section 5.2.1 in Chapter 5 for women from 16 to 44.5 years.

Prevalence

At the start of the model, for each of the four smoking categories, the age and gender-specific prevalence of smoking status was applied to mirror the known prevalence of these states in the English population. The prevalence rates for smoking pregnant women were taken from the Health Survey for England (2006), as described in Chapter 5. From the survey it was possible directly to obtain data describing pregnant women by age group and smoking status.

Those whose cigarette smoking status was "never smoked cigarettes at all" were classed as non-smokers, whereas those who said they "used to smoke cigarettes occasionally" or "used to smoke cigarettes regularly" were classified as former smokers. 11.21% (n=2) of answers in the HSE were missing and therefore not considered.

The prevalence data on pregnant smokers used in the model is reported in Table 6.6, which shows that pregnant women under 24 years had the highest prevalence smoking rate. More detailed data from the HSE 2006 is available at Appendix 6.6.

Table 6.6 Prevalence of smoking status among pregnant women (aged 16 to 44.5 years)

Age	Current smoker (S)	Former (F)	Non-passivenon-never smokers (NPNS)	Passive never-smokers (PNS)
16-24	0.37	0.16	0.41	0.06
25-34	0.10	0.31	0.55	0.04
35-44	0.11	0.21	0.65	0.04

To calculate the average number of babies delivered per pregnancy in the UK setting, the Office for National Statistics, the Northern Ireland Statistics and Research Agency, and the National Services Scotland were consulted to obtain separate data for England, Ireland and Scotland, before calculating a total average for the UK. The most recent data was from 2007, and it was assumed to have remained unchanged in 2010. The results from this data are shown in Appendix 6.7.

Sources of effectiveness: quit and relapse rates

Table 6.7 shows differences in sources of effectiveness between models M1 to M5 and M6 and M7, the models introduced in this chapter.

Table 6.7 Summary of differences between M1-M5 and M6-M7

Models	Parameters related to effectiveness		
	Background quit rate	**Relapse rate**	**Interventions**
M1-M5	2%	21%	General population interventions
M6-M7	Overall weighted mean background quit rate (first two cycles) and 2% (rest of cycles)	70%	Specific interventions for pregnant women

Each estimate for the quit rate of a particular intervention was calculated and compared to the particular background cessation rate in the trial where the intervention was taking place. Calculation of an overall weighted mean relapse rate was carried out using the methods developed by Bland and Kerry (1998). Initially, the background cessation rate

calculated for each individual trial was used, but after the intervention had occurred, the general background cessation rate of 2% was applied. In the first cycle, the last six months of the pregnancy, the during-pregnancy quitting rates were used, whereas in the second cycle, cessation rates immediately after pregnancy were considered. This data was adapted from Flack et al. (2007a), who did a specific literature review to obtain it. No relapse was assumed where there was no intervention – the background quit rate was applied here – while between months six and twelve it was assumed that all interventions had a 70% relapse rate. According to Flack et al. (2007a), their communication with Peter Hajek suggested that 70% of pregnant women who stop smoking will relapse within a year. A review of the NHS database was conducted to corroborate this estimate, and the findings indicate that the relapse rates range from 70% to 85% among women who smoke but quit at some time during their pregnancy (Fang et al., 2004). Thus, the 70% used in the model is a conservative estimate. After 12 months everything reverted back to background cessation rates.

Public health interventions to stop smoking among pregnant women differ from general population smoking cessation programmes. The interventions modelled for pregnant women were: midwife brief advice (MBA); computer counselling (CC); health education methods (HEM); proactive calls worst case (PCW); proactive calls best case (PCB); nicotine replacement therapy (NRT); peer counselling (PC); proactive calls, educational booklet, counselling and education interventions concerning nicotine fading, relaxation and social support at delivery (BD); and proactive calls, educational booklet, counselling and education interventions concerning nicotine fading, relaxation and social support two weeks after delivery (BAD). See Table 6.8 for further details. These interventions, which particularly focus on reducing smoking among pregnant women, are different from those evaluated so far in M2, M3, M4 and M5, which focus on the adult general population (see Section 4.1.6, Chapter 4).

Table 6.8 Background and intervention pregnancy and post-pregnancy quit rates

Intervention	Cessation rate during pregnancy		Cessation rate immediately after pregnancy		Source
	Background rate	Intervention rate	Background rate	Intervention rate	
Studies identified and parameter values used in model					
MBA	11.40%	11.60%	11.40%	11.60%	Hajek et al. (2001)
CC	1.70%	5.70%	3.50%	8.10%	Lawrence et al. (2003)
HEM	2.00%	16.00%	6.00%	13.00%	Walsh et al. (1997)
PCW	14.90%	18.20%	14.90%	18.20%	Solomon et al. (2000)
PCB	14.90%	18.20%	14.90%	18.20%	Solomon et al. (2000)
NRT	25.00%	28.00%	18.00%	21.00%	Kapur et al. (2001) and Wisborg et al. (2000)
PC	21.00%	24.00%	21.00%	24.00%	Malchodi et al. (2003)
BD	90.00%	61.00%	90.00%	61.00%	Buchanan 2002
BAD	80.00%	52.00%	80.00%	52.00%	Buchanan 2002

Note: There was no need to temporarily adjust these cessation rates because they occurred during the pregnancy, that is, in a 6 month cycle.

6.2.2 Economic model

The aim of this analysis was to determine, using a Markov decision model, the relative cost-utility of different smoking cessation interventions identified by the NICE report (Flack et al., 2007a) on the health effects of smoking during pregnancy. The population examined here is a cohort of 1000 pregnant women, who were classified according to their smoking status. The impact of maternal smoking during pregnancy on first year babies was measured, as were the health effects of smoking on pregnant women. Therefore, when the external effect was incorporated in the model the population of the model increased in average number of babies per delivery per smoker.

A Markov (state transition) model was developed in Microsoft EXCEL (Microsoft Corporation). The structure of the model was adapted from that of the model detailed in Chapter 5 of this thesis, and informed by current research literature and expert opinion. Apart from the population, which differs from that used in M1-M5, the models used in this chapter (M6 and M7) also differ from M3 in the addition of two new health states to the model structure: like M4 and M5, the models in this chapter also include non-passive never-smokers and passive smokers (M3 only considered smokers, former smokers and death health states). The difference between M6 and M7 lies in the incorporation of external effects. M6 does not incorporate smoking during pregnancy, whereas M7 does. See Table 6.9 for details.

Table 6.9 Summary of differences between M3, M6 and M7

Models	Starting population in Markov model					Incorporation of health effects of smoking during pregnancy on women and babies' first year of life
	Pregnant smokers	Pregnant former smokers	Pregnant non-passive never-smokers	Pregnant passive never-smokers	Death	
M3	x	x	x	x	√	x
M6	√	√	√	√	√	x
M7	√	√	√	√	√	√

√≡ included in the model
x≡ not included in the model

To value the impact of smoking during pregnancy on babies' first year of life, the number of babies' first year of life depended on the number of pregnant smokers by age from the Markov model. The analysis adopted the same perspective and cycle length as M4 and M5 (see Section 5.2.2 in Chapter 5 for details).

The model estimates[67]: (a) the impact on average lifetime costs due to smoking during pregnancy (£ 2010); and (b) quality-adjusted life-years (QALYs) lost to pregnant women and first year babies due to smoking during pregnancy. The estimates were finally adjusted according to the distribution of probability of being pregnant according to age (ONS, 2009). As stated earlier (see Section 6.2.1), the effectiveness outputs again differ from those calculated and obtained in M2 and M3 (see Section 5.2.2, Chapter 5 for discussion of how they differ in M4 to M11).

Model structure

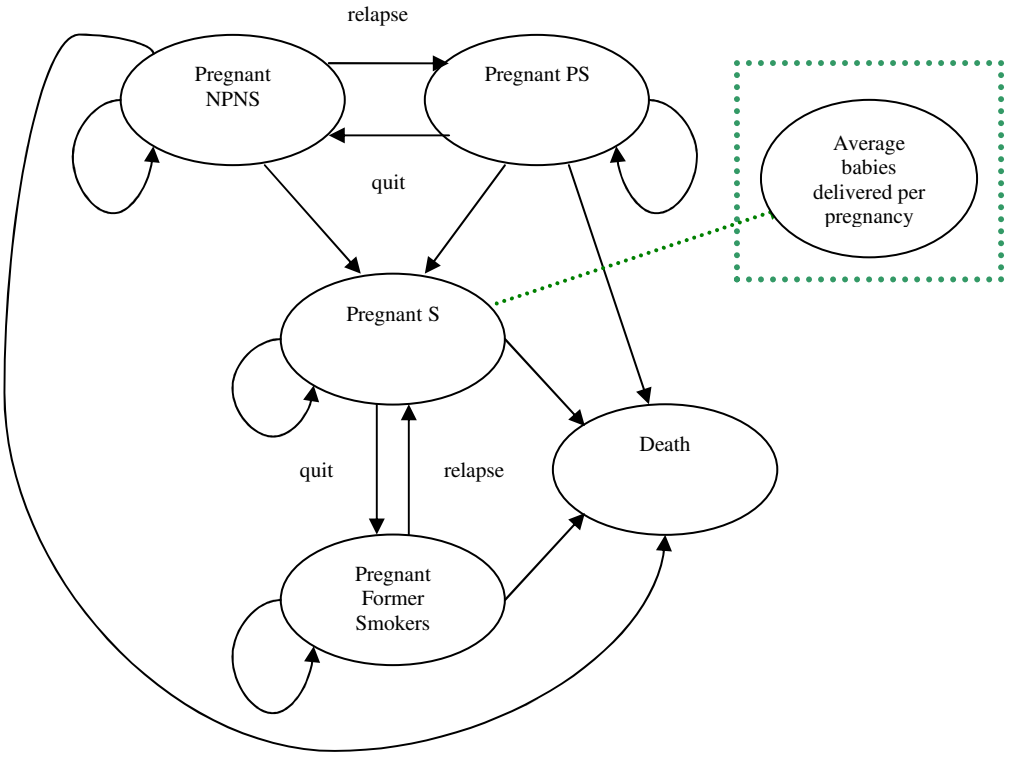
Within the Markov state transition model, pregnant women reside in one of five discrete health states. At regular time intervals (the model cycle) pregnant women make at most one transition between states. During each cycle, all pregnant women must be in one of the health states in the model. The probabilities attached to each transition between model cycles are based on the data used in Flack et al's (2007a) report and, where new

[67] To facilitate presentation and interpretation, only the results for the least and most cost-effective smoking cessation programmes are presented.

data was needed (i.e. costs or utilities of health effects of smoking during pregnancy on women and first year babies), systematic literature reviews were carried out.

A structure diagram of the model is shown in Figure 6.1.

Figure 6.1 Structure diagram of smoking cessation interventions aimed at pregnant women aged 16 to 44.5



Passive smoking and non-passive never-smoking pregnant women[68] were included in the model, along with pregnant smokers, pregnant former smokers and the death state. This was done in order to introduce the health effects of smoking during pregnancy into the model. Women entered the model in their third month of pregnancy. In the first cycle of the model, women were pregnant; when they started the second cycle they were post-partum. From the second cycle onwards, women were deemed to have exited pregnancy and they were treated as female adults (see M4 and M5). The health effects on babies in their first year of life are a function of the pregnant smokers' cohort.

[68] The starting distribution of the cohort of pregnant women was calculated using prevalence data. The model covers pregnant smokers, pregnant former smokers, pregnant passive smokers and pregnant non-exposed non- smokers in order to maintain the same structure as previous models (M4 and M5).

Although Flack et al. (2007a) argued that the impact on babies of smoking during pregnancy should be studied over the first five years of life[69], no evidence could be found regarding the costs and utilities associated with low birth weight and SIDS for such a period. For this reason, only the utility and of life-years lost from SIDS occurring in the first year were taken into account.

6.2.3 Time horizon

The time horizon of the model comprised a cohort of pregnant women aged from 16 to 44.5 years followed for the lifetime period.

6.2.4 Discount rate

Both costs and benefits (QALYS) in the model have been discounted at the same annual rate as in M2, M3, M4 and M5.

6.2.5 Cost-effectiveness ratios and net monetary benefit

The same methodology as was used in M4 and M5 was applied to calculate ICERs and NMB for each intervention (see Section 5.2.5 of Chapter 5 for details). NMB was calculated considering a threshold of £20,000.

6.2.6 Uncertainty

Parameter uncertainty in this cost-effectiveness model was addressed by conducting univariate and probabilistic sensitivity analysis, as in M4 and M5 (see Section 5.2.6 in Chapter 5). The variables selected for univariate analysis (background cessation rate, cost of interventions and relapse rate) were the same as in Chapter 5 (see Section 5.2.6). However, for the probabilistic sensitivity analysis, only the relative risk of getting a particular disease due to smoking during pregnancy, the utility values and costs

[69] Mrs Lesley Owen, NICE smoking specialist, recommended the inclusion of the impact on babies' first five years of life.

remained constant; the incidence rates for starting smoking during pregnancy and the effectiveness of smoking cessation programmes among pregnant smokers were parameters specific to this model. The differences in effects and costs arising from the inclusion in the model of health effects on babies` first year of life were derived using Montecarlo simulations (n=1000). A cumulative average of NMB iterations was presented to study the number of iterations needed to reach stability on the NMB threshold.

6.2.6.1 Choosing distributions for the parameters

The same distributions were chosen for parameters as were used in M4 and M5 (see Appendix 6.8 for details), and the same number of replications was performed (n=1000).

6.2.6.2 Cost-effectiveness acceptability curves

As reported for M4 and M5, cost-effectiveness acceptability curves were deployed for the least and most cost-effective interventions (see Section 5.2.6.2). Cost-effectiveness acceptability curves (CEACs) were derived from the joint distribution of incremental costs and incremental effects resulting from comparing each intervention with the base case, as in M4 and M5. CEACs were constructed by recording the number of times each alternative generated the highest Net Benefit in the simulations run using M6 and M7 (Claxton, 2008). Histograms of net monetary benefit results are presented to study the heterogeneity in the NMB predicted estimates.

6.3 Results

The impact of smoking during pregnancy on first year babies will be presented in terms of average lifetime costs and average lifetime QALYs lost per pregnant adult and per pregnant adult and baby. The results obtained from the Markov model are shown in Table 6.10, which differentiates between M6 (the model excluding health effects on first year babies) and M7 (which includes them).

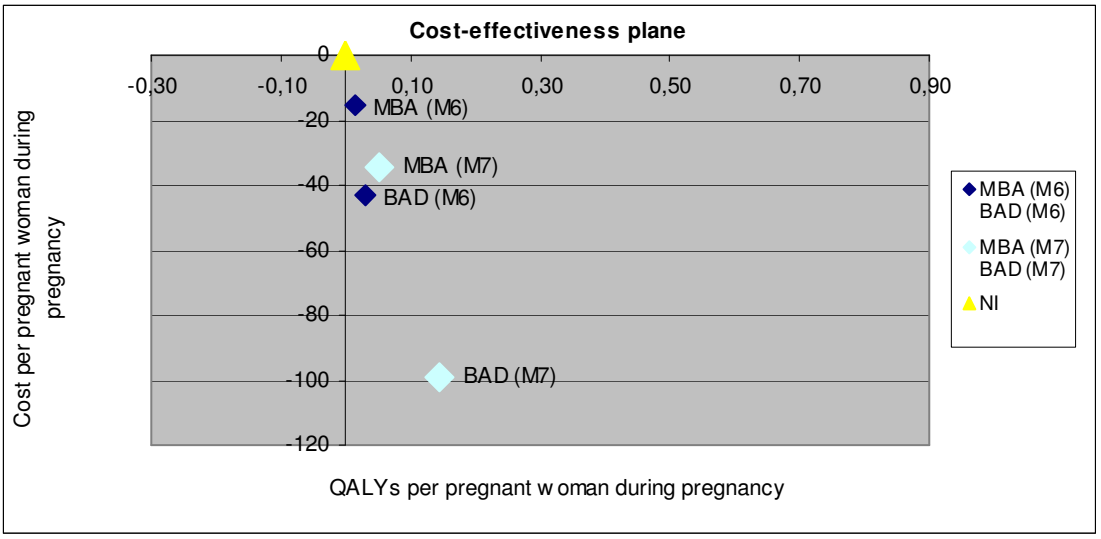
Table 6.10 M6 and M7 estimates of average costs and QALYs lost per pregnant woman (cohort of 1000 pregnant women aged 16 - 44.5) + average babies delivered by pregnancy (0-1 years); starting distribution: according to prevalence; health states: smokers; former smokers; non-passive never-smokers; passive smokers; and death

Pregnant women interventions	Discounted average COST per pregnant woman (M6)	Discounted average COST per pregnant woman (M7)	Discounted QALYs lost per pregnant woman (M6)	Discounted QALYs lost per pregnant woman (M7)	NMB per pregnant woman (M6)	NMB per pregnant woman (M7)
NI	1477.07	1642.95	4.1296	4.4685		
MBA	1461.58	1608.77	4.1152	4.4158	304.40	1087.65
BAD	1433.82	1543.76	4.0995	4.3239	645.20	2989.97

M6=M3+incorporation of non-smokers in the Markov model, but excluding health effects on first year babies from smoking during pregnancy
M7=M3+incorporation of non-smokers in the Markov model, but including health effects on first year babies from smoking during pregnancy

Cost-effectiveness and NMB analyses reached the conclusion that BAD was the most cost-effective intervention, compared with no intervention, both when external effects were excluded (M6) and included (M7). This is therefore the recommended intervention, whether or not smoking during pregnancy is included. When the results from M6 and M7 are compared, i.e. when the health effects on babies' first year of life are taken into account, external effects are seen to be responsible for an extra lifetime cost of £109.94 per pregnant adult and baby and 0.2244 extra lifetime QALYs lost per pregnant adult and baby. The NMB value for the most cost-effective intervention was £645.20 when the external effect smoking during pregnancy was excluded, and £2989.97 when it was included – a difference of £2344.77 in absolute NMB. Graph 6.1 compares the differences in costs and QALYs lost when external effects are excluded and included. To facilitate the interpretation of the graphical results, QALYs lost were converted to QALYs gained adjusting the negative sign.

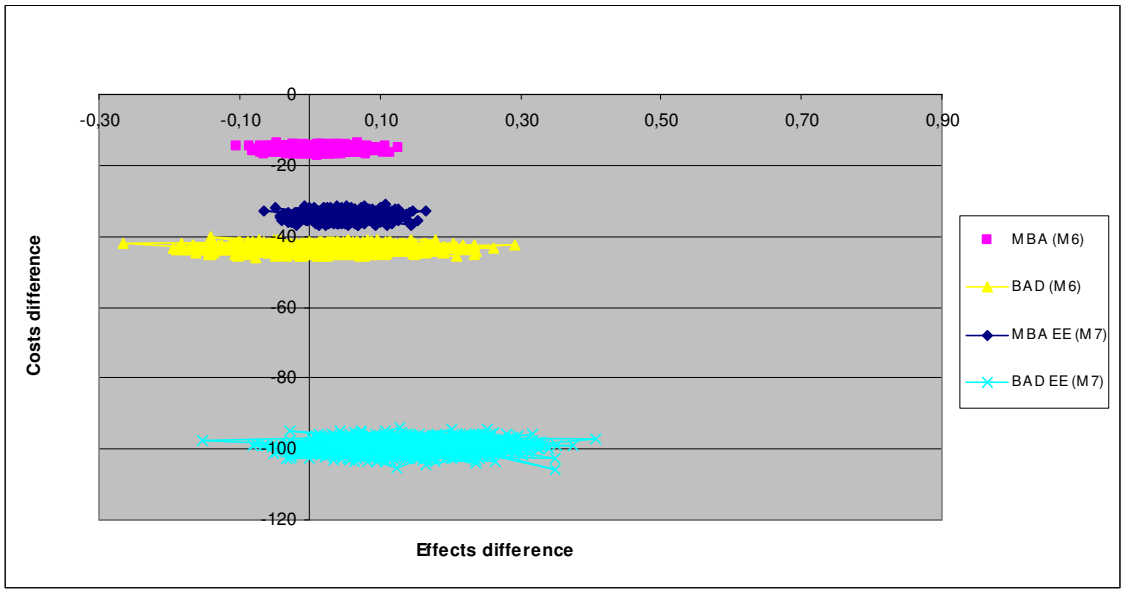
Graph 6.1 Costs and QALYs lost per pregnant woman when external effect on babies' first year of life is excluded (M6) and included (M7)



The effects on the estimates of three inputs (decrease of background cessation rate to 1.2%, cost of interventions equal to zero, and 10% variation in relapse rate) were studied to preserve consistency with Flack et al. (2007a), as in Chapter 5. Neither the deterministic sensitivity analysis on background quit rate, nor intervention costs equal to zero, nor the 10% variation in relapse rate had any impact on the ICER and NMB ranking, though the results for costs and QALYs changed slightly when external effects were included. Having specified distributions for all the relevant parameters of the model, probabilistic analysis was undertaken. This process formed a single replication of the model results; a total of 1000 replications from the model are presented on the cost-effectiveness plane in Graph 6.2, including results from both M6 (health effects on first year babies of maternal smoking in pregnancy excluded) and M7 (health effects included). The graph indicates that higher uncertainty exists around the most cost-effective interventions. Graph 6.2 shows the incremental cost plotted against incremental effectiveness for the results of the Markov simulation when external effects are not included. The graph suggests much uncertainty around the cost-effectiveness ratio, and indicates that BAD is the most cost-effective intervention. The fact that BAD demonstrates the highest variability and widest 95% confident interval (CI) in terms of cost savings (-45.03, -41.54) and QALYs gained (-0.1354, 0.1790) could be explained as the consequence of this intervention exhibiting the highest rate of effectiveness, and therefore the highest standard deviation (standard deviation is assumed to be 10% of the

effectiveness rate). Ultimately, however, compared to the no intervention option, all the interventions seem to be cost-effective.

Graph 6.2 Monte Carlo simulation results on the cost-effectiveness plane for MBA and BAD in M6 and M7 (including health effects on first year babies from adults smoking during pregnancy)

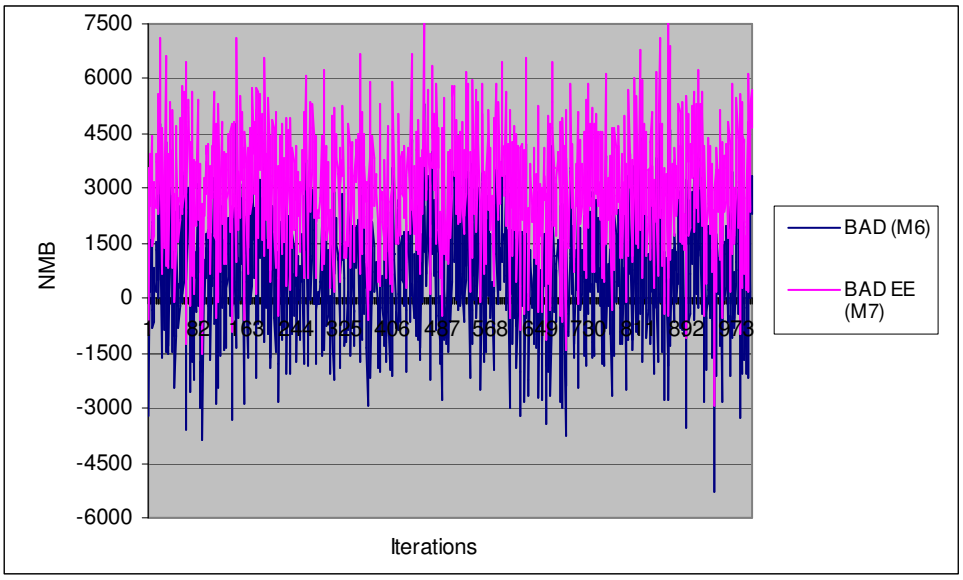


When external effects are included (MBA EE and BAD EE), all interventions compared to no intervention are dominant rather than cost-effective. In this case, the uncertainty diminishes in terms of QALYs gained (95% CI (-0.0208, 0.2942)), but it increases in terms of cost savings (95% CI (-102.62, -95.97)). The change in terms of effects could be explained by the clear reduction in QALYs due to the incorporation of SIDS and LWB into the model. However, the increase in cost variability could be due to the introduction of LBW effects on first year babies. There is a clear shift from the first quadrant to the third quadrant of the cost-effectiveness plane. In other words, when external effects are included, this has a clear impact on decision-making. When the external impact on babies` first year is included in the model, the change in the 95% CI for costs and QALYs for the most cost-effective intervention show there is a higher level of uncertainty.

Graph 6.3 presents the uncertainty surrounding the NMB of the most cost-effective intervention, when the health impact of maternal smoking in pregnancy on babies` first

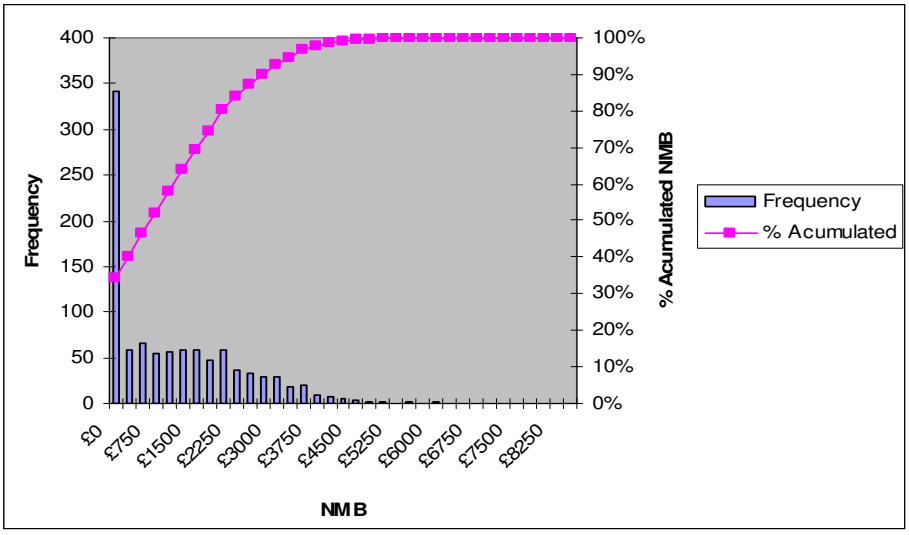
year is included and when it is excluded. Higher uncertainty is clearly observed around the NMB when the external effect is taken into account.

Graph 6.3 NMB of the most cost-effective intervention when the impact on babies' first year of life is included (BAD EE; M7) and when it is excluded (BAD; M6)



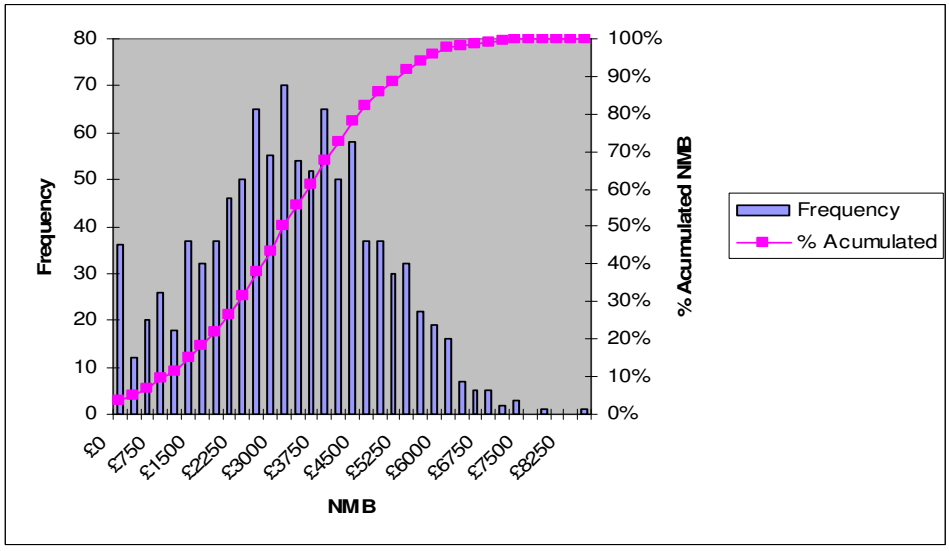
Cost-effectiveness acceptability curves were calculated for models not incorporating (M6) and incorporating (M7) external effects (see Appendix 6.9 for details). However, because, when external effects are introduced, the BAD programme has 100% probability of being cost-effective, these graphs are not very informative. For this reason, histograms showing the NMB for the most cost-effective intervention are presented instead. As the cost-effectiveness model is able to predict NMB as a function of the prediction pattern, it was used to generate a prediction of the NMB based on a comparison of BAD versus no intervention. A histogram of the distribution of predicted NMB results (in terms of incremental cost per QALY gained from BAD) is presented in Graph 6.4. It is important to recognise that this distribution represents the estimated heterogeneity with regard to NMB. The median (IQ range) NMB across the heterogeneous population was estimated as approximately £750 per QALY. Overall, 90% of the estimates were estimated to have a point estimate of NMB below £3000.

Graph 6.4 Distribution of predicted NMB for BAD in M6



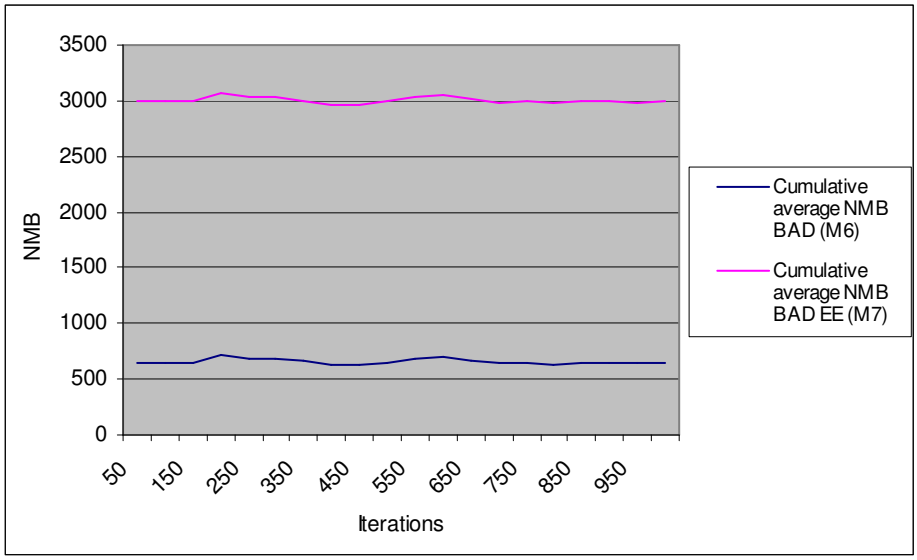
However, when the impact on babies' first year of life is included (see Graph 6.5), the median (IQ range) NMB increases to £3000 per QALY. Overall, around 90% of the estimates were estimated to have a point estimate of NMB below £5250. It is thus evident that when the external effect is included, the NMB of the most cost-effective intervention rises.

Graph 6.5 Distribution of predicted NMB for BAD in M7



Graph 6.6 shows that the results for the most cost-effective intervention (external effects excluded) become stable at around 700 iterations. The results derived from the 1000 iterations here therefore seem to be robust. When external effects are included, same iterations (around 700) are needed to achieve robust results.

Graph 6.6 Cumulative average NMB for BAD in M6 and M7



6.4 Discussion

This chapter attempts to incorporate the impact of smoking during pregnancy on babies' first year of life in an economic evaluation of smoking cessation interventions. It takes a completely different perspective from Flack et al. (2007a), who calculated the additional costs associated with first year babies born to smoking mothers, but did not incorporate them into the economic evaluation of smoking cessation programmes for pregnant women. The value of this chapter lies not just in the methods it outlines for incorporating external effects, but also in its discussion of how incorporating these effects into cost-effectiveness assessments might impact upon policy decisions. This chapter also provides insights into the uncertainty which surrounds the parameters driving the model. The main question is whether the cost-effectiveness of the smoking interventions recommended for pregnant women changes when external effects are taken into account, and if so, what the magnitude of that change is.

Data on maternal smoking and resource utilisation from the Oxford Record Linkage Study, published by Petrou et al. (2005), was used to calculate the additional costs associated with children whose mothers smoked during pregnancy. It specifies exactly where these costs come from (low birth weight and sudden infant death burden).

The static Markov model was used to incorporate external effects into the economic evaluation and calculate the extra lifetime costs and QALYs lost per pregnant woman and baby due to smoking during pregnancy. This chapter also suggests that the taxonomy of the models used in economic evaluation so far is incomplete (see Section 5.4 for details). Looking at the results, the inclusion of external effects on first year babies caused by maternal smoking during pregnancy led to no changes in ICER ranking, as expected. Results from both deterministic and probabilistic models led to a similar conclusion. However, as discussed in Chapter 5, there was an impact on the magnitude of the ICER. BAD was revealed to be the most cost-effective intervention in both scenarios.

Weaknesses in the model are the widely varying sample sizes cited and some questionable relapse rate data. These introduced additional uncertainty in both models M6 and M7. For instance, the disparity in sample size (30 women in Hackman`s trial as opposed to 1120 women in Hajek, West & Lee) suggests that effectiveness rates may not be comparable or robust across smoking cessation programmes for pregnant women. The relapse rate for smoking during pregnancy is quite high, and assumptions were made about going back to the background quit rate after pregnancy, as the adult population did in M4 and M5. According to Flack et al. (2007a), Peter Hajek (2001) suggested that 70% of pregnant women who stop smoking will relapse within a year. Fang et al. (2004) and Lopez et al. (2008) supported this estimate, establishing an interval for the relapse rate of 70% to 85% and 70% to 80% respectively. Bolling et al. (2007a) suggested that 30% of mothers who stopped smoking during pregnancy resumed smoking within a year of giving birth, while Secker-Walker et al. (1998) reported a relapse rate *during* pregnancy of 15% to 30%. Given these widely varying statistics, we should be conservative about the conclusions we draw from the results obtained, though the sensitivity analysis applied to this parameter showed no change in terms of cost-effectiveness ranking.

It should be noted that models M6 and M7 are basically driven by the weighted background quit rate, effectiveness of interventions and relapse rates. For instance,

although the three highest ranking smoking cessation interventions among pregnant women reported close to 100% success rates, these included self-reported unaided quitters rather than just smokers actually treated. Although the variability of effectiveness rates (quit rates) used in our model was scrutinised by means of probabilistic sensitivity analysis, it is nevertheless advisable to be cautious in our treatment of the results. The estimates for cessation rates after pregnancy are the weakest in the model, because in many interventions these rates were not reported. Moreover, there is no commonly agreed cut-off point: studies variously take three, five or eight weeks after delivery. Probabilistic analysis was run establishing, and not, a distribution to each parameter, and studying their impact. Although there was no impact in terms of cost-effectiveness or NMB ranking, better data is needed on these parameters to properly establish confidence intervals and study the uncertainty they introduce.

Prevalence rates for smoking during pregnancy in the United Kingdom provided by the Infant Feeding Survey (IFS) 2005 (Bolling et al., 2007) were in accordance with those used in the models M6 and M7 calculated from the Health Survey for England (HSE) 2006 data. In the IFS, smoking prevalence among pregnant women aged 20 and under and 20-24 was 45% and 29% respectively, whereas in the model, a 37% smoking prevalence rate was adopted for pregnant women aged 16 to 24. Between 25 and 39 years, and 30 and 34 years, the prevalence rates calculated by the IFS were 15% and 10% respectively. The HSE reports an 11% prevalence rate in this age group. Finally, the IFS calculated a prevalence rate of 9% among pregnant smoking women aged 35 and over, while the HSE`s figure was 11%. Had these values been used in models M6 and M7, it would have made no difference either to the results or the ICER ranking.

One potential limitation of the external effect as it is incorporated into the model is that it does not take into account maternal deaths (death while pregnant or within 42 days of the end of pregnancy, from any cause related to or aggravated by the pregnancy), direct deaths (deaths resulting from obstetric complications of the pregnant state) or indirect deaths (deaths resulting from previous existing disease but aggravated by the physiologic effects of pregnancy (Fisher, 2008)). General female mortality rates during pregnancy by age interval (rather than gestation-specific infant illnesses and neonatal and post-neonatal mortality rates) could be adopted as a proxy for mortality in the model. Although this may introduce bias in terms of the effectiveness of interventions,

it should have no impact on cost-effectiveness or NMB ranking of programmes. This proxy was not considered in order to keep the model simple, though some data on deaths during the pregnancy period has been published (Moser et al., 2007). According to Blair et al. (2006), most SIDS deaths happen within the first eight months of life, though this economic evaluation considers the RR of SIDS for smokers` children during the first year of life. In other words, this assumption introduces further parameter uncertainty. The analysis includes information regarding smoking in pregnant women up to 44.5 years old, but does not take into account smoking by any other household members. This may also introduce bias into the results in terms of costs and QALYs, though smoking patterns among other family members will presumably not be changed by interventions focused on pregnant women.

In general, future research should rely on better relapse estimates, and clinical trials studying the health effects of smoking during pregnancy on women. The next chapter of this thesis will introduce transmission of smoking behaviour to the other two external effects already studied, passive smoking and smoking during pregnancy, to study the impact of the incorporation of this last external effect into economic evaluation of smoking cessation programmes.

CHAPTER 7 Economic Evaluation of Smoking Cessation Interventions: considering smoking dynamics and passive smoking

7.1 Introduction

Chapters 5 and 6 examined the impact of passive smoking and smoking during pregnancy respectively, in an economic evaluation of alternative smoking cessation programmes using a static Markov model. Chapter 7 aims to assess the impact of the third external effect, transmission of smoking behaviour, in an economic evaluation of smoking cessation. Brennan et al (2006) suggested that static models, such as decision trees or Markov models are the main approaches adopted by health economists in conducting economic evaluation. Static models unlike dynamic models, however, cannot accommodate the 'interactions between individuals', necessary for transmitting an infectious disease, or smoking behaviour in this particular case (Barton et al., 2004; Brennan et al., 2006). There is therefore a need for a dynamic model because the external effect considered in this chapter (i.e. transmission of smoking behaviour) involves a transmission mechanism. Castillo-Garsow et al (1997) and Sharomi and Gumel (2007) emphasised the need of a dynamic model to account for transmission of smoking behaviour.

There is a large body of literature on both the theoretical and empirical aspects of the transmission dynamics of infectious diseases (Keeling and Rohani, 2008; Anderson and May, 1991; Nokes and Anderson, 1988; Fine, 1993) which is aimed at explaining observed epidemiological patterns and predicting the consequences of the introduction of public health interventions to control infection and disease. Edmunds et al (1999) and Beuthe et al., (2002) noted that specific economic evaluation guidelines are needed to accommodate those health benefits (herd-immunity effects). Transmission dynamic models are mainly used to incorporate the health benefits in a cost-effectiveness analysis of vaccination programmes (Beuthe et al, 2002) given the positive external effects accruable from such programmes. Vaccination gives indirect protection to non-vaccinated people.

Transmission of smoking behaviour appears to be a negative external effect generated via contact with smokers. Smoking cessation programs would result in fewer smokers in the population and the number would decline, at least partly, as more individuals attend those programs. While a dynamic framework could account for the declining rate at which 'never smokers' become 'smokers', in a static model framework this rate would remain unaltered ignoring the fact there will be fewer and fewer never smokers who risk start smoking. The declining rate is important to consider because it may have an effect on the cost-effectiveness of a smoking intervention. Therefore, the static model may not provide the correct picture of the cost-effectiveness analysis. Therefore, a dynamic approach seems to be the adequate model framework to incorporate the external effects of transmission of smoking behaviour (Sharomi and Gumel, 2007; though as it will be pointed in the discussion of this chapter, this thesis cannot claim that the model built in this chapter is a true dynamic model because though captures some of the population dynamics, it does not capture the second and higher order effects).

In this chapter, the incorporation of the transmission of smoking behaviour in an economic evaluation of smoking cessation interventions is undertaken, singly or in combination with passive smoking. The inclusion of more than one external effect at a time is because the analysis focuses on a cohort of smokers from the general population and another cohort of their contacts and group of interventions that are common to the external effects being considered. The objectives of the chapter are to: (a) conduct a literature search on smoking dynamic models to identify an appropriate framework to incorporate the transmission of smoking behaviour; (b) apply dynamic modelling techniques to allow the incorporation of external effects to capture the disease dynamics (c) estimate the impact of incorporating the transmission of smoking behaviour into economic evaluation of smoking cessation programs; and, (d) to compare, in terms of relative impact on economic evaluation, the incorporation of the transmission of smoking behaviour with passive smoking previously incorporated, in chapters 5.

This chapter first presents a mathematical model of the long-term dynamics of smoking transmission behaviour among general adult population between 16 and 69 years (M8). This is followed by a modification of the model to incorporate the external effects of passive smoking (M9) while accounting for transmission of smoking behaviour. Third, an economic evaluation of the cost-effectiveness of smoking cessation interventions, based on data used in a previous chapter (Chapters 5) of this thesis is presented.

7.2 Methods

The methods include how the literature review on smoking dynamic models was conducted, including the search strategy, selection criteria and findings. It also details the economic model used to incorporate the transmission of smoking behaviour. This section also shows how to incorporate the transmission of smoking behaviour using a cohort dynamic model, and the addition of passive smoking external effect in this model. Model parameters are also described, concentrating on the concept of "force of infection".

7.2.1 Systematic review of smoking dynamic models

The aim of this systematic review was to examine literature on smoking dynamic models to inform the incorporation of the transmission of smoking behaviour into economic evaluation.

Search strategy

Comprehensive literature searches were undertaken in July 2008 and involved 6 bibliographic databases (Web of Knowledge, Econlit, Mathscinet, NHS EED, HEED and Cochrane Library) as well as bibliographies of relevant reviews on smoking. The search was restricted to smoking, English Language and human subjects, with no time restrictions. The free text search terms were "smoking", "cost benefit", "cost effectiveness", "economic evaluation", "cost", "valuation", "critical appraisal", "model, pecuniary", "technological", "knowledge", "network", "external effects", "externalities" and "spillovers". Search terms were contrived to retrieve papers on dynamic models related to smoking. These terms were modified to suit individual databases, given the nature of search engines. Appendix 7.1 gives further details.

Selection criteria

A selected paper had to satisfy all the following criteria: (a) present a dynamic model focussed on smoking behaviour; (b) the structure of the model should be fully detailed; and, (c) written in English language as there were no resources for translation. This

review differed from an earlier literature review that concentrated on economic models of smoking cessation interventions (see Appendix 4.2 for details) in that the previous review aimed to find only empirically tested models, whereas in this chapter, that is not an important requirement.

Results

Appendix 7.2 shows that titles or/and abstracts of 18 papers produced by the search were screened leading retrieval of 15 papers. The excluded papers were duplicates (see Appendix 7.3 for included references). A total of 11 papers did not merit inclusion: (a) one paper was not smoking related (James and Venn, 2006); and (b) ten papers (Collins and Lapsley, 1999; Ahmad and Franz, 2008; Van Baal et al, 2007; Ahmad, 2005a; Leffondré et al, 2006; Liu and Powers, 2007; Mannan and Koval, 2003; Wang et al, 2006; Chan and Kapadia, 2006; Feenstra et al, 2005) were not presenting dynamic model structures according to the different smoking habits. Overall, 4 papers were selected for review. However, two more papers were obtained from references and therefore included in the review (Castillo-Garsow et al 1997; Tengs et al, 2001b).

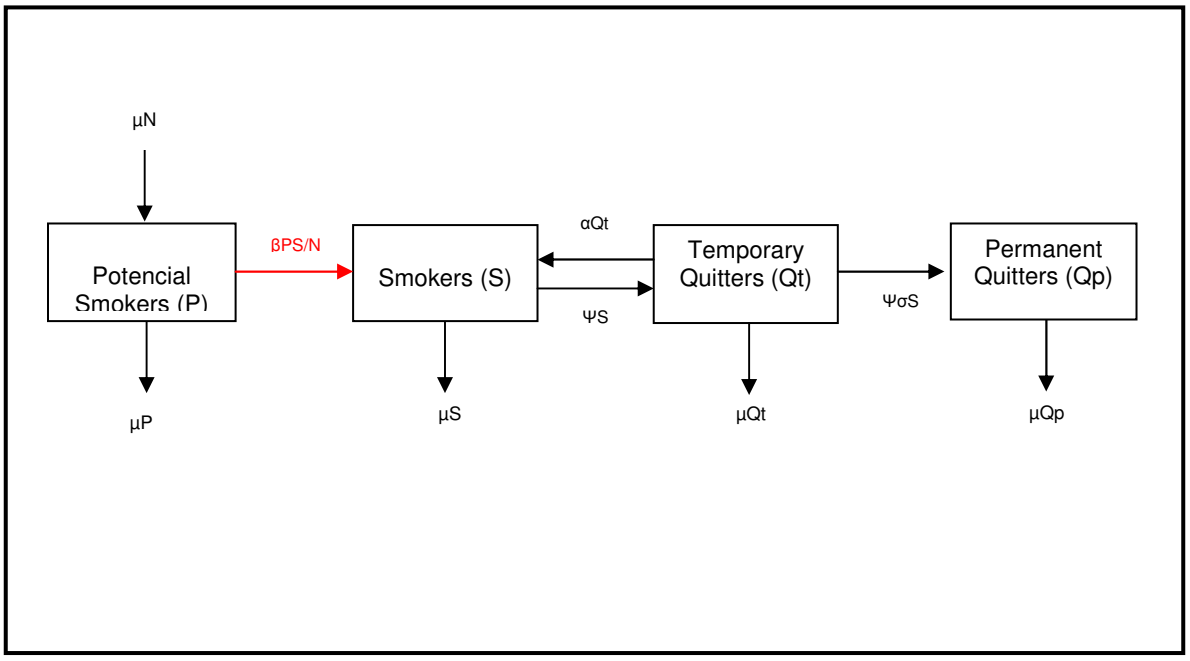
The findings of this literature review indicated that only six (Castillo-Garsow et al 1997; Sharomi and Gumel, 2007; Tengs et al, 2001a; van Genugten et al, 2003; Tengs et al, 2001b; Ahmad, 2005b) of the eighteen papers found had used dynamic models of smoking. However, only two papers presented full details on the dynamic models (Castillo Garsow et al, 1997; Sharomi and Gumel, 2007). Castillo-Garsow et al (1997) using a general epidemiological model to describe the dynamics of tobacco use among adolescents. A general model for drug abuse adaptable to study the dynamics of tobacco use was specified using three classes of individuals: S (individuals susceptible to become regular users); D (individuals who are regular drug users) and R (individuals recovered from habitual drug use). The rate of transmission (frequently defined in the infectious disease area as the 'force of infection') depended on the regular drug users at a specific time in the population. A recovery rate per habitual drug user and a relapse rate per recovered individual were a function of D and incorporated in this model. This general mathematical model was extended to include demographic factors in the population considered; to make relapse dependent on the presence of drug users, and to assess effectiveness of rehabilitations programs. The model showed the endemic character of tobacco use. Sharomi and Gumel (2007) adapted the mathematical model based on Castillo-Garsow et al (1997) to assess the dynamics of smoking and its public

health impact in the community. This model incorporated different classes of smokers according to the frequency of smoking, the transition dynamics between these subclasses, and, the public health impact of smoking-related illnesses. The transmission dynamic model used differential equations to define each health state in the model, as frequently transmission dynamic models do (Edmunds et al, 1999; Brisson et al, 2000; Trotter et al, 2006; Sufton et al, 2006; Bauch et al, 2007). Although Tengs et al (2001a), van Genugten et al (2003), Tengs et al (2001b) and Ahmad (2005b) presented empirically tested dynamic model structures, the parameters of the model estimations were not fully reported. Apart from that, the model structure presented in all these papers was in concordance with that presented by Sharomi and Gumel (2007), which is fully detailed below.

To establish my model structure incorporating transmission of smoking behaviour, I analysed the conventional dynamic model used by Sharomi and Gumel (2007). In this paper, the authors specified that the number of potential smokers (term used to refer to non-smokers) is increased by the recruitment of individuals into the non-smoking class (at a rate: μN, where μ is the natural rate of people increasing the population modelled, and N the total population). For simplication, Sharomi and Gumel (2007) assumed that the natural rate of people increasing the population modelled was the same as the natural death rate to keep the population size constant. It is assumed that never-smokers can acquire smoking habits (and become smokers) via effective "contacts" with smokers (at a rate $\beta=c*q$, where c is the average number of contacts per unit time; and q is the probability of becoming a smoker for a member of the potential smokers class following contact with a smoker). In other words, it is assumed that the acquisition of smoking habit is analogous to acquiring disease infection; the more "contact" a potential smoker has, the higher the likelihood of such an individual acquiring smoking habit. This acquisition of smoking habits, and therefore the transmission of smoking behaviour, is referenced as force of infection in a conventional dynamic approach (i.e. infectious diseases). Sharomi and Gumel (2007) did not try to estimate neither beta nor any other parameter. It was a paper concentrated in providing a rigorous mathematical study to assess the dynamics of smoking, but no application was carried forward at any stage.

A flow diagram for a basic SIR (Susceptible-Infected-Recovered) health states dynamic model was created by Sharomi and Gumel (2007). This example of a SIR model represents graphically the transmission of smoking behaviour (see Box 7.1 for details).

Box 7.1 Structure of a smoking SIR health states model (adapted from Sharomi and Gumel, 2007)



Definition of parameters and variables:

P	≡Non-smokers (potential smokers)
S	≡Smokers
Qt	≡Smokers who temporary quit smoking
Qp	≡Smokers who permanently quit smoking
N	≡Total population
β	≡rate at which non-smokers can acquire smoking habits (and become smokers) via "effective" contacts with smokers
Ψ	≡quit rate
α	≡rate of revert to smoking when smokers temporarily quit smoking (relapse rate)
σ	≡fraction of temporarily smokers who permanently quit smoking
μ	≡rate of recruitment and mortality

Source: Sharomi and Gumel (2007)

To mathematically represent the relationships among the different health states represented in Box 7.1, differential equations are extensively used. Differential equations in Box 7.2 are simply reporting what Sharomi and Gumel did.

Box 7.2 Differential equations of a smoking SIR model

Rate of change in the number of potential smokers over time

dP/dt= $\mu N - (\beta PS/N) - \mu P$

Rate of change in the number of smokers over time

dS/dt= $(\beta PS/N) + \alpha Qt - (\mu + \psi)S$

Rate of change in the number of temporary quitters over time

dQt/dt= $\psi (1- \sigma)S - (\mu + \alpha)Qt$

Rate of change in the number of permanent quitters over time

dQp/dt= $\psi \sigma S - \mu Qp$

Source: Sharomi and Gumel (2007)

Models of infectious disease transmission need to represent the population level effect of processes that occur at the individual level (Keeling and Rohani 2008). An uninfected individual's risk of becoming infected (referred to as the force of infection) depends on the prevalence of infectious individuals, which is a population level characteristic. Therefore, translating this concept into the smoking context, a never smoker' risk of becoming a smoker depends on the prevalence of smoking in the population. It also depends on the rate of contact, direct or indirect, between smokers and never smokers in the household. Therefore, the transmission of smoking behaviour in a population is a dynamic process and the individual risk of smoking can change over time depending on the number of infectious individuals in the population. The population rate of infection in each time period depends upon the number of never smokers and the number of smokers of that time period. To incorporate the external effect of transmission of smoking behaviour, the change in the force of infection (FOI) needs to be accounted for.

The transmission of smoking behaviour modelled using a conventional transmission dynamic (compartment) approach would be calculated using the risk that a never

smoker becomes a smoker during a given time (FOI). The never smoker category should be split in two different categories non-passive and passive never smokers. The reason is because the transmission of smoking behaviour is likely to be higher in the latter, because by definition their contact with smokers is greater. This is what my model adds to Sharomi and Gumel's work, the idea of modelling smoking transmission distinguishing between non-passive and passive never smokers. The risk of never smokers depends on two factors: (a) the number of smokers present in the population at that time (S); and, (b) the probability that a non-passive or passive never smoker comes into effective direct or indirect contact with a smoker (β). According to Abbey (1952), an effective contact is defined as a contact sufficient to lead to smoking if it occurs between a non-passive never smoker and a smoker (see equation E7.1)

$$FOI_{NPNS} = \beta_{NPNS} * S \qquad (E7.1)$$

and, a passive never smoker and a smoker (see equation E7.2)

$$FOI_{PNS} = \beta_{PNS} * S \qquad (E7.2)$$

where betaNPNS is likely to be lower than betaPNS. For large populations, the number of smokers present in the population (S) will be divided (adjusted) by the total population (N).

See further details in Appendix 7.4. The probability that a specific smoker and never smoker individual comes into effective contact between time t and t+1 (β) is needed for calculating the transmission of smoking behaviour with that approach. A literature review using the google scholar engine was conducted and also the papers obtained from the systematic review of smoking dynamic models (see section 7.2.1) were reviewed to check the existence of this required parameter and Professor John Edmunds, as an expert in the transmission dynamic models, was also consulted. However, there was no available data to calculate this parameter. In infectious diseases, where transmission dynamic models are widely used and studied, there is a particular area of research that focuses just on the calculation of transmission rates of diseases and their probability of effective contact (Goeyvaerts et al, 2010; Björnstad et al, 2002; Heptonstall, 1996). Therefore, because an accurate calculation of this parameter is out of the scope of this thesis and there is an interest of keeping same Markov model structure for comparability reasons with previous models, the beta parameter was not

specifically calculated, but proxied using two cohorts in the model. The contact between never-smokers and smokers (β) was modelled by inter-relations between two cohorts: cohort of smokers (cohort a) and cohort of passive smokers (cohort b). Cohort b is driven by: (a) the number of existing smokers in cohort a in each particular time period, and (b) the number of smokers and former smokers who quit and relapse respectively in cohort a. This movement between number of smokers and former smokers in cohort a will affect the number of non-passive never smokers and passive never smokers.

The impact of smoking cessation interventions will affect the smoking cohort (cohort a) and therefore the number of passive smokers generated by each smoker at cohort b. It will also affect the number of people quitting and relapsing in cohort a. Because the number of passive smokers in cohort b will also depend on number of smokers quitting smoking and former smokers relapsing smoking in cohort a, the smoking cessation interventions will also impact costs and QALYs lost on cohort b. In every time period that smokers quit smoking in cohort a, passive smokers become non-passive never smokers in cohort b at quit plus mortality rate of smokers. For instance, the movement from passive never smokers to non-passive never smokers is due to a smoker who they live with has quit or died. And conversely, non-passive never smokers may become passive never smokers if someone they live with takes up smoking (or relapses). As more effective is the intervention and more smokers quit smoking in the smoking cohort, higher number of people is leaving the state of passive smoker to become a non-passive never smoker again in passive never-smoker cohort.

Something else to consider is that for an infectious disease, the only way you can get the disease is if the pathogen is transmitted to you. But, it seems that this is not true for behaviours like smoking. There are other factors out of our control that make people start smoking for other reasons (i.e marketing influence from tobacco companies, psychosocial reasons). In this thesis, because of data limitations, the transmission of smoking behaviour was restricted to live with a smoker, but this is not entirely true, though it is probably the highest influencial factor.

7.2.2 Economic model

One model containing two cohorts were developed in Microsoft EXCEL (Microsoft Corporation) to account for the transmission of smoking behaviour, one for a general smoking cohort and, the other for a cohort of passive smokers generated by the smokers cohort. The structure of the two cohorts composed model used the model structure of the replicated model M3 (see section 4.1.2, Chapter 4) and M4 and M5 (see section 5.2.2, Chapter 5), and is described below.

The model estimates: (a) impact on average lifetime costs per adult (£ 2010); and (b) quality-adjusted life-years (QALYs) lost per adult due to transmission of smoking behaviours and passive smoking. This chapter introduces four new models: M8, which includes cohorts a and b but does not include transmission of smoking behaviour; M9, which includes cohorts a and b and passive smoking; M10, which includes cohort a and b and transmission of smoking behaviour; and M11, which contemplates cohorts a and b, passive smoking and transmission of smoking behaviour. These models are compared by pairs (M8 versus M10 and M9 versus M11) to study the magnitude of the effect of incorporating this third external effect (i.e. transmission of smoking behaviour). The additive impact of two external effects is studied in this chapter (M8 versus M11). The population is simulated over time, as in chapters 5 and 6. To capture the transmission of smoking behaviour two cohorts are modelled in parallel. The first cohort, *cohort a*, is a cohort of 1000 smokers at whom the smoking cessation interventions are targeted. This model structure is the one used for M3 in chapter 4. Whereas, the second cohort, *cohort* b, is a cohort of never-smokers who are living with members of cohort a, and are thus susceptible to the effects of and transmission of smoking behaviour. Cohort b is of mixed ages between 16 to 25 years because this is the age range when most smokers start smoking. A wide range of literature suggests that the transmission of smoking behaviour is more likely to occur within age bands or peer groups (Thomas et al, 2006; Thomas et al, 2008; Harris and Lopez-Valcarcel, 2008). However, for simplication purposes no different influences were assumed to occur by different age clusters of people. Therefore, it is assumed that in the age interval of 16 to 25 years, the never-smokers are susceptible to be influenced by the smoker population, and therefore, the transmission of smoking behaviour could occur. Therefore, there is a need to calculate thr number of passive never smokers, aged between 16 and 25 years, generated by a smoker. This will vary with the age of the smokers. In the first cycle of the model, the

number of passive smokers generated by a smoker was calculated using data from the Household Survey for England, which takes place in a household context. Because of the calculation difficulties of this number, the proxy used was the division of the number of never smokers divided by the number of smokers in the whole population interviewed. Therefore, every smoker in cohort a generate 0.42 passive smokers in cohort b aged between 16 and 25 years. From second cycle onwards, the number of passive smokers generated by a smoker is calculated from the existent number of passive smokers in previous cycle in cohort b divided by the number of smokers in previous cycle in cohort a. Cohort a is supposed to live with never-smokers who are between 16 and 25 years to have the chance to transmit the smoking behaviour. However, it does not seem sensible to assume that people at any age in cohort a could live with a young adult between 16 to 25 years. Therefore, there is a need to establish a boundary around wich is the age at which people would not live with young people between 16 to 25 years. Because the upper age limit boundary assumed to get pregnant is 44 years (see chapter 6), the smokers cohort, cohort a, living with never smokers, cohort b, will be adults between 16 and 69 years (i.e 44 years is the latest age to deliver a baby and he/she will reach the age of 25 years when the smoker parent is 69 years). Refer to Table 7.1 for details on population and external effects differences between M8 M9, M10 and M11, and models previously presented in chapters 5 and 6.

Table7.1 Summary of differences among M4, M5, M6, M7, M8, M9, M10 and M11

Models	Population					Incorporation of health effects of passive smoking on adults and children	Incorporation of health effects of smoking during pregnancy on women and babies	Incorporation of transmission of smoking behaviour
	1000 adults	1000 adults + 96.5% of adult smokers' children	1000 pregnant woman	1000 pregnant woman + average babies delivered by pregnancy	Number of passive smokers generated by 1000 smokers			
M4	√	x	x	x	x	x	x	x
M5	x	√	x	x	x	√	x	x
M6	x	x	√	x	x	x	x	x
M7	x	x	x	√	x	x	√	x
M8	√ *	x	x	x	√	x	x	x
M9	√ *	√*	x	x	√	√	x	x
M10	√ *	**x**	x	x	√	**x**	x	√
M11	√ *	√*	x	x	√	√	x	√

√≡ included in the model
x≡ not included in the model
*≡ In these models, the starting population in cohort a are 1000 smokers adults, whereas in M4, M5, M6 and M7 the starting population are distributed according to smoking habits.

There is a need to compare the impact of including the transmission of smoking behaviour with not including it. However, as detailed in Table 7.1, starting population across models (M4, M5, M6, M7, and M8 or M9 or M10 or M11) are different. Therefore, there is a need to create four new models to value the incorporation of the transmission of smoking behaviour. M8 will be same as M10, and M9 same as M11 but with no transmission between cohorts a and b (i.e. X and Y from Figure 7.1 will be set to zero).

The models used in this chapter (M8, M9, M10 and M11) differ from M4, M5, M6 and M7 in the incorporation of the transmission of smoking behaviour and the starting population considered. M4, M6, and M8 did not consider any external effect but has different starting population groups, whereas M10 incorporated the transmission of smoking behaviour. M5 and M9 incorporated passive smoking, but M9 has a different starting population group. M11 apart from passive smoking also incorporates the transmission of smoking behaviour (Table 7.1). M8, M9, M10 and M11, apart from considering a 1000 smokers as the starting population, it also includes a second cohort

of never smokers living with smokers (passive smokers) generated by the thousand smokers cohort. The proportion of passive smokers between 16 and 25, assumed to be the age interval when transmission of smoking behaviour happen, generated by a smoker was calculated using the Health Survey for England (2006). This survey takes place in a household context. The number of passive smokers per smoker is calculated dividing the total number of never-smokers between 16 and 25, in the population interviewed, from the total number of smokers between 16 and 69 years in the population. The model stops when the smoking cohort reaches the age of 69 because is considered that after that age there is no chance to live with a young adult between 16 and 25 years old. The analysis takes the perspective of the National Health System and uses a cycle length of six months, similar to models in previous chapters (section 5.2.1, Chapter 5; and, section 6.2.1, Chapter 6).

Model structure to calculate transmission of smoking behaviour

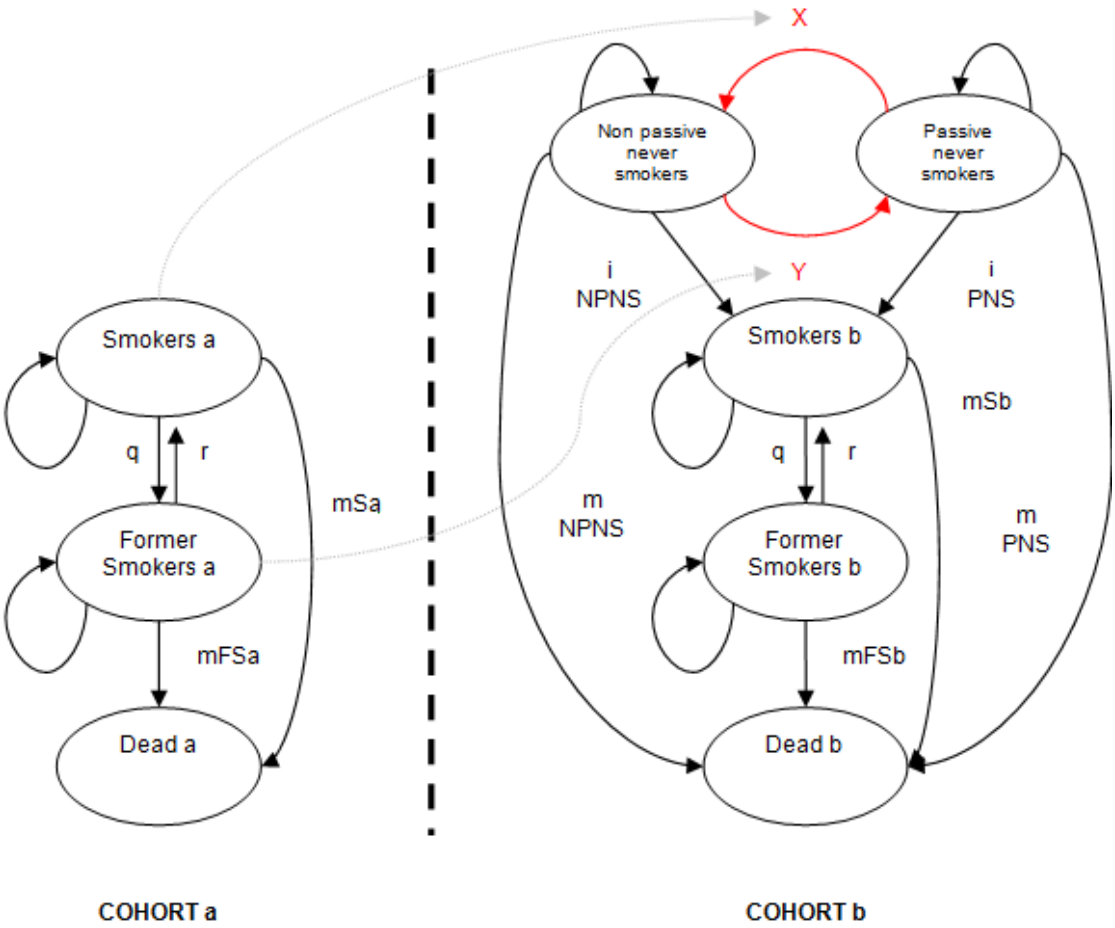
This dynamic model (Sharomi and Gumel, 2007) was useful in terms of establishing a model structure to incorporate transmission of smoking behaviour into an economic evaluation model, but the model was not populated. Therefore, gaps existed as to how to populate this model structure, and to adapt the model structure to incorporate the external effects under consideration in this thesis. Therefore, the static Markov model structure I replicated from Flack et al (2007) and used to evaluate the different smoking cessation interventions in Chapter 4, and the one I used to incorporate passive smoking, in chapter 5, were linked and adapted to reflect the transmission dynamic model of smoking. The only difference from the Markov model used to incorporate passive smoking in chapter 5 with the dynamic model I built in this chapter is that the Markov model assumes a constant force of infection and, therefore, the uptake of smoking does not depend on the number of smokers in the population. There is a need to accommodate a force of infection dependant on the number of smokers in the population to account for the transmission of smoking behaviour. The author also consulted with an expert on the transmission dynamic model, Professor John Edmunds, to confirm suspicions about the unique difference between a static and dynamic model, dependence on number of current infectious individuals in the population (i.e. smokers). Therefore, to accommodate the transmission of smoking behaviour and allow the comparison of the model structures of economic evaluation models in this chapter with

those of previous chapters, the static Markov model was transformed to a transmission cohort dynamic model. In this occasion, the model contains two cohort of people, a smokers cohort (cohort a) and a passive smokers cohort (cohort b). The cohort of passive smokers (cohort b) depends on the number of smokers (cohort a). In cohort a, when smokers quit or former smokers relapse smoking this influences the number of passive never smokers becoming non-passive never smokers in the population and otherwise. Therefore, the number of never-smokers who are living with smokers accounts for the influence of a cohort of current smokers in the population.

Markov-type approach

To develop the two-cohort dynamic model using a Markov-type approach, explicit assumptions about the smoking transmission route are made. Transmission of smoking behaviour (new cases of smokers) is build using two cohorts model: (a) a first cohort of 1000 smokers between 16 and 69 years (cohort a), who cohabitates with (b) a never-smokers cohort between 16 and 25 years (cohort b). The never smokers cohort is derived from multiplying the smokers cohort (1000 smokers) by 0.42 passive smokers (number of passive smokers generated by a smoker), obtaining the never smokers who are at risk of transmission. The model structure for cohort b used in this chapter is based on a slightly modified version of the model presented in Chapter 5. The transmission is captured by calculating the transition probability from non-passive never smoker to passive never smoker (red arrow Y in Figure 7.1) and viceversa (red arrow X in Figure 7.1), which changes over time, accounting by age and sex differences. See Figure 7.1 for details of the new dynamic model built using a Markov-type approach.

Figure 7.1 Structure of Markov models used to capture transmission of smoking behaviour



Definition of parameters and variables:

INPNSt	≡ Incidence rate for non-passive non-smokers (proportion of $NPNS_t$ who start smoking during period)
$iPNS_t$	≡ Incidence rate for passive non-smokers (proportion of PNS_t who start smoking during period)
q_t	≡ Quit rate for cohort a smokers (proportion of S_t who give up smoking during period)
r_t	≡ Relapse rate for cohort a ex-smokers (proportion of FS_t who start smoking during period)
mS^a_t	≡ Mortality rate for cohort a smokers (proportion of S^a_t who die during period)
mS^b_t	≡ Mortality rate for cohort b smokers (proportion of S^b_t who die during period)
mFS^a_t	≡ Mortality rate for cohort a ex-smokers (proportion of FS^a_t who die during period)
mFS^b_t	≡ Mortality rate for cohort b ex-smokers (proportion of FS^b_t who die during period)
$mNPNS_t$	≡ Mortality rate for non-passive non-smokers (proportion of $NPNS_t$ who die during period)
$mPNS_t$	≡ Mortality rate for passive non-smokers (proportion of PNS_t who die during period)
X_t	≡ Proportion of PNS moving to NPNS during time period
Y_t	≡ Proportion of NPNS moving to PNS during time period

The two new transition probabilities (X and Y) incorporated in the model are needed to capture the transmission of smoking behaviour, concept described in Castillo-Garsow (2000), and Sharomi and Gumel (2007) and, to allow individual risk of smoking to change over time. These two new transitions capture the interaction between the two

cohorts, smokers (cohort a) and passive smokers (cohort b, adults between 16 and 25 years susceptible to be influenced to become a smoker because of living with a smoker).

The two health states, non-passive and passive never smokers, interact via variables X and Y. For further details, see equation 7.3 for the transition probability from passive never-smoker to non-passive never smoker and, equation 7.4 for the transition probability from non-passive never smokers to passive never-smokers.

(Equation 7.3)

$$X_t = u * S_{t-1}^{a}\left(q_{t-1} + mS_{t-1}^{a}\right) + w * S_{t-1}^{b}\left(q_{t-1} + mS_{t-1}^{b}\right)$$

where Xt is the proportion of passive never-smoking cohort b people, between 16 and 25 years, living with a smoker who quit or died last year. This has two components, one for the smokers cohort a people and one for the passive never-smokers cohort b people; *u* is defined as the number of never-smokers living with each smokers (i.e passive smokers), and *w* as the number of never-smokers living with each never smoker.

(Equation 7.4)

$$Y_t = u * FS_{t-1}^{a} * r_{t-1} + w * (FS_{t-1}^{b} * r_{t-1} + NPNS_{t-1} * iNPNS_{t-1} + PNS_{t-1} * iPNS_{t-1})$$

Similarly, Yt is the proportion of non-passive non-smoking cohort b living with somebody who took up smoking last year, and therefore, considering a component for cohort a people, and for cohort b people.

The starting population has a *u* fixed, as detailed previously in this section (u=0.42). When cohort a starts aging, *u* is recalculated for each time period in cohort b dividing the number of passive smokers in cohort a from previous time period by the current number of smokers in cohort a from previous time period.

For simplicity reasons, the number of never-smokers living with each never-smoker could assumed to be equal to zero (w=0), and therefore, no transmission of smoking behaviour occur between never-smokers living with never-smokers.

Therefore, the transmission of smoking behaviour has been modelled indirectly by assuming that as smokers quit, this shifts never-smokers from the PNS to the NPNS categories, and as the latter have a lower rate of smoking uptake this reduces the number of new smokers in the future. But, this is again assuming that transmission of smoking behaviour only works thorugh people living in the same house. This is an illustrative approach used in this thesis, but others ways to model the transmission exist. This will be discussed in section 7.4.

Death rates in cohorts a and b are all cause mortality rates, same as in previous models (from M1 to M7). However, the death and incidence rates of cohort b are particular from a group of people aged between 16 and 25 years.

Each cycle in these equations, likewise previous models (described in Chapters 4, 5 and 6) is a function of one or more of the state variables NPNS, PNS, S and FS meaning that the value of the terms change as the state variable changes. Transition probabilities among different health states were calculated, same as in chapters 5 and 6.

7.2.3 Model parameters

In order to run the model, a number of key input parameters, as with models detailed in chapters 5 and 6, were required: uptake of smoking; prevalence of smoking habits; mortality; quit and relapse rates; effectiveness rates; and, prevalence, costs and QALYs associated with passive smoking. In order to allow for comparisons among models, parameters of both static and dynamic cohort models were the same as in chapter 5 and chapter 6. This is also the case for uptake rate of smoking. Therefore, data values for these parameters were obtained from a variety of sources which are described in Chapter 5 and 6 (section 5.2.2, Chapter 5; and section 6.2.2, Chapter 6). The only difference between parameters used in cohort b and previous models (M4, M5, M6 and M7) is that because this is a cohort of adult people in a particular age interval, the transition probabilities used for all parameters has been calculated from the averaged different rates from 16 to 25 years old.

7.2.4 Time horizon

The time horizon of the models accounting for smoking transmission behaviour (M8 and M9) and not accounting for it (M10 and M11) is set to the lifetime period.

7.2.5 Discount rate

Both costs and benefits (QALYS) in the model have been discounted at an annual rate of 3.5%, according to NICE guidelines (National Institute for Health and Clinical Excellence, 2004) and as for previous models in chapters 5 and 6.

7.2.6 Cost-effectiveness ratios and net monetary benefit

The same methods used in M4 and M5 were applied to calculate ICERs and NMB for each intervention (see for details section 5.2.5, Chapter 5). NMB estimates were calculated using a £20 000 threshold.

7.2.7 Uncertainty

Deterministic and stochastic sensitivity analysis was carried out as in chapters 5 and 6 to study parameter uncertainty.

7.2.7.1 Choosing distributions for the parameters

The same distributions used in chapters 5 and 6 were chosen for parameters. Moreover, the same number of replications performed in M4, M5, M6 and M7 were calculated for M8, M9, M10 and M11. The probabilistic sensitivity analysis accounted for variability in the smoking incidence (same as in chapter 5 and 6).

7.2.7.2 Cost-effectiveness acceptability curves

As reported for M4 and M5, and M6 and M7 cost-effectiveness acceptability curves of different interventions were provided for M8, M9, M10 and M11 (see for more details section 5.2.6.2, Chapter 5; and, 6.2.6.2, Chapter 6).

7.3 Results

The dynamic models outlined in this chapter were evaluated to estimate lifetime costs and QALYs lost of: (a) incorporation of transmission of smoking behaviour itself (M8 versus M10), and (b) transmission of smoking behaviour and passive smoking using a dynamic cohort model (M9 versus M11). The results reported in this section are including results for cohorts a and b.

7.3.1 Accounting or not for transmission of smoking behaviour (M8 versus M10)

The transmission dynamic model for adults outlined in this chapter was evaluated to estimate average lifetime costs and QALYs lost for lifetime period. Results are shown in Table 7.2, differentiating between the model not including transmission of smoking behaviour itself (M8) and the model including transmission of smoking behaviour (M10) for cohorts a and b.

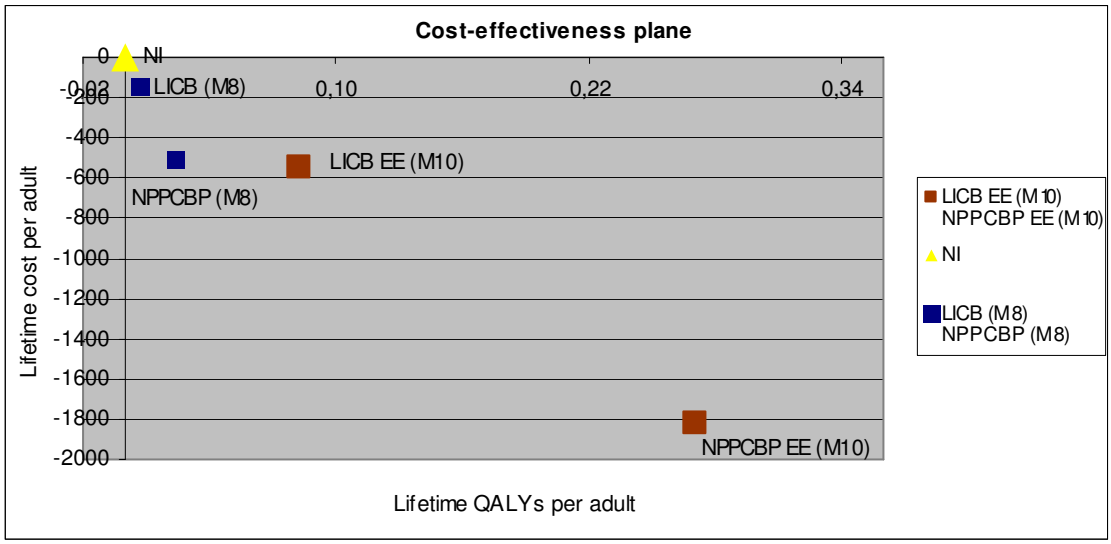
Table 7.2 M8 and M10 estimates of average lifetime costs per smoker and QALYs lost per passive smoker smoker where transmission of smoking behaviour may and may not occur (cohort of 417 adult passive smokers; between 16 and 25 years old ; lifetime period reaching 100 years; starting distribution: passive never smokers)

Interventions	Discounted average COST per adult (M8)	Discounted average COST per adult (M10)	Discounted QALYs lost per adult (M8)	Discounted QALYs lost per adult (M10)	NMB per adult (M8)	NMB per adult (M10)
NI	16849.21	16427.10	8.3498	8.2710		
LICB	16705.27	15878.60	8.3430	8.1881	280.67	2205.76
NPPCBP	16341.05	14604.77	8.3262	8.0003	979.86	7235.80

When including transmission of smoking behaviour there is an extra saving on cost per passive smoker for the most cost-effectiveness intervention of £1736.28, and an

additional QALY lost reduced per passive smoker of 0.3259 (See graph 7.1). This is due to the benefits of the smoking cessation intervention on the never-smokers population living with smokers in the same household.

Graph 7.1 Lifetime costs and lifetime QALYs lost per passive smoker not accounting (M8) and accounting for transmission of smoking behaviour (M10)



In summary, the impact of acconting for the transmission of smoking behaviour into an economic evaluation of smoking cessation programs lies in a cost saving of £1736.28 per passive smoker and less QALYs lost reduced per passive smoker of 0.3259.

7.3.2 Accounting or not for transmission of smoking behaviour and passive smoking (M9 versus M10)

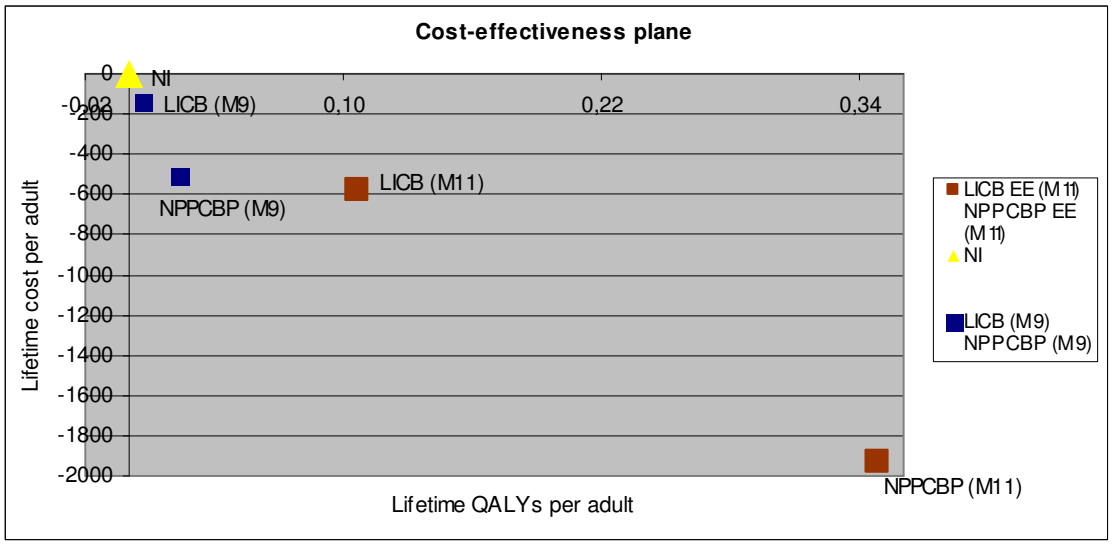
This particular dynamic model was evaluated to estimate average costs and QALYs lost for lifetime period accounting and not for transmission of smoking behaviour and incorporating passive smoking. Results are shown in Table 7.3, differentiating between M9 (model including passive smoking) and M11 (model including transmission of smoking behaviour and passive smoking) for cohorts a and b.

Table 7.3 M9 and M11 estimates of average lifetime costs and QALYs lost per passive smoker where passive smoking in adults and children is incorporated and transmission of smoking behaviour may and may not occur (cohort of 427 adult passive smokers + (96.5% of adult smokers children); between 16 and 25 years (+ 0-15 years); lifetime period reaching 100 years; starting distribution: passive never smokers)

Interventions	Discounted average COST per adult (M9)	Discounted average COST per adult (M11)	Discounted QALYs lost per adult (M9)	Discounted QALYs lost per adult (M11)	NMB per adult (M9)	NMB per adult (M11)
NI	17275.08	16819.34	8.7430	8.6475		
LICB	17131.15	16238.52	8.7362	8.5408	280.67	2713.61
NPPCBP	16766.93	14892.02	8.7194	8.2995	979.86	8885.90

When adding transmission of smoking behaviour to passive smoking, adults, and children passive smoking, there is an extra saving on cost per passive smoker for the most cost-effectiveness intervention of £1874.91, and an additional QALY lost reduced per passive smoker of 0.4199. (See graph 7.2).

Graph 7.2 Lifetime costs and lifetime QALYs lost per passive smoker adult accounting for passive smoking in adults and children (M9) and passive smoking and transmission of smoking behaviour (M11)



In summary, the impact of introducing one or two external effects into an economic evaluation of smoking cessation programs lies in an extra saving cost of £138.63 per passive smoker and less QALYs lost reduced per adult and adult smoker's children of 0.094.

7.3.2.1 Parameter uncertainty

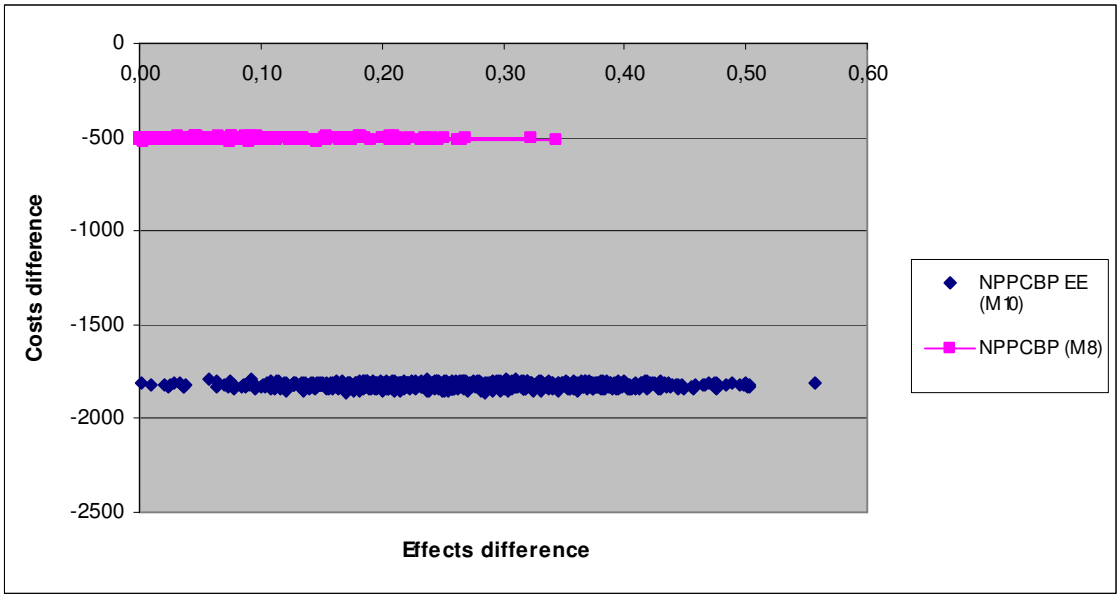
Although the deterministic sensitivity analysis on background quit rate and intervention costs were not uncertainties particularly related to the transmission of smoking behaviour, this sensitivity analysis was calculated for consistency with Flack et al (2007) and, previous chapters of this thesis. Neither the deterministic sensitivity analysis on background quit rate nor intervention costs equal to zero had an impact on the ranking of ICER and NMB in M8, M9, M10 and M11, as expected, though the estimates changed.

Having specified distributions for all the relevant parameters of the models M8, M9, M10 and M11 (same distributions as for M4, M5, M6 and M7), the probabilistic analysis was undertaken. First, results for M8 and M10 are presented, and later on for M9 and M11.

Including transmission of smoking behaviour (M8 versus M10)

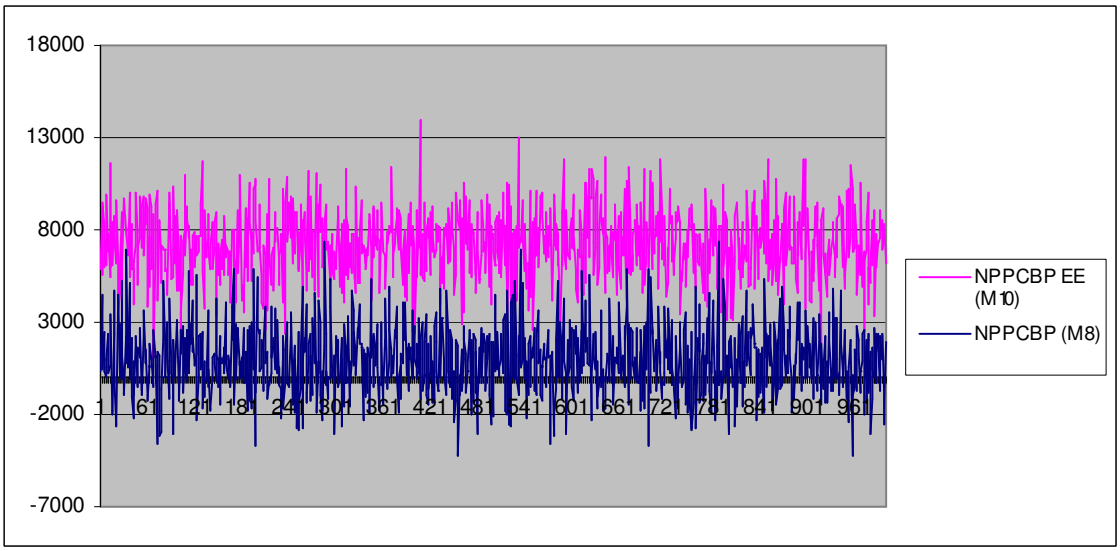
A total of 1000 replications from the model are presented on the cost-effectiveness plane in Graph 7.3 for the model including including transmission of smoking behaviour. Graph 7.3 shows that the majority of simulations lie in the third quadrant from the cost-effectiveness plane. For M8, the 95% CI on costs is (-518.06, -497.36) whereas for QALYs lost is (95%CI (0.1515, 0.2221) for the most cost-effective intervention (NPPCBP).Whereas for M10, the 95% CI on costs is (-1845.39, -1800.78) whereas for QALYs lost is (95%CI (0.0915, 0.4473) for the most cost-effective intervention (NPPCBP).

Graph 7.3 Monte Carlo simulation results on the cost-effectiveness plane for M8 and M10 (including transmission of smoking behaviour)



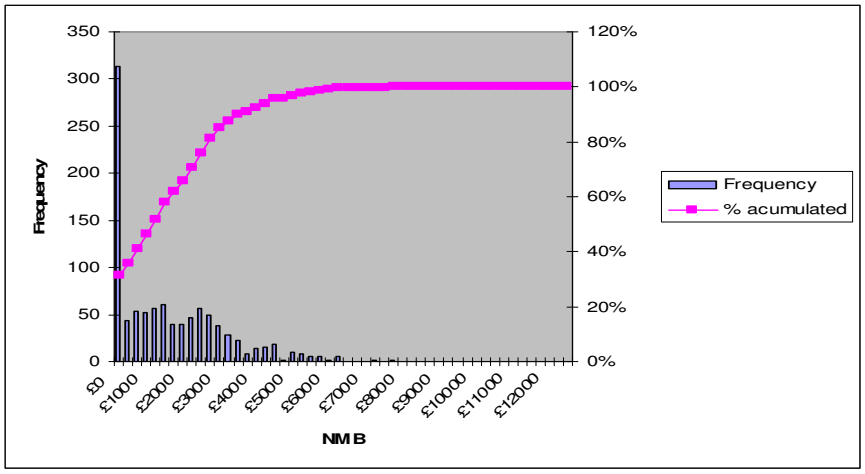
A graphical representation of the uncertainty around NMB, when including (M10) or not (M8) the impact of transmission of smoking behaviour in the most cost-effective intervention is presented in Graph 7.4.

Graph 7.4 NMB when including transmission of smoking behaviour in the most cost-effective intervention (NPPCBP EE; M10) or not (NPPCBP; M8)

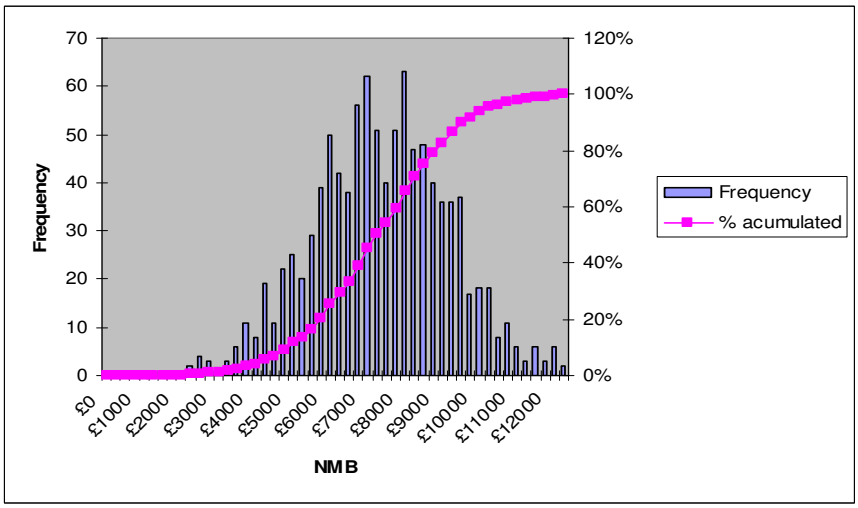


Cost-effectiveness acceptability curves were calculated for incorporating external effects. However, because when external effects are introduced the NPPCBP programme is most cost-effective intervention with a 100% probability, cost-effectiveness acceptability curves are not considered much explanatory, and therefore histograms of NMB for the most cost-effective intervention are presented instead, as in previous chapters 5 and 6. Graph 7.5 presents the histogram of NMB when transmission of smoking behaviour is not accounted for and Graph 7.6 when it is. Graph 7.5 shows that the median (IQR) NMB was estimated approximately £1000 per QALY. Overall, 90% of estimates were estimated to have a point estimate of NMB below £3500. Whereas is Graph 7.6, when transmission of smoking behaviour is accounted for, the median (IQR) NMB was estimated approximately £7250 per QALY. Overall, 90% of estimates were estimated to have a point estimate of NMB below £9500.

Graph 7.5 Distribution of predicted NMB for NPPCBP at M8

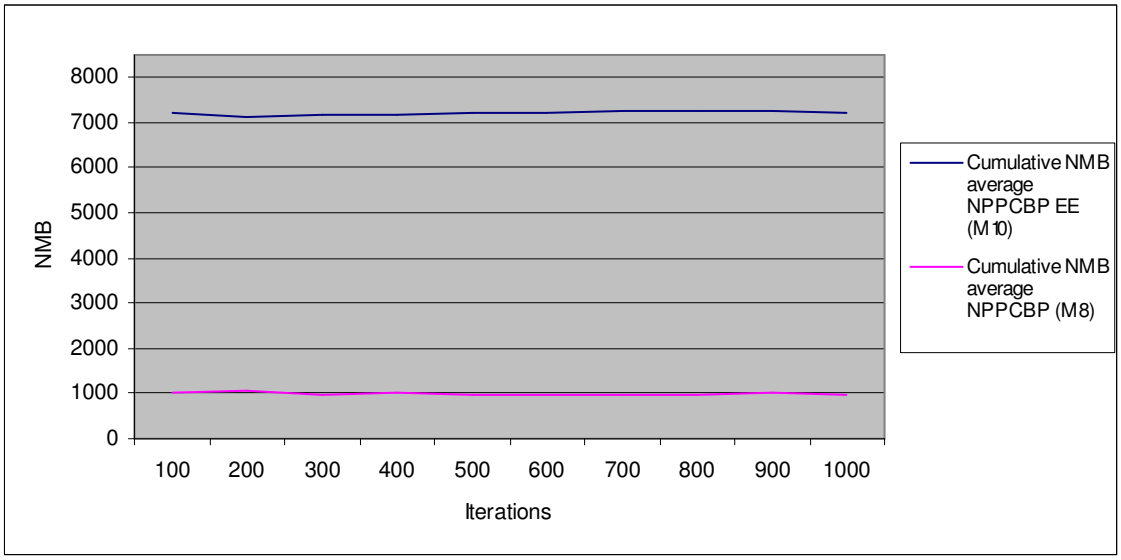


Graph 7.6 Distribution of predicted NMB for NPPCBP at M10



Graph 7.7 shows that around 100 iterations, the results for the most cost-effective intervention when not incorporating transmission of smoking behaviour (M8), are stable, therefore, the results from these thousand iterations seems to be robust. However, around 650 iterations are needed when the transmission of smoking behaviour is incorporated.

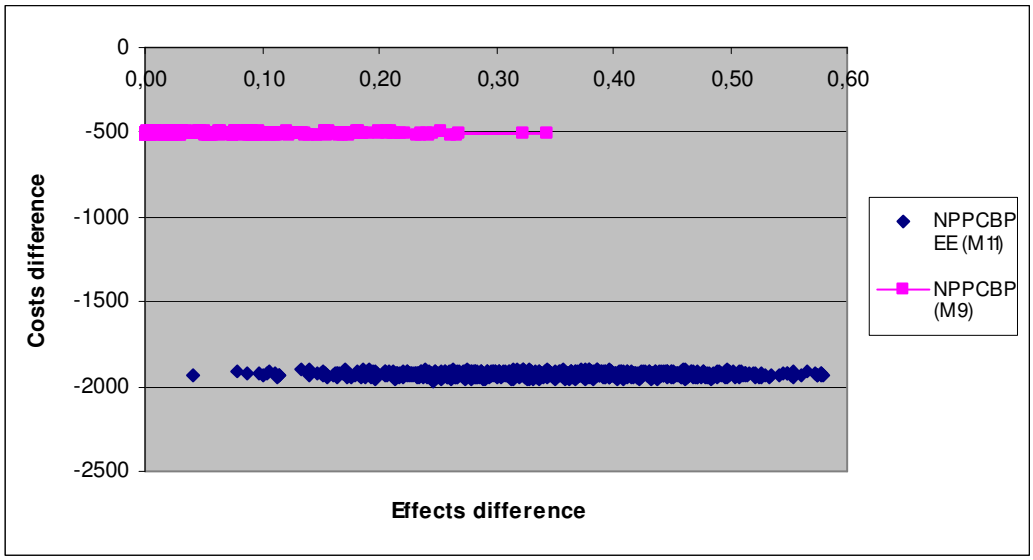
Graph 7.7 Cumulative NMB average for LICB and NPPCBP in M8 and M10



Including transmission of smoking behaviour and passive smoking (M9 versus M11)

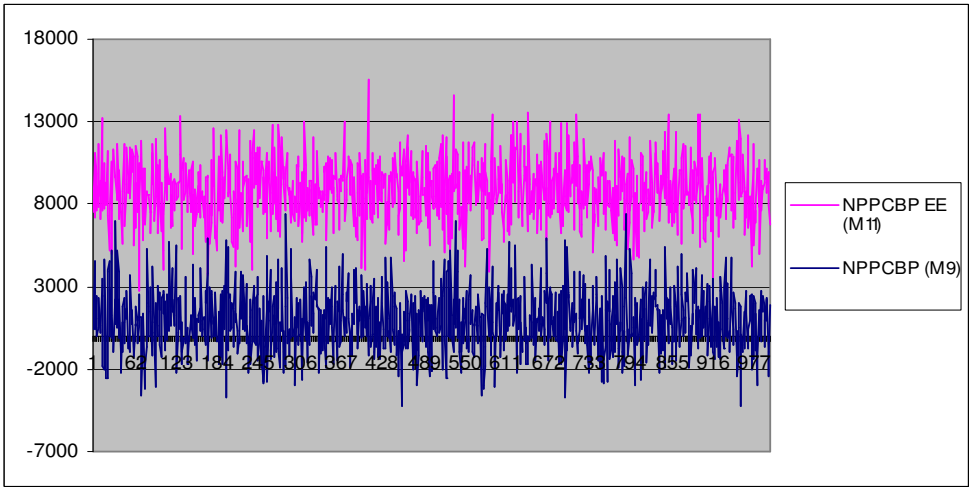
A total of 1000 replications from the model are presented on the cost-effectiveness plane in Graph 7.8 for the model including passive smoking and transmission of smoking behaviour. Graph 7.8 shows that the majority of the 1000 simulations lie in the third quadrant from the cost-effectiveness plane. When passive smoking is introduced in the model the 95% CI on costs is (-518.06, -497.36) and the 95%CI on QALYs lost is (0.1515, 0.2221). However, when transmission of smoking behaviour and passive smoking are introduced the 95% CI on costs is (-1951.82, -1904.53) and the 95%CI on QALYs lost is (0.1688, 0.5243).

Graph 7.8 Monte Carlo simulation results on the cost-effectiveness plane for M9 and M11 (including transmission of smoking behaviour)



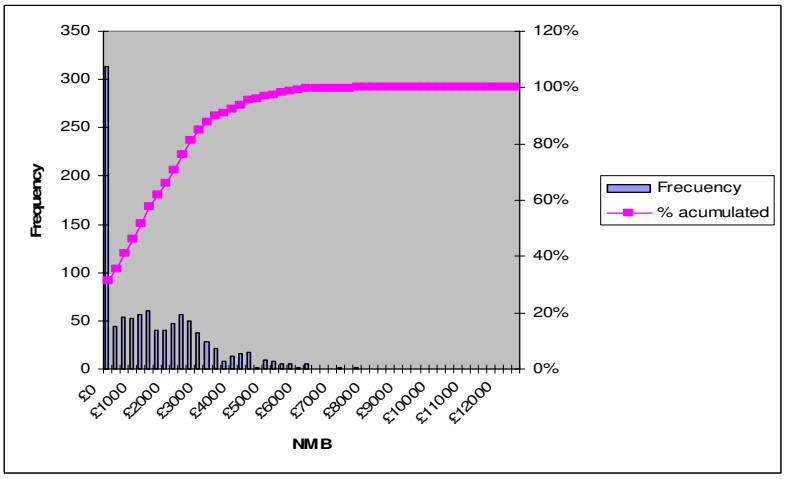
A graphical representation of the uncertainty around NMB, when including the impact of passive smoking and transmission of smoking behaviour (or not) in the most cost-effective intervention is presented in Graph 7.9. Higher NMB is observed when transmission of smoking behaviour is added to passive smoking.

Graph 7.9 NMB when including passive smoking in the most cost-effective intervention (NPPCBP EE; M11) and including passive smoking and transmission of smoking behaviour (NPPCBP; M9)

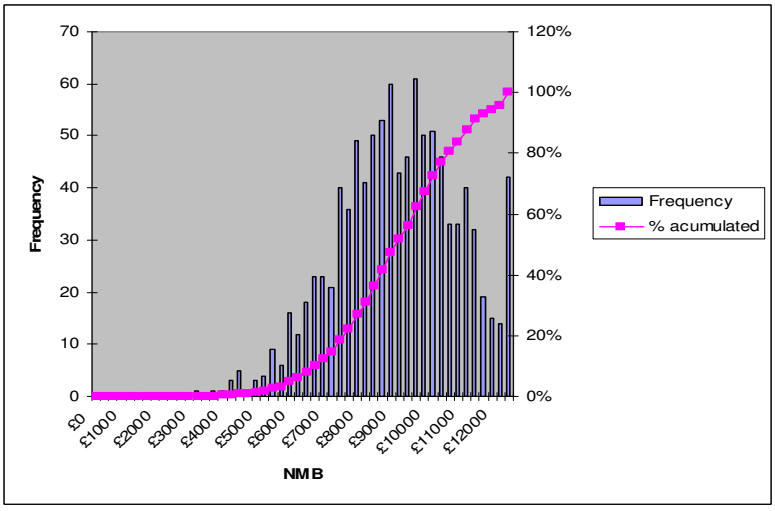


Cost-effectiveness acceptability curves were also calculated for not incorporating (M9) and incorporating (M11) transmission of smoking behaviour, but they were again not considered much explanatory, and therefore histograms of NMB for the most cost-effective intervention are presented instead, as in previous chapters 5 and 6. Graph 7.10 presents the histogram of NMB when passive smoking is introduced and Graph 7.11 when passive smoking and transmission of smoking behaviour. Graph 7.10 shows that the median (IQR) NMB was estimated approximately £1000 per QALY. Overall, 90% of estimates were estimated to have a point estimate of NMB below £3250. However, graph 7.11 shows that the median (IQR) NMB was estimated approximately £9000 per QALY. Overall, 90% of estimates were estimated to have a point estimate of NMB below £11250.

Graph 7.10 Distribution of predicted NMB for NPPCBP at M9

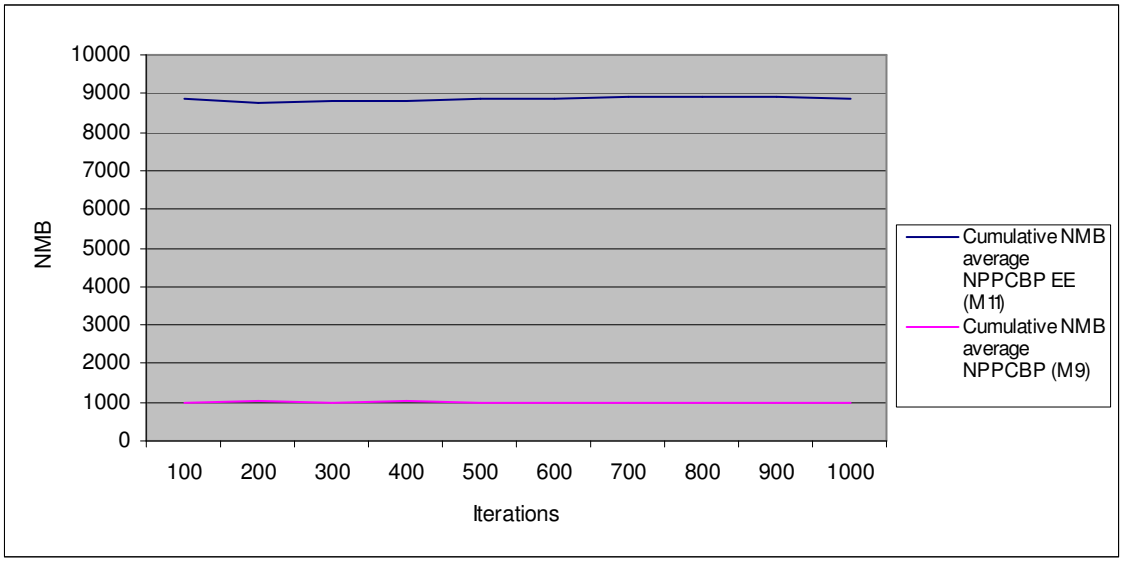


Graph 7.11 Distribution of predicted NMB for NPPCBP at M11



Graph 7.12 shows that around 100 iterations, the results for the most cost-effective intervention when not incorporating transmission of smoking behaviour but incorporating passive smoking, are stable, therefore, the results from these thousand iterations seems to be robust. However, when passive smoking and transmission smoking behaviour are accounted for, up to 650 iterations are needed to reach results stability.

Graph 7.12 Cumulative NMB average for LICB and NPPCBP in M9 and M11



7.4 Discussion

This model incorporates an important aspect associated with tobacco smoking, smoking transmission behaviour, which had not been accounted in the two previous models described in this thesis. This investigation could inform the current policy debate regarding the most cost-effective smoking cessation programs. To my knowledge, published economic evaluation of smoking cessation interventions to date has not addressed dynamics of smoking behaviour.

To incorporate transmission of smoking behaviour, two cohorts of people were needed, trying to capture the influence of a cohort smokers over a passive never smokers cohort. This was the main difference between models from previous chapter 5 and 6. The starting population of the model is different, though the structure of the model is preserved. According to the results, the transmission of smoking behaviour has more impact on lifetime costs and QALYs lost estimates than passive smoking and smoking

during pregnancy. However, difficulties in terms of lack of data were encountered in trying to capture the transmission of smoking behaviour, and therefore results need to be carefully interpreted. Lifetime costs and QALYs were also significantly different when passive smoking was also incorporated in the dynamic model. As expected, changes of the cost-effectiveness ranking were not detected. When passive smoking is already incorporated in the economic evaluation and a second external effect, transmission of smoking behaviour is added, a greater impact in terms of extra lifetime costs and QALYs lost is observed. The impact of transmission of smoking behaviour is shown by the difference, in terms of extra lifetime costs and QALYs lost per passive smoker when comparing M8 to M10 (£1736.28 and 0.3259 QALYs lost per passive smoker) model. Moreover, in the model including passive smoking, the impact of transmisison of smoking behaviour is shown by the comparison between M9 and M11 (£1874.91 and 0.4199 QALYs lost per passive smoker).

Although mathematical modelling has been extensively used to address questions of public health importance, not much has been done in terms of the mathematical modelling of human social behaviour (Brisson et al, 2000; Brisson and Edmunds, 2003; Trotter et al, 2005). In particular, with the exception of the basic model in Brauer and Castillo-Chavez (2000) and Castillo et al (2000), and the extended model in Sharomi and Gumel (2007), the author is not aware of any mathematical study for fully examining the impact of smoking in human population. In addition, none of the existing models has incorporated external effects such as passive smoking or smoking during pregnancy. This chapter demonstrates the possibility of transforming a static model currently informing decision making (ie Flack et al, 2007) into a "dynamic" model.

However, it might be that I can not claim that this is a true "dynamic model". The cohort of passive never smokers declines as the model runs. This is because i) I am not replacing them with new susceptible contacts of the initial smoking cohort (e.g. as cohort a's children move into the 16-25 age group), but also ii) there is no onward transmission from cohort b (e.g. to their children). Therefore, my "dynamic model" is missing second and higher order transmission. How much this matters depends on the circumstances (the force of infection, mixing patterns, etc). If transmission is weak, the second and higher order effects will not make much of a difference to the overall costs and effects. But if transmission is strong, they could outweigh the immediate costs and effects for cohorts a and b (as with an epidemic of an infectious disease).

This unconventional approach undertaken has advantages and limitations in relation to a more conventional transmission dynamic model. The main advantage is to use a common decision analytic tool, such as Markov model, to capture the transmission of smoking behaviour. Therefore, it encourages the incorporation of relevant but complicated external effects, such as the transmission of smoking behaviour, in simple model structures which are used to inform policy making. This fact implies that not extended changes need to be done to the existing economic evaluation models to try to capture broader costs and benefits, and to incorporate the societal perspective into the analysis. However, these advantages also need to be weighted by some limitations. Some assumptions as the household context; number of passive smokers generated by the smokers living in a household are generated; not capturing the transmission of smoking behaviour from adult smokers to other non-adults members of the family, such as children; or not chance to capture different influence on transmission of smoking behaviour according to the particular age of the population need to be considered and recognised when unconventional transmission dynamic approaches are used. Whereas the transmission of smoking behaviour is mainly captured by the probability that a non-passive or passive never smoker comes into effective direct or indirect contact with a smoker (β), unconventional approaches need to try to capture this transmission through modelling different inter-relations into the model, through many times the steps to do so are more transparent and understandable for those who are responsible for taking decisions.

There is not necessarily a conceptual difference between the conventional dynamic model and a Markov-type approach. The later is just a simplified implementation of the former. In both the number of people in a given state at a given time is just the number of people in that state at the previous time point, plus people who entered between the two time points, and minus those who left between the two time points. The main difference regarding the transition probabilities between the health states represented in the dynamic model detailed in Appendix 7.4 and the static model structure used so far (for M4, M5, M6 and M7) is that the number of potential smokers (i.e never smokers) depends on the number of smokers in the population. So far, this has not been considered and incorporated into the cohort model. However, an important difference between a cohort model as the one presented in this chapter and a population dynamic

model is that in a conventional population model I would model a whole population with replacement, whereas in here I have modelled a cohort of 1000 smokers.

Regarding the model structure, there is also a difference around the never smokers health state. Although from chapter 5 onwards, never smokers' health state (i.e potential smokers) has been considered in the model, this had been divided in two different health states: non-passive and passive never smokers. However, Sharomi and Gumel (2007) did not differentiate between non-passive and passive never smokers health state, where it is assumed that both health states are included in the non-smokers group. Therefore, the graphical representation of Box 7.1 and the differential equations from Box 7.2 should be adapted to contemplate the division of the non-smokers health state (see Appendix 7.4 for further details). The only difference between Box 7.1 and Figure 7.1 is that the transmisison of smoking behaviour (coloured in red in Box 7.1) needs to be captured and built into the Markov Model structure (arrows in red in Figure 7.1), making that rate dependant on the number of smokers in the population.

Recruitment of new individuals into the non-smokers health state was considered and included in the basic dynamic model approach by Sharomi and Gumel (2007), whereas no groups of people entering in the model were allowed in previous models built in Chapter 5 and 6 from this thesis. For simplication for the purposes of the PhD, it was decided to stick to that decision and to not incorporate new people entering in the model.

Unlike Sharomi and Gumel (2007) in the Markov model approach: (a) no distinction is made according to frequency of smoking among individuals, and between those smokers who quit smoking either temporarily or permanently because there was no time for this within the scope of this PhD; and, (b) transmission of smoking behaviour is only considering the household context due to data limitations. This last limitation should be considered reasonable regarding the recent smoke-free law which does not allow smoking neither at work or public places. Thus, the household is assumed to be the place where passive smoking more intensively occurs.

Although not considered in this thesis, other factors such as tobacco advertising and mass consumption of tobacco in the community could influence this process (and,

hence, should be included in the function governing the generation of new smokers in the community).

The degree, or frequency, of smoking, where some smokers do so in a mild manner (categorised as mild smokers) while others may smoke more frequently (defined as chain smokers) per unit time should be further explored in the model. The transition dynamics (back-and-forth movement) between these subclasses of varying smoking frequencies is recommended for incorporation into a model to further explore its influence. However, to do so, would require good epidemiological data regarding the frequency of smoking, as of starting smoking, and number of cigarettes smoked every day. There is no quality data on rate of number of new smokers, as detailed in section 5.2.1 in Chapter 5, by age and the number of cigarettes you smoke. This particular data is key for dynamic models of smoking, because this is one of the variables used to calculate the force of infection. Panel data could be really useful to calculate the trend of the probability of uptake of smoking by age. It would, however, be preferable to have such data classified by whether current smokers were passive smokers prior to the uptake of smoking in order to capture the transmission of smoking behaviour estimate.

Further research could be carried out in order to study the transmissibility of smoking behaviour. The basic reproduction number (Ro, which is a composite measure of the transmissibility, is the main component of the force of infection), can be defined as the average number of people who start smoking produced by one smoker introduced into a never smoker population, should be explored. This basic reproduction number has not been calculated in this model because it is out of the scope of this thesis, but it is assumed to be captured in the force of infection concept. To calculate a better estimate of the force of infection, there is a need to explore and calculate the basic reproduction number of smoking. It would also be interesting to know the epidemic feature of smoking (Gomes et al, 2005), how the force of infection evolves with times passes and, how the smoking cessation interventions are influencing the trend of that parameter. With a more complete understanding of lifetime smoking dynamics, it would be possible to forecast how overall population smoking rates would vary in the short and long run

According to Bantle and Haisken-DeNew (2002), youths living in families with both parents smoking are 3.3 times more likely to smoke themselves, while a ‘smoking’

father raises the probability by the factor 2.8 and a 'smoking' mother by the factor 2.1. Therefore, further research should be done in the future trying to distinguish these grades of influence according to sex.

Apart from passive smokers, data was extrapolated from a household context (see section 5.2.2, Chapter 5). This is intuitive as the closer you are to a smoker, and therefore you are considered a passive smoker, the more you are likely to be influenced by the smoking behaviour. However, this feature could be further explored (i.e. transmission of smoking behaviour when you are a never smoker by media or other forms of influencing people).

The dynamic model built in this chapter incorporates a proxy for a heterogeneous mixing pattern of population to describe the transmission dynamics of smoking behaviour. This indicates that transmission of smoking behaviour exists with people between 16 and 25 years old. However, Flay et al (1994) shows the existence of differential influence of parental smoking and friend's smoking on adolescent smoking. Also, peer effects have also been widely studied. Therefore, future 'smoking' dynamic models could account for the different relationship of smoking by age to smoking uptake and cessation by different age groups. Social interactions play a prominent role in determining behavioural and economic outcomes on smoking. These issues concerning interactions effects are sure to remain a fertile ground for future research. Moreover, in the future, this type of model taxonomy could be transferred to study the impact of dynamics on public health interventions of other behavioural problems, such as obesity (Christakis and Fowler, 2007) or alcohol (Mortimer and Segal, 2006).

The person-to-person spread of smoking cessation appears to have been a factor in the population-level decline in smoking in recent decades (Christakis and Fowler, 2008). Moreover, there appear to be different clusters in the society (age groups, people with same social activities, receiving same type of education and attending same institution, etc) within the social network which could lead to different transmission of smoking behaviour patterns (Christakis and Fowler, 2008). This suggest a potential further research step to create a network of analytic methods to study the extent of the person-to-person spread of smoking behaviour and the extent to which groups of widely connected people quit together, though it seems that not much data is available to do it reliably.

This chapter shows that including dynamic effects seems to be worthy. Although there is a need to recognise that there is no good data available on the contact rate between smokers and never smokers, which drives the impact of transmission of smoking behaviour, the numerical impact seems not to be important. Therefore, the conclusions of this chapter seem to point that developing a dynamic model seem to be worthy to incorporate transmission of smoking behaviour in economic evaluation of smoking cessation interventions. Further research on getting a better estimate on the beat parameter could be plausible; however, policy making regarding smoking cessation programmes is likely not to be affected by the findings.

CHAPTER 8 Comparison of all models including and not external effects

8.1 Introduction

Chapter 8 compares the models used in chapters 5 to 7 (M4 to M11) to explore the potential impact of incorporating external effects into decision-making for public health programmes. It considers the size of the various external effects valued in this thesis and their relative importance in terms of costs and QALYs. The comparison also provides a natural point for reflection on the methods by which to incorporate external effects into the economic evaluation of public health programmes. In so doing, this chapter: (a) compares the incorporation of the impact of passive smoking, smoking during pregnancy and transmission of smoking behaviour into the economic evaluation of smoking cessation programmes and (b) examines the methods used to incorporate external effects into economic evaluation of those interventions.

Although the results of all eleven smoking cessation programmes have been calculated, this chapter focuses mainly on the most cost-effective intervention because the ranking of cost-effectiveness did not vary between interventions.

8.2 Value of incorporating passive smoking, smoking during pregnancy and transmission of smoking behaviour in the economic evaluation of smoking cessation programmes

The main purpose of this section is to compare and contrast the eight models presented in chapters 5 to 7 some of which include external effects and others that do not.

Table 8.1 shows the differences across models in terms of costs and QALYs lost according to the population group modelled. This table presents results separately for those models dealing with the general population, those focusing on pregnant women, and those focused on a cohort of smokers (cohort a) generating a cohort of passive smokers (cohort b). Cost and QALYs in M5 represent the burden on the 3.5% of adult passive smokers and the 96.5% of child passive smokers in the population that is

generated by the 22% of the population modelled who are smokers. The starting population in this case was 1000 adults categorised according to their smoking status. However, in M6 where the population (n=1000) is pregnant women the effects of smoking during pregnancy are accounted for in the 'burden' identified as the average number of babies delivered by pregnant woman (M7). Costs and QALYs from the general and pregnant population are difficult to compare because these groups experienced different smoking cessation programmes and varying levels of effectiveness' (NPPCBP for general population and BAD for pregnant women). For instance, the interventions for pregnant women are specifically designed for this particular group of the population. Moreover, from M8 to M11, the starting population is a cohort of 1000 smokers and a cohort of 417 passive smokers. This also adds difficulties on the comparisons among models. The table below presents the standard error of the difference between the two means, which was calculated using the methods of unequal variance (Armitage et al, 2002):

$$SE\ (avg1 - avg2) = \sqrt{((s1^2/n1)+(s2^2/n2))}; \qquad (E8.1)$$

where "avg" is average, 's'' the standard deviation of each mean, and 'n' the sample size.

Table 8.1 Comparison of incremental lifetime costs, QALYs lost and NMB differences per person between models for the most cost-effective intervention (from M4 to M11)

Models	Description of models	Most cost-effective intervention	Discounted average COST per adult or pregnant	Incremental cost (mean and SE)	Differences in COST	Discounted average QALYs lost per adult or pregnant	Incremental QALY lost (mean and SE)	% Differences in QALYs lost	NMB[70]	Incremental NMB (mean and SE)	% Differences in NMB	Units
General adult population												
M4	Replication of Flack et al (2007) model with relevant changes considered and changes to the starting distribution of population	**NPPCBP**	3582.76	base case	base case	3.4024	base case	base case	1267.66	base case	base case	per adult lifetime
M5	M4 including passive smoking	**NPPCBP**	3736.83	154.07 (79.98)	4.30%	3.5022	0.0998 (0.0673)	2.93%	2460.12	1192.46 (85.20)	94.06%	per adult lifetime
Pregnant women population												
M6	Replication of Flack et al (2007) model, for females only, with relevant changes considered, including changes to the starting distribution of population	**BAD**	1433.82	base case	base case	4.0995	base case	base case	645.20	base case	base case	per pregnant woman during pregnancy
M7	M6 including impact of newborn babies from smokers mothers	**BAD**	1543.76	109.94 (8.94)	7.66%	4.3239	0.2244 (0.0285)	5.47%	2989.97	2344.77 (136.06)	363.42%	per pregnant woman during pregnancy
Smokers (cohort a) and passive smokers (cohort b)												
M8	M3 used to model a cohort of 1000 smokers, and M4 used to model a cohort of 417 passive smokers generated by a smoker. Not including transmission of smoking behaviour	**NPPCBP**	16341.05	base case	base case	8.3262	base case	base case	979.86	base case	base case	per adult lifetime
M10	M8 including transmission of smoking behaviour	**NPPCBP**	14604.77	-1736.28 (280.34)	-11.88%	8.0003	-0.3259 (0.0777)	-4.07%	7235.80	6255.94 (193.74)	638.45%	per adult lifetime
M9	M3 used to model a cohort of 1000 smokers, and M4 used to model a cohort of 417 passive smokers generated by a smoker. Not including transmission of smoking behaviour but including passive smoking	**NPPCBP**	16766.93	base case	base case	8.7194	base case	base case	979.86	base case	base case	per adult lifetime
M11	M9 including transmission of smoking behaviour and passive smoking	**NPPCBP**	14892.02	-1874.91 (280.87)	-12.59%	8.2995	-0.4199 (0.0908)	-5.06%	8805.90	7826.04 (216.94)	798.69%	per adult lifetime

[70] The NMB is calculated when a QALY (lost or gained) is valued at £20 000.

The lifetime discounted average cost and lifetime discounted QALYs lost from an adult population (M4) are compared with results obtained when passive smoking of adults and children (M5 for adult and child passive smokers. The biggest impact in terms of NMB is for transmission of smoking behaviour (see Table 8.1). When M5 (adult population including adult and child passive smokers) is compared with M4 (adult population) lifetime costs per adult increase by 4.30%, lifetime QALYs lost by 2.93% and NMB by 94.06%.

For the population of pregnant women, discounted lifetime average cost and discounted lifetime QALYs lost (M6) are compared with results obtained when health impacts on babies' first year of life (M7) are incorporated. When M7 (pregnant women, including average number of babies delivered per pregnancy) is compared with M6 (pregnant women) lifetime costs increases by 7.66%, lifetime QALYs lost by 5.47% and NMB by 363.42%.

For the smokers and passive smokers cohorts discounted lifetime average cost and discounted lifetime QALYs lost are compared. The first comparison tries to isolate the transmission of smoking behaviour (M8 versus M10) and the second comparison adds the impact of transmission of smoking behaviour on top of passive smoking consequences. In both cases, the transmission of smoking behaviour when a smoker cohort is receiving smoking cessation interventions highlights a positive external effect in terms of savings costs and QALYs lost to the population. This external effect seems to be the most relevance in terms of costs and QALYs gained.

No prior comparison of the importance of these external effects exists in economic evaluations of smoking cessation programmes and there is scant awareness of the impact of external effects on economic evaluation outside smoking cessation programmes. Fortunately, however, the Department of Health recognises the effects on babies health due to smoking during pregnancy as the principal impact of tobacco on others' health (SCOTH, 2004) and reflects this view in policy its making (for example, smoke-free law introduced in public places in UK). The findings of this thesis as to which are the most important external effects therefore match both empirical evidence and policy direction.

The uncertainty of parameters surrounding incremental NMB increases with the higher lifetime costs and QALYs lost differences. For instance, there is higher parameter uncertainty in the area of costs and QALYs for the general adult population than for pregnant women. Therefore, the incorporation of external effects into economic evaluation adds bias around the ICER or average NMB, and more uncertainty, but this has to be balance against the fact that bias is reduced as more relevant costs and health effects are accounted for.

NICE's 'Methods for the development of NICE public health guidance' (2009) recommends using 'reference-case' assumptions as a basis for cost-effectiveness analysis: (a) the perspective on costs should be public sector, including NHS and PSS and (b) the perspective on outcomes should include all health effects on individuals. This implies that all costs generated by smoking should be included in economic the evaluation of smoking cessation programmes. Failing to incorporate external effects, therefore, is inconsistent with the advice on the appropriate reference for public health, and decision making based on this position involves a degree of bias, because of missing costs and health effects generated by smoking, around the ICERs presented in the cost-effectiveness analysis of smoking cessation programmes. (i.e. NHS costs and health effects of passive smoking including effects on baby health caused by smoking during pregnancy are not included in the economic evaluation of smoking cessation programmes). NICE also argues that the guidance development process must ensure that *all* important health effects and resource costs are included in an economic evaluation but when external effects are excluded, this does not happen.

The findings of this thesis suggest that transmission of smoking behaviour is the external effect with the largest impact. This should, therefore, be considered the most important external effect to be incorporated in economic evaluations of smoking cessation programs. Interestingly, this external effect also happens to generate the most inappropriate and weak data with which to measure and value it. Although much research in the last 20 years has focused on the transmission of smoking behaviour (Bantle and Haisken-De New, 2002; Harris et al, 2008; Ditre et al, 2008; Alexander et al, 2001; Christakis and Fowler, 2008; Simons-Morton et al, 2001; Gilleskie and Strumpf, 2000), there is little data on transmission parameters. Chapter 7 highlighted the lack of data of the beta parameter which drives the whole model. The beta parameter

has been studied for longer in vaccination than other programmes, so better proxies are available in that area (Farrington, 1990; Scott et al, 2004). Future research should, therefore, encourage better estimates of the beta for the transmission of smoking behaviour to improve study of the impact of this external effect.

The incorporation of external effects produced no difference in the ranking of the cost-effectiveness of the different public health interventions but this was expected because smoking cessation programmes are highly cost-effective. It follows, therefore, that no impact on decision-making could have occurred between competing programmes. Nor would the inclusion of these external effects have changed a decision about whether the best or worst intervention would be cost-effective, because the evidence already showed that the smoking cessation interventions were very efficient uses of public expenditure. Adding these external effects would simply further improve their existing levels of efficiency. However, when considering less cost-effective public health programmes (i.e. if the ICER were closer to £20,000 or £30,000) this may well have had an effect on decision making. To answer this question, future research could focus on the incorporation of external effects into less cost-effective interventions than smoking cessation programmes.

There is evidence (Brisson and Edmunds, 2003; Ford et al, 2004; McIntosh et al, 2005) that incorporating positive external effects, such as the herd-immunity effect, into economic evaluation makes a difference in terms of costs and QALYs. Research for this thesis identified a similar pattern for negative external effects. The main positive external effect that has been studied so far (herd-immunity effect) and the negative external effects assessed in the health area, have been on the consumption side. Findings in chapter 3 highlight that in sectors other than health, such as transport or environment, external effects on the consumption side have been the most studied part of the market. However, external effects do exist on the production side (see Chapter 3), so future research could incorporate external effects on the production side and compare both their absolute and relative importance with those on the consumption side.

As may be seen in chapter 4, in the areas with a long tradition of measuring and valuing external effects, there is no specific criterion as to which external effect to choose. The general criterion used by these sectors was the availability of epidemiological data to

justify the importance of that particular external effect. Chapter 5, 6 and 7 also highlight the importance of considering the availability of data when deciding whether or not to incorporate a particular external effect. In order to sharpen choice when deciding which of several different external effects to incorporate into an evaluation when all have enough available data on their epidemiological relevance, future research should attempt to establish a criterion which will rank the importance of external effects.

8.3 Methods for incorporating external effects into the economic evaluation of public health interventions

Although it might be assumed that when two different external effects are incorporated in an evaluation model, (e.g. transmission of smoking behaviour and passive smoking) the impacts on extra lifetime costs and lifetime QALYs lost will be a simple summary of individual external effects (i.e. transmission of smoking behaviour plus passive smoking or smoking during pregnancy), this may not be the case. This is because the populations included in each model are different and therefore the number of total costs and QALYs do not lend themselves to simple summitry. For instance, M5 (which included the external effect of passive smoking), and M11 (which included transmission of smoking behaviour and passive smoking) included a different starting population, according to smoking habits and a smokers cohort respectively. The inclusion of children increased the population of these two models (M5 and M11) when compared with the other models. However, smoking during pregnancy is accounted for by falls in the average number of babies delivered at the end of the pregnancy. The populations of M6 and M7 were pregnant females, including a group of three month pregnant smokers who remained pregnant for the first six-month cycle. M7 (which included smoking during pregnancy) included the average number of births per pregnant smoker in addition of the cohort of pregnant smokers during the fertile period assumed to be from 16 years to 44.5 years old. All differences in population across all models suggests that ideally, the model best able to incorporate external effects appropriately would be a general whole population model rather than one for a cohort. Including everyone in the model facilitates the interpretation of results for lifetime costs and QALYs lost, and eases comparisons across models with comparable populations.

Table 8.3 compares the population characteristics for each model developed in this thesis. Appendix 8.1 provides details of the full set of population characteristics and the analytic horizon of all models used.

Table8.3 Population characteristics from M1 to M11

Models	Population			
	Adults	Passive adults and children	Pregnant women	Average babies from pregnancy delivery
M1	√	x	x	x
M2	√	x	x	x
M3	√	x	x	x
M4	√	x	x	x
M5	√	√	x	x
M6	x	x	√	x
M7	x	x	√	√
M8*	√	x	x	x
M9*	√	√	x	x
M10*	√	x	x	x
M11*	√	√	x	√

√≡ included in the model
x≡ not included in the model
*≡ different starting population. Model composed by two cohorts: cohort of 1000 smokers (cohort a) and 417 passive smokers generated 1000 smokers (cohort b).

M1, M2 and M3 considered everyone starting as a smoker, whereas in the other models, the cohort was distributed according to smoking habit prevalence by age and sex. This was needed in order to incorporate the external effects of passive smoking into the model. Therefore, two extra population groups were included from M4 onwards (i.e. never smokers who are non passive and never smokers who are passive) to account for passive smoking.

Apart from differences of populations across models, other parameters and assumptions had to be adjusted to enable the incorporation of external effects. A summary of relevant parameters and assumptions used alongside models may be found in Appendix 8.2. Incidence rates were needed from M4 to M11, when 'never smokers' who were either non passive or passive were incorporated into the model to account for adult

passive smoking (see section 5.2.1, Chapter 5). Conversion from being a passive 'never smoker' or on passive to a smoker was expressed as a transition probability.

When passive smokers were accounted for in M5 and M11, extra costs were incorporated into the cost-effectiveness analyses to cover QALYs lost, and the incidence of asthma, wheeziness, cough, acute otitis media and otitis media with effusion episodes, generated among passive child smokers between the ages of 0 and 15 years, When adult passive smokers were accounted for using the same models (for both M5 and M11) extra costs were introduced for QALYs lost because of lung cancer and coronary heart disease. However, when the external effect of smoking during pregnancy was accounted for in M7 extra costs were incorporated in the economic evaluation for QALYs lost lifetime for SIDS and QALYs lost for first year of life for LBW.

In Chapters 5 and 7, one assumption adopted was that passive smoking is irrelevant if you are a smoker or former smoker. Another was that it does matter if you are a never smoker. The justification for this position is that most evidence concerning the risks of passive smoking involves never smokers not smokers or former smokers who were passive smokers in the same population. In order to ensure strict coherence with the data, this assumption was adopted in the model.

Data on passive smoking was derived from the Health Survey for England (HSE) (2006), which assumed a household context. At the time, that assumption was reasonable. Today of course, it is forbidden by law to smoke in public places (e.g. at work) but in the past this was not the case. Sloan et al (2004) provided a detailed analysis of the price of smoking, which explained both the burden imposed on the smoker and his/her family and that placed on other unwilling members of society. The health effects of smoking on others were proxied by valuing the effects of environmental tobacco smoke defined simply as being married to a smoker and therefore, also a proxy in a household context. Ignoring other sources of exposure to secondary smoke on which they had no information, such as other persons in the household, the workplace and in other public areas, was one of their main assumptions Therefore, this chapter supports the findings of Sloan et al (2004) who examined the impact of external effects on the household and attempted to incorporate this valuation into economic evaluation - the UK tool of decision makers. According to the HSE

(2006), passive smokers are created by those who smoke inside and not outside the house/flat. Therefore, this assumption could slightly mislead the actual rate of prevalence of passive smokers.

No robust trials and epidemiological studies have been conducted to confirm the link between the illnesses outlined in Chapters 5 and 7 and passive smoking. There appears to be enough evidence to conclude that smoking is causally associated with tuberculosis [TB] (Chiang and Enarson, 2007), but the relative incidence of risk for passive and non passive smokers is not possible to calculate at the moment. Little data on the effect of ETS on disease of the eye (Lois et al, 2008) exist in the literature.

A static model such as the Markov was used in this thesis to incorporate passive smoking and smoking during pregnancy into economic evaluations. This suggests that a taxonomy of models of economic evaluation is so far, incomplete. Barton et al (2004) provided an overview of alternative approaches to modelling in economic evaluation and highlighted situations where each of the alternative modelling techniques could be employed. The authors recommend that the selection of the appropriate model for the evaluation of a health care intervention should be based on the independence of individuals in the model. If there is interaction between individuals and therefore feedback on external effects (i.e. transmission of smoking behaviour), then discrete event simulation and dynamic models should be used. The authors recommend decision trees and Markov models when there are no external effects. However, no modelling approach is recommended when external effects exist but there is no feedback (i.e. passive smoking or smoking during pregnancy). Therefore, findings from this thesis indicate that when that is the case, a decision tree and Markov model could be used to incorporate external effects which have no feedback. The taxonomy established by Barton et al (2004) does not specify which is the most adequate model for incorporating external effects into economic evaluation, when interaction between individuals does not occur. The expanded taxonomy in the paper by Brennan et al (2006) does not resolve this issue either.

Static Markov models are, therefore, able to account for some external effects - at least those (passive smoking and smoking during pregnancy) which appear to have a higher impact on costs, QALYs lost and NMB, as demonstrated in this thesis. However, this opens the debate as to whether or not it is sensible to move to dynamic models in order

to capture transmission of behaviour. According to findings in Chapter 7, transmission of smoking behaviour has the highest impact on costs and effects when used in the economic evaluation of smoking cessation programmes. However, it needs to be recognised that results of the dynamic model are driven by the contact between smokers made with never smokers (beta), and no sound evidence was found for this parameter. It was proxied with the data available but better quality data is needed, in order to ascertain the true impact of transmission of smoking behaviour. There will always be a trade-off between understandable and intuitive models and the complicated new generation of models. The findings of this thesis indicate that one should use static Markov models to incorporate widely recognised external effects supported by available epidemiological data and be conservative in the use of dynamic models, unless sound and reliable data is available. This might be explored further in the future research agenda.

Chapter 3 shows that contingent valuation approaches to cost-benefit analysis, have been used extensively to measure and value health and non-health related external effects in other sectors. However, only those studies which incorporated health effects were examined here: non-health effects were not calculated. One of the strengths of this thesis is that it demonstrates that cost-effectiveness analysis is an appropriate way to incorporate external effects under the NICE approach. Chapter 3 confirms that cost-benefit analysis has been extensively used in other sectors to incorporate non-health effects. It is possible, therefore, that a broader measure than QALYs would incorporate non-health effects more successfully. For example, environmental impact is a non-health effect attributable to smoking because there is some evidence of the social damage caused by cigarette butts in roadways (Novotny et al, 2009) or, more seriously, of fires (ODPM, 2006). Further research into the incorporation of non-health effects could strengthen the debate about whether NICE should reconsider the CBA as the primary rather than secondary analysis, especially now that health technologies have been added to its portfolio of public health programmes to be assessed.

8.4 Summary

This chapter summarise average lifetime costs and QALY gained or lost differences alongside models that include and others that exclude external effects (from M4 to

M11). These comparisons provide a clear picture of the magnitude of costs and QALYs lost for each external effect, their differences and the uncertainty around the estimates currently being used. Methods by which external effects may be incorporated into public health interventions are also discussed.

CHAPTER 9 Conclusion

9.1 Introduction

In the context of health policy, consideration of passive smoking and smoking during pregnancy has played a central role in the provision of public health programs. There was therefore, a need to incorporate the valuation of these external effects into economic evaluation to improve its relevance as a decision making tool. Of particular importance in the empirical studies of this thesis was the need to demonstrate how external effects could be accounted for in the economic evaluation of smoking cessation interventions and to study the impact of external effects on guidance based on cost-effectiveness analyses given to decision makers. The findings suggest that when external effects are introduced into the economic evaluation of smoking cessation interventions, lifetime costs and QALYs lost change, though the ranking of interventions is not modified, as might have been expected. The subsequent sections of this chapter offer: (a) an overview of the contributions of the thesis to the literature; (b) the limitations of the thesis; (c) the policy implications of the findings; (d) recommendations for future research; and, (e) and concluding remarks.

This thesis has been structured in nine chapters. Chapter 2 explains the economic theory of external effects and its application to health care markets. It specifies types (positive and negative) and categories (technological and pecuniary) of external effects, reviews private and public solutions for the use of these effects and sets the context for provision of public health programmes. It also explores the importance of accounting for the external effects of health care in economic evaluations in the context of NICE. In conclusion, it explains the need to review the measurement and value methods used to incorporate external effects into the economic evaluation of public health programmes.

Chapter 3 explores measures and approaches to the valuation of external effects and conducts a systematic literature review of nine different sectors with a tradition of using external effects. Negative technological external effects were the most commonly studied in those nine sectors and they were concentrated on the consumption side of the market. The most studied aspect of external effects was their impact on health and the

environment using a wide range of different measures, and the most frequently used approach to the evaluation of external effects was contingent valuation which was used to inform cost-benefit analyses. However, NICE recommends the use of cost-effectiveness analysis as the first approach for economic evaluation of public health interventions. Therefore, this was the approach used to value and incorporate external effects into economic evaluation of a public health programme.

Chapter 4 reviews economic evaluations of smoking cessation programmes which have incorporated external effects. As no previous economic evaluation was found a new form of economic evaluation is suggested for smoking cessation programmes to inform NICE guidance (Flack et al, 2007a), and this replicates the model which incorporates the external effects of smoking. This chapter evaluates the accuracy of replication methods; discusses the model and its replication; and, incorporates changes in the model to overcome its deficiencies or modelling limitations and incorporate external effects. The main change in the model is the addition of two new population groups (non-passive and passive never smokers) to facilitate the incorporation of external effects.

The first external effect to be incorporated in the economic evaluation of smoking cessation interventions is passive smoking in adults and children, and it is detailed in Chapter 5. The population models the smoking status of a thousand adults, by age and sex. To account for passive smokers between the age of 0 and 16 years, the external health effects of 96.5% of these young passive smokers generated from the smoker population modelled are factored into the process. The health effects caused by passive smoking in adults are lung cancer and coronary heart disease, and those for children are asthma, wheezing, cough, acute otitis media, and otitis media with effusion. The smoking cessation programmes are focused on a general adult population. Although there is no impact on the ICER and NMB ranking, as predicted, there is an impact on the proportion of extra costs (£154.07) per adult and QALYs lost (0.0998) per adult when passive smoking in both adults and children, is incorporated into the economic evaluation. The increment on NMB of £1192.46 is due to the incorporation of passive smoking into the model.

Chapter 6 incorporates the impact on the first year of babies' lives caused by their mothers' smoking during pregnancy. The population modelled in this case is one thousand pregnant women, categorised by age and smoking status during the pregnancy

period. To account for health effects on the first year of babies' lives, the average number of babies delivered per pregnancy was incorporated into the model. The health effects identified are low birth weight and infant sudden death syndrome. In this chapter, the smoking cessation programmes are focused on pregnant women. Although there is no impact on the ICER and NMB ranking, as expected, there is an impact on the proportion of extra costs (£109.74) and QALYs lost (0.2244) per pregnant woman when smoking during pregnancy is incorporated into the economic evaluation. The increase in NMB of £2344.77 is due to the inclusion in the model of health effects on the first year of babies' lives.

In chapter 7, transmission of smoking behaviour is incorporated into the economic evaluation of smoking cessation interventions as a single external effect and in combination with passive smoking. The same static Markov model used in Chapters 5 and 6, but two different cohorts are modelled in here, one depending one the other. As in chapters 5 and 6, there is no impact on the ICER and NMB ranking. When transmission of smoking behaviour alone is incorporated into the economic evaluation, it has an impact on savings costs (-£1737.81) per adult, QALYs lost reduced (0.3218) per adult. When transmission of smoking behaviour is incorporated in previously passive smoking model, it has a greater impact on savings costs (-£1876.42) per adult, QALYs lost reduced (0.4161). The highest positive impact on costs, QALYs lost and NMB occurs where external effects appear in combination with transmission of smoking behaviour.

Chapter 8 compares the varying impacts on costs, QALYs lost and NMB of the incorporation of transmission of smoking behaviour itself or together with passive smoking into the economic evaluation of smoking cessation programmes. It also discusses the methods used to incorporate external effects into economic evaluation of public health interventions. The incorporation of the transmission of smoking behaviour on its own has a higher impact on costs and QALYs lost, than incorporation of either passive smoking or smoking during pregnancy alone. Because of its high impact, there seems great benefit in building dynamic models of the economic evaluation of smoking cessation programmes simply to introduce transmission of smoking behaviour. This thesis also shows how static models might be used in cost-effectiveness analysis to incorporate health related external effects. However, non health related effects are not

considered in this thesis and broader measures than QALYs may well be needed to value them. CBA could be used to incorporate these non health external effects, as other sectors traditionally use them.

9.2 Contributions of the thesis

The relevance of incorporating external effects into public sector decision-making is well documented. However, to date, they have rarely been incorporated into economic evaluations of public health programmes. This thesis has filled a gap in the literature by including health related external effects in an economic evaluation, using smoking cessation programmes as a case study.

The most important contribution which this thesis makes to research on health related external effects is to detail the methods by which these effects may be incorporated into the economic evaluation of costs and QALYs, and to compare the relative importance of different types of external effects and their impact on the evaluation. It has demonstrated that static Markov models might be used to incorporate non-dynamic external effects and dynamic models may be used to incorporate external effects with dynamicity or transmission.

For first time, passive smoking, smoking during pregnancy and transmission of smoking behaviour is quantified in terms of cost and QALYs as a result of incorporating these external effects into cost-effectiveness analyses. This thesis explicitly incorporates the societal impact of certain external effects to aid the public health decision making process, thus improving the quality of economic evaluation by enabling the social costs of smoking behaviour to be measured.

Economic evaluation of other public health interventions could be helped by this research in four different ways. First, as it has proved possible to use cost-effectiveness analyses to incorporate negative external effects on the consumption side, the same methodology could be used for other type of public health interventions, particularly behavioural programs, because of the possibility of including dynamics effects (e.g. transmission of eating habits in the context of obesity or alcohol consumption in homes where parents regularly abuse this substance). Secondly, prior to incorporating external

effects in economic evaluation, it is important to think about the availability of epidemiological data as this will determine the extent to which external effects can be incorporated into an economic valuation of public health programmes. Thirdly, findings from chapter 3 shows that contingent valuation is the approach most frequently used in other sectors with a long tradition of measuring and valuing non-health external effects and this suggests that broader measures than QALYs might be needed it to incorporate non-health related effects. This opens the debate as to whether cost-benefit analysis is the most appropriate way of incorporating non-health effects.

This thesis is the only health study that has adapted the categorization of external effects from non-health related disciplines. No other study has attempted such a cross-disciplinary approach.

9.3 Limitations of the thesis

Notwithstanding its contributions, this thesis has its limitations and these are detailed below in order of importance.

The main limitation is that it has not found a criterion that can be used consistently to distinguish the most relevant external effects, impacts and measurements to guide decision making. Some studies chose to concentrate on a particular external effect in order to establish the full social costs and benefits as a basis for efficient pricing and allocation of resources, or to study the implications for economic evaluation. However, no established criteria exist to rank the importance of external effects and their inclusion depends currently on epidemiological evidence and the size of costs and QALYs.

Non-health effects were not considered. Chapter 3 indicates that a broader measure will be needed to capture this type of external effects. Findings from this research suggest that cost-benefit analysis is the most appropriate way of including those effects that are not in cost-effectiveness analyses. The incorporation of non-health effects might challenge the primary analysis used by NICE (cost-effectiveness analysis).

Only external effects on the consumption side generated by smoking are incorporated in this thesis. However, external effects on the production side generated by smoking (e.g.

tobacco companies and the economy of countries which produce tobacco) have not been incorporated. These external effects on the production side might have the opposite impact, in terms of ICER or NMB, to external effects originated on the consumption side by smoking and affect policy decision regarding economic evaluation of smoking cessation programmes.

There are also data weaknesses in the economic evaluation of smoking cessation programmes and the valuation of external effects, as for example, the validity and generalisability of the quitting and relapse rate in the economic evaluation of smoking cessation programmes. In general, further research should rely on better estimates on the relapse rate. In addition, the evidence of effectiveness provided by Flack et al (2007a) and Flack et al (2007b) is taken from very diverse sources and trials with a significant disparity of sizes. This suggests that effectiveness rates may not be comparable in the same robust way across smoking cessation programmes for adult and pregnant women populations.

Some data weaknesses relate to external effects. Firstly, economic valuation of pregnant women accounts only for general female mortality rates in the pregnancy age interval. No burden of gestation-specific infant illnesses and neonatal and post-neonatal mortality rates has been considered in order to keep the model simple, though some data on mortality has been published (Moser et al, 2007). Moreover, according to Blair et al (2006) most SIDS deaths happen within the first 8 months of life, though this economic evaluation assumed the RR of smokers for SIDS to be constant for the first 5 years of life Secondly, the modelling has been limited by a reliance on self report data for passive smoking prevalence. In particular, the use of the definition 'living with a smoker' captures less than half the variation in cotinine concentration in non-smokers (Breteler et al, 1994) and does not take into account exposure in workplaces and public areas (Llewellyn et al, 2009). Measurement of cotinine by medical appliances or staff would have provided more robust estimates. In addition, the model only considers passive smokers who have never smoked, which precludes those smokers and former smokers who also rationalise themselves as passive smokers.

The quality of the studies used to identify data may also be questioned. All study designs used were vulnerable to potentially important confounders, yet many of these were not recorded or, if recorded, could not be adjusted for in any analysis.

Furthermore, studies did not describe measures taken to prevent bias, and no intervals recommending values for further use in policy decisions (Eshet et al, 2005) were reported.

Finally, there are differences between costs on the original model (M1) and the replication (M2). M2 was peer-reviewed by health economists from the Health Economics Research Group and by Matthew Taylor from the York Health Economics Consortium, one of the authors of M1. The cost detailed in the NICE report for an episode of myocardial infarction was not the one used in the model 1 (M1). The cost they used was higher than it should have been which could explain the higher costs they obtained in the ICER compared with those from this research. The results for QALYS are similar, the trend in costs and QALYs among different interventions following the same direction in both models. Therefore, one could accept the replication of the M1 as correct and add the external effects. There are also limitations inherent within the basic model that has already been noted by Flack et al (2007a). First, due to the lack of data on the relative risk of contracting each condition by smoking status' it was not possible to split former smokers into 'recent' and 'long-term' categories. It is unclear what the impact of this simplification will have on the models' results. If the probability of developing some or all of the conditions returns to the level found in non-smokers after a certain period of time, the model will have overestimated the number of people with each condition. This in-turn may have resulted in an overestimation of the associated costs and an underestimation of the associated QALYs. Moreover, models should have been accounted for by different smoking frequency levels and adjusted for that.

9.4 Policy implications of the findings from the thesis

The findings of this thesis generally suggest that although the ranking of cost-effective interventions does not change with the addition of external effects, there is a clear impact on costs and QALYs. This has implications for public health interventions generally and smoking cessation in particular.

To date, most smoking cessation therapies and programmes that have been shown to offer effective treatment have also been highly cost-effective (Parrot and Godfrey, 2004;

Lazzaro and Nardini, 2008). Incorporating passive smoking, smoking during pregnancy and transmission of smoking behaviour does not change the ICER or NMB ranking and would not, lead NICE to change its recommendations on smoking cessation in respect of those effects. However, other public health interventions with ICERs closer to the £20,000 threshold should be evaluated to see if the incorporation of external effects would change policy guidance.

Incorporation of negative external effects on the production side (e.g. productivity losses in tobacco producer companies) might be the only factor capable of changing policy making for smoking cessation because it reduces the gain in cost per QALY lost. Accounting for these external effects would imply the need to study the impact of non-health benefits and move towards the use of CBA.

The findings of this thesis suggest that discrete population models would be a more appropriate means of incorporating external effects because they can be used to compare the impact of incorporation without the need for complex and difficult comparisons that stem from populations with a multiplicity of sub-sections.

9.5 Research agenda

Future research could now be taking forward by: (a) incorporating and modelling external effects in economic evaluation; and, (b) improving the smoking cessation research agenda.

The research agenda for modelling external effects could include:

a) Developing methods to account for non-health related external effects. This would imply moving to CBA which would challenge the primary analysis used by the NICE approach (cost-effectiveness analysis);
b) Exploring the impact of incorporating external effects on the production side (i.e. tobacco companies) of the economic evaluation of smoking cessation interventions. Potential changes in the ICERs or NMB ranking could be observed with the incorporation of these external effects;

c) Considering whether guidance on public health interventions closer to the £20,000 or £30,000 threshold might change if external effects were accounted for in economic evaluation;
d) Developing general population models for the evaluation of public health programmes in order to incorporate and assess the differences between various external effects and and avoid problem of multiple populations.

This research would also suggest that the smoking cessation agenda could benefit from the following research:

e) Further study of the impact of transmission of smoking behaviour, with better data evidence, especially for the force of infection;
f) One of the most important parameters of this model is the uptake rate for smoking. This parameter was proxied regarding the data available on the Health Survey for England (2006). In that study, people were asked at what age they started smoking. The problem is that the current tendency to start smoking would almost certainly have varied during the recently extended National Health Service smoking cessation interventions. The intention was to track individual over time but this was precluded because household identification codes were different for each survey wave. Better data is needed if one is to make reliable estimates of the incidence of smoking;
g) However, the validity and generalisability of the effectiveness (i.e. quit and relapse rate) rates of the smoking cessation programmes used in the model are limited. Meta-analyses during effectiveness trials would be needed to ensure the appropriateness of trials and the validity of comparisons made by them;
h) There is a lack of up-to-date evidence meta-analysis on the health effects of passive smoking by children. There is, for example, some evidence to the effect that smoking is causally associated with tuberculosis (Chiang and Enarson, 2007) and diseases of the eye (Lois et al, 2008) but it was not possible to obtain meta-analyses of the relative risk to passive and non-passive smokers. Meta-analyses of the health effects of passive smoking by children would greately help future estimates of these factors.

9.6 Concluding remarks

This thesis contributes to knowledge in a variety of ways. Firstly, it provides the first empirical analysis in the UK of the effects of incorporating the external effects of public health smoking interventions into the decision making process for economic evaluation. The analysis shows that incorporating external effects into economic evaluation makes a clear difference, to costs and QALYs, in the cost-effectiveness analysis of public health interventions.

Secondly, it has contributed to the setting of a research agenda for the incorporation and modelling of external effects in economic evaluation and the smoking cessation agenda.

Thirdly, it suggests improvements that need to be considered when making economic evaluations of smoking cessation interventions, by replicating an existing model from NICE. It has also demonstrated that static models can be used to incorporate non-dynamic external effects. However, when compared with the external effects of passive smoking and smoking during pregnancy, transmission of smoking behaviour has a greater impact on costs and QALYs in economic evaluation. This suggests that there is probably need to develop further dynamic models in smoking cessation interventions.

Fourthly, it identifies different categories of external effects by applying definitions from other disciplines to the area of public health. It also identifies methods for the measurement and evaluation of external effects in nine different areas and attempts to extrapolate these methods to the health field.

The overarching purpose of this thesis has been to incorporate external effects into economic evaluation using smoking cessation interventions as a case study. The substantive contribution has been to estimate the size of passive smoking, smoking during pregnancy, and transmission of smoking behaviour. Comparison of the size of different types of external effects and their impact on economic evaluations indicated that transmission of smoking behaviour has the biggest impact on costs and QALYs in the economic evaluation of smoking cessation programs, whereas for a population of pregnant women, the external health effects on babies' is has the lowest impact on costs and QALYs. This thesis is the only study that has estimated the size of these external

effects, and incorporated them into economic evaluation of a public health programme. It therefore contributes to an improvement in the potential quality of future economic evaluations and decision making.

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APPENDICES

Appendix 1.1 Editorial published by Trapero-Bertran et al (2009a)

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Editorial

Evaluación económica de las intervenciones antitabáquicas: ¿nos dejamos algo en el tintero?

Economic Evaluation of Smoking Cessation Interventions: Have We Overlooked Something?

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Mundialmente el consumo de tabaco es, junto con el sida, la mayor causa de fallecimientos[1–6]. Si los patrones de consumo actuales persisten, en el siglo xxi habrá cerca de mil millones de muertes causadas por esta adicción[1–6]. Además, sus efectos están creciendo rápidamente año a año, lo que se debe, entre otras causas, a los efectos ralentizados del aumento del tabaquismo en la población más joven[1–6]. El número de jóvenes fumadores del año 2000 tendrá una fuerte influencia en el número de muertes en el año 2050 y posteriores[1–6]. La realidad es que el tabaco inflige mortalidad y morbilidad, y continúa costando cifras de miles de millones a las Administraciones Públicas. Aunque en los últimos años los gobiernos europeos han trabajado de firme en campañas y medidas antitabáquicas, las estrategias públicas que deben seguirse continúan formando parte de todos los foros de discusión. Trabajos publicados recientemente en España, en esta misma Revista, describen y promueven intervenciones contra el tabaquismo[7,8]. Aunque falta evidencia para valorar los resultados de la deshabituación tabáquica a largo plazo[9], parece evidente que la mayor parte de las intervenciones en este sentido son coste-efectivas; es decir, el número de personas que dejan de fumar, teniendo en cuenta el ahorro de costes en términos de morbilidad y mortalidad, compensa con creces el coste adicional de la intervención desde el punto de vista social[10]. Ahora bien, desde el enfoque más analítico de la economía de la salud, surgen dudas sobre si las evaluaciones económicas utilizadas para facilitar la correcta toma de decisiones comprenden un cálculo correcto y realista del impacto que tiene el tabaco en la morbilidad y mortalidad y del consecuente ahorro de costes. Algunas de las preguntas fundamentales son: ¿es realista el número de muertes y comorbilidades asociadas al tabaco de las evaluaciones económicas actuales que se emplean para la toma de decisiones?, ¿son importantes los efectos externos como el tabaquismo pasivo?, ¿cómo debemos incluirlos en las evaluaciones económicas?

El objetivo de las evaluaciones económicas en intervenciones antitabáquicas es comparar cuál es la intervención que con menos recursos consigue disminuir, en mayor cantidad, el número de fumadores y, con ello, las comorbilidades asociadas, de las cuales podríamos destacar el cáncer de pulmón, la enfermedad coronaria, la enfermedad pulmonar obstructiva crónica, el infarto de miocardio y el accidente cerebrovascular (ictus)[10]. Durante esta última década, en la que se han desarrollado los métodos de evaluación económica, se ha hablado siempre de 3 elementos para poder calcular el coste de las enfermedades: costes directos, costes indirectos y costes intangibles[11]. Los costes directos son, en la mayoría de los casos, los recursos en el sector sanitario, pero a veces podrían incluir gastos en que incurre el paciente y recursos de otras agencias estatutarias y cuerpos voluntarios[11]. Los costes indirectos se entienden, en la mayoría de los casos, como tiempo laboral y, costes y beneficios indirectos son sinónimos de pérdidas y ganancias de productividad[11]. Por último, los costes intangibles se refieren a aquellas consecuencias que son difíciles de medir y valorar, como la mejora en salud per se, o el dolor y el sufrimiento asociados a un tratamiento determinado[11]. Aunque todos ellos tienen una definición, ninguno de estos términos se utiliza de manera homogénea en los trabajos de investigación, donde no hay un concepto unívoco de costes, con lo que la mayor parte de estas denominaciones crean confusión, en lugar de conducir a la homogeneidad de criterios. Si aplicamos estos conceptos de coste a las intervenciones antitabáquicas, está claro que podremos calcular la carga de enfermedad, pero ¿realmente contemplamos todos los costes significativos que origina el tabaco, u obviamos otros costes relevantes? Según las definiciones anteriores, las evaluaciones económicas simplemente contemplarían costes internos, es decir, costes originados por y para la persona que recibe la intervención antitabáquica, incluidos los directos y los indirectos. Pero ¿qué sucede con los costes externos? ¿Es que no son importantes los costes que un fumador ocasiona a la sociedad?

En mi opinión, los costes externos constituyen un concepto que debería incorporarse en las evaluaciones económicas, ya que hay evidencia de que producen una carga en salud relevante en nuestra sociedad[12–14]. Los efectos externos se definen como aquellas acciones de una persona o empresa que imponen un coste a otras personas o empresas sin que éstas reciban

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compensación alguna, o bien, cuando una persona o una empresa beneficia a terceros pero no obtiene una recompensa por proporcionar ese beneficio[15]. En el ámbito del tabaco, los efectos externos que se exhiben son negativos; es decir, generan costes a la sociedad. Se podría citar como ejemplo los riesgos para la salud de los no fumadores debidos al humo del tabaco en el ambiente, lo que se conoce como tabaquismo pasivo[12]. La consideración de los efectos externos en la evaluación económica es cada vez más común, como se demuestra en publicaciones recientes[11,16,17]. La asignación de recursos a la evaluación económica de intervenciones antitabáquicas no será óptima a menos que se contemplen todos los costes y beneficios de la intervención; es decir, para que estos cálculos sean certeros, es necesario estudiar cómo tener en cuenta e incorporar los efectos externos a estas intervenciones. La importancia capital de incluir su valoración reside en que la toma de decisiones podría estar basada en evaluaciones económicas inapropiadas si no se consideran los efectos externos. En otros campos como el medio ambiente[18], el transporte[19], la agricultura[20], la innovación[21] o la tecnología[22], se han contemplado, medido y valorado los efectos externos desde hace tiempo, pero éste no es el caso en salud. Recientemente se han publicado 4 trabajos sobre efectos externos dentro del ámbito sanitario[23–26]. En los 4 casos se trata de efectos externos positivos, es decir, beneficios para la sociedad. Tres de ellos valoran los efectos externos de un programa de vacunación en el contexto de una evaluación económica[23–25], y el restante habla de la importancia de incorporar los efectos externos humanitarios en las evaluaciones económicas en el área de la salud[26]. Estos efectos externos humanitarios, conocidos como *caring externalities*, emergen cuando la utilidad o satisfacción de un individuo es una función creciente de la atención sanitaria recibida por otros individuos en la sociedad[26]. Los 3 primeros trabajos son los únicos publicados, según mi conocimiento, que hacen referencia a la valoración e incorporación de los efectos externos en evaluaciones económicas dentro del área de la salud, concretamente en el área de las enfermedades infecciosas[24,25]. Es decir, incluyen y valoran no sólo el beneficio que genera una vacuna al individuo que la recibe, sino también el beneficio que esta intervención reporta a la sociedad. En estos trabajos se destaca la importancia de incorporar estos beneficios sociales a las intervenciones sanitarias. En el caso de las intervenciones antitabáquicas, 3 de los efectos externos ocasionados por el tabaco y referenciados en la literatura médica como relevantes son: el tabaquismo pasivo[12], la influencia del comportamiento de un fumador en su entorno[27] y el consumo de tabaco de una mujer embarazada[28].

Ahora bien, la siguiente pregunta que surge es: ¿cómo medimos o valoramos estos costes externos? En los estudios antes citados, el método que se utiliza para valorar el efecto positivo externo de la vacuna de la meningitis es la aplicación de un modelo de transmisión dinámico que tiene en cuenta que, en la medición del impacto de la intervención, el riesgo de la infección depende de la prevalencia de los individuos infectados en la población. De esta manera, en la evaluación económica se incorporaría el efecto externo positivo a la valoración del impacto y, en consecuencia, los costes y beneficios de la intervención. En el caso del tabaco, hay evidencia de que su consumo actúa como una epidemia, ya que en las familias el hecho de que el padre, la madre o ambos sean o no fumadores ejerce una influencia involuntaria en el comportamiento de los hijos respecto al tabaco[27]. ¿Podríamos utilizar estos modelos dinámicos para valorar los efectos externos del tabaco? De hecho, el carácter epidémico en los primeros momentos de la juventud parece que puede estudiarse utilizando modelos matemáticos dinámicos. Existe una clara dinamicidad en el comportamiento de la persona; cuando mayor sea el número de fumadores, mayor será la probabilidad de que otros individuos empiecen a fumar y mayor será el número de fumadores pasivos. A partir de evidencia reciente se recomienda el uso de los modelos dinámicos para valorar el impacto del tabaco en la sociedad[29]. Parece, pues, que los modelos dinámicos ofrecen una forma de medir y valorar algunos de los efectos externos en salud. Desde hace mucho tiempo se emplean en áreas como el medio ambiente o la innovación, aunque en estos ámbitos se denominan modelos de red (*network models*). Si bien estos modelos constituyen una opción clara para medir los efectos externos, su uso no es imprescindible. Estos modelos matemáticos son complicados y la mayoría de las veces necesitan aplicaciones informáticas especializadas que rara vez son intuitivas. Es cierto que los modelos dinámicos representan una opción para incorporar efectos externos a la evaluación económica de intervenciones sanitarias, pero también puede recurrirse a otros métodos, de menor calidad en el estricto sentido metodológico, pero que no dejan de ser aproximaciones a la valoración de los efectos externos.

De hecho, en un trabajo reciente sobre el tabaquismo se mide y valora el efecto externo del tabaquismo pasivo[12]. Los cálculos se hacen sobre la base de la reducción de la esperanza de vida que sufre un individuo casado con un fumador. No es un método de cálculo complicado y, al mismo tiempo, cumple la función de estimar el coste social del tabaquismo pasivo.

En resumen, y dando respuesta a las preguntas que al principio nos planteábamos, el hecho de no incorporar los efectos externos en las evaluaciones económicas hace que el número de muertes y comorbilidades asociadas no sea realista y, por lo tanto, pueda conducir a la toma de decisiones inapropiadas. La evidencia disponible destaca el tabaquismo pasivo como un efecto externo relevante, pero ni en el área de la salud ni en otras áreas hay consenso sobre la metodología que debería utilizarse para su valoración. Parece pues que se abrirían líneas de avance en el tema de los efectos externos si se pudiera dar respuesta a cuestiones como en qué medida cambiarían las decisiones tomadas por los órganos responsables de política si se incluyeran dichos costes externos en las evaluaciones económicas, y si estos modelos podrían hacerse extensivos para el cálculo de las externalidades de cualquier intervención.

Simplemente espero que este editorial haya suscitado el interés de los lectores en referencia a la incorporación de los efectos externos en las futuras evaluaciones económicas dentro del área de la salud.

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opinión

¿CUAL ES EL IMPACTO SOCIAL DE QUE YO FUME?: UN CASO APLICADO A EFECTOS EXTERNOS

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Las externalidades o efectos externos expresan las consecuencias de una acción/actividad realizada por un agente económico que recaen sobre terceros de manera no intencionada alterando sus utilidades y/o sus funciones de producción, sin que sean compensados por ello[1].

Grandes economistas como Arrow, Stiglitz, o Culyer, entre otros, han definido dos tipos de efectos externos. Por un lado los negativos, aquellos que generan costes sociales, y por otro los positivos, aquellos que generan beneficios sociales, siendo ambos tipos susceptibles de aparecer tanto en actividades relacionadas con la producción como con actividades de consumo.

También se han establecido dos categorías principales de efectos externos: los tecnológicos y los pecuniarios. Los primeros se definen como aquellos que tienen un efecto en los recursos. Un ejemplo típico sería la contaminación generada por una fábrica o residuos de su proceso productivo. Los segundos se definen como aquellos que operan a través de los precios. Por ejemplo, un aumento de la demanda de viviendas en un área rural podría incrementar los precios de éstas generando así dificultades a otros agentes para acquirir una propiedad en esa zona. Entre estas dos categorías, las que han recibido mayor atención a lo largo del tiempo han sido los tecnológicos. Si aplicamos la definición de efectos externos tecnológicos al campo de la salud, podrían definirse como aquellas acciones que afectan a la salud de terceros. Un ejemplo de efecto externo tecnológico negativo sería el tabaquismo pasivo, entendido como la inhalación involuntaria del humo del tabaco existente en espacios cerrados, el cual procede de la contaminación del ambiente producida por el humo de tabaco consumido por las personas fumadoras, que conlleva una serie de enfermedades asociadas.

A lo largo de la última década, en la que tanto se ha avanzado en los métodos de evaluación económica, hemos hecho uso de los costes y beneficios privados de las diferentes intervenciones o programas, sin contemplar, en la mayoría de ocasiones, estos efectos externos. Es lógico que, frente a este escenario, nos planteemos si la metodología que empleamos es la más adecuada para medir y valorar el impacto en las políticas públicas de un programa y si estamos valorando correctamente el coste y beneficio social de una intervención.

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Legado de los efectos externos en otras disciplinas

La medición y valoración económica de los efectos externos ha sido un campo estudiado históricamente por disciplinas como la agricultura, el medio ambiente, la innovación, la tecnología, las telecomunicaciones, los transportes y la educación.

La Comisión Europea ha publicado varios trabajos evaluando el impacto social de diferentes políticas públicas relacionadas con la energía, transportes y medio ambiente, en donde se identificaban, medían y valoraban los efectos externos generados[2-4]. Estos trabajos han servido de punto de partida y guía para desarrollar numerosos estudios de impacto de diferentes programas o intervenciones, aunque su influencia en el campo de la salud ha sido muy limitada.

De estas disciplinas podemos importar los tipos y categorías de efectos externos que han sido utilizados de manera homogénea. Por otro lado, aunque las metodologías de cuantificación utilizadas no siguen un criterio explícito, sí coinciden en la importancia y necesidad de su valoración, y exponen ejemplos de posibles métodos a utilizar. Algunas de estos métodos serían la valoración contingente a través de estudios de capacidad de pago (o también llamados "willingness to pay"), precios hedónicos, modelos de elección discreta, método del capital humano, costes de tratamiento, costes de reemplazo, método del coste del viaje, o métodos de coste de limpieza. Si bien es cierto que no existe una pauta detallada sobre cuándo se debe utilizar un método concreto en vez de sus alternativas, lo importante es que existen métodos con los que podemos empezar a cuantificar los efectos externos. En disciplinas como el medio ambiente, la evaluación de los efectos externos se ha llevado a cabo a través de modelos dinámicos o de red, los cuales permiten la modelización de la transmisión de partículas contaminantes a través del aire, siendo una herramienta útil a tener en cuenta en otras disciplinas para modelizar procesos de transmisión. Los efectos externos más ampliamente estudiados han sido los tecnológicos negativos. Ello nos permite atisbar un sinfín de posibilidades en el campo de la investigación de los efectos externos más comunes y que más atención requerirían en el área de la salud.

¿Qué conocemos de los efectos externos en salud?

Kenneth Arrow en un artículo seminal publicado en 1963 en la revista American Economic Review ("Uncertainty and the welfare economics of medical care") ya identificó los efectos externos como fallo de mercado característico del mercado de salud. El ejemplo citado en su artículo, en un contexto de enfermedades transmisibles, era el caso de un individuo que rechazaba vacunas o diagnóstico. Al obrar de este modo, este individuo no sólo ponía en riesgo su salud sino la de terceras personas. Con este sencillo ejemplo podemos ver que el coste o beneficio privado de un programa de vacunación no coincide con el coste o beneficio social, lo que nos lleva a una asignación y distribución de los recursos sub-óptima. Trabajos más recientes[1] ha seguido estudiando y destacando la importancia de los efectos externos en salud en conjunción con la evaluación económica, aunque al final vemos pocas aplicaciones pragmáticas de la teoría a la hora de tomar decisiones. En ocasiones, los economistas de la salud lo acabamos incluyendo estos efectos en los análisis debido a que no existen criterios o metodologías explícitas de como incluirlos. Recientemente se han publicado trabajos donde uno de los objetivos establecidos era cuantificar los efectos externos[5-6]. En éstos trabajos se han utilizado diferentes métodos cuantitativos para valorar diferentes efectos externos positivos originados por un programa de vacunación. En una publicación del año 2003, Brisson y Edmunds cuantificaron el efecto rebaño de un programa de vacunación con un modelo dinámico, y en cambio, en el año 2004, los mismos autores utilizaron la valoración contingente para cuantificar el efecto humanitario de una vacuna.

Tenemos diferentes ejemplos de efectos externos tecnológicos en salud y de su relevancia. Por ejemplo, el conocido "efecto rebaño" (o "herd-immunity effect"), se trata de un efecto externo positivo, derivado de los programas de vacunación. En el trabajo de Trotter y Edmunds (2005)[7], los autores plantearon un estudio de evaluación económica de la vacuna conjugada para la enfermedad meningocócica por serogrupo C incluyendo y no incluyendo el "efecto rebaño". La metodología empleada fue un modelo dinámico, el cual permitió que la probabilidad de transición a un estado infeccioso dependiera del número de individuos infectados en una población, de la probabilidad de contacto entre individuos y de la efectividad de transmisión de la infección en el contacto. La conclusión de este trabajo demuestra que cuando no se contemplan los efectos externos se hace una infravaloración del impacto de la vacuna, y por tanto, la toma de decisiones puede resultar errónea.

Asimismo, existe una amplia bibliografía sobre los efectos externos positivos humanitarios (también llamados "caring externalities"), que emergen cuando la utilidad o satisfacción de un individuo es una función creciente de la atención sanitaria recibida por otros individuos en la sociedad[8]. A pesar de que muchos de estos trabajos encuentran evidencia de que existen diferencias entre los beneficios sociales que reporta a la población y el beneficio o valor que éstos estarían dispuestos a pagar para que terceras personas se beneficiaran, no se ha estudiado demasiado la magnitud de estos efectos externos y su influencia en la toma de decisiones.

Otros ejemplos menos estudiados son el efecto externo negativo producido por el desarrollo de infecciones nosocomiales debido a intervenciones hospitalarias; el efecto externo positivo de disminución de agresiones o crímenes gracias a campañas de prevención de alcohol; el efecto externo negativo del tabaquismo pasivo producido por el hábito tabáquico, el cual se verá mas adelante en detalle; o incluso efectos externos negativos alimentarios en la familia debido a desequilibrios en los hábitos alimenticios de una persona adulta en el hogar. Como vemos, la disciplina sanitaria contiene multitud de ejemplos de efectos externos, aunque no sabemos exactamente su grado de relevancia, su magnitud y su influencia aplicada en la toma de decisiones. Y, aunque existe evidencia que los modelos dinámicos son una alternativa a considerar para poder incorporar sus efectos, su utilización no es condición sine cua non para poder valorar dichas externalidades.

Tabaquismo: un caso aplicado de efectos externos

El tabaco inflige mortalidad y morbilidad y continúa generando un coste sanitario de miles de millones de euros a las Administraciones Públicas europeas. Aunque en los últimos años los gobiernos europeos han trabajado firmemente en campañas y medidas antitabáquicas, las estrategias públicas que se deben seguir continúan formando parte de todos los foros de discusión. La evaluación económica es, y ha sido, una herramienta clave para facilitar la correcta toma de decisiones en

programas de deshabituación tabáquica, a pesar de que podrían surgir dudas sobre si el número de muertes y comorbilidades asociadas al tabaco utilizados en las evaluaciones económicas actuales se podrían considerar realistas o no. Hasta ahora, simplemente se han contemplado los costes privados originados por el tabaco, es decir, los costes originados por la persona que fuma. Pero, ¿qué sucede con los costes externos?, ¿Es que no son importantes los costes que un fumador ocasiona a la sociedad? Hay evidencia en la literatura de que, en el contexto de la adicción tabáquica, se generan tres efectos externos importantes: el tabaquismo pasivo, fumar durante el embarazo y la transmisión de comportamiento entre los fumadores (Un excelente trabajo reciente es el de Harris y González López Valcárcel [9]). Volviendo a nuestra clasificación de externalidades, se trataría de efectos externos negativos que surgen por el lado del consumo y su naturaleza es tecnológica, ya que afectan al bienestar o salud de los individuos ajenos de modo directo a la acción de fumar. La realidad es que aunque somos conscientes de que existe este coste social en ocasiones lo ignoramos, sin tener evidencia de la magnitud que este coste representa.

Las enfermedades más importantes asociadas al tabaco son el cáncer de pulmón, las enfermedades coronarias, la enfermedad pulmonar obstructiva crónica (EPOC), y el accidente cerebrovascular. Existe evidencia de que las tres primeras están asociadas al tabaquismo pasivo, con lo que estamos infravalorando los datos de morbilidad y mortalidad del tabaco. Sloan (2004)[10] en uno de sus últimos trabajos, "*The price of smoking*", cuantifica el efecto externo del tabaquismo pasivo, aunque no incorpora esta valoración en una evaluación económica para medir el impacto. Los cálculos los hace en base a la reducción de esperanza de vida que sufre un individuo casado con un fumador. Este trabajo es un ejemplo de estimación del coste social con un método de cálculo no complicado, y nos serviría para estimar tanto el efecto externo del tabaquismo pasivo, como el coste que se origina en la salud de los bebés cuando las mujeres fuman durante el embarazo. Al mismo tiempo esta estimación sería relativamente sencilla de incorporar en un modelo de Markov. Sin embargo, en el efecto externo de la transmisión del comportamiento de los fumadores, se necesitan cálculos matemáticos más desarrollados que en un modelo estático, para asesorar el dinamismo del fumar y su impacto en la salud pública. Los modelos dinámicos en esta ocasión, nos ayudarían a contemplar este coste social originado por el comportamiento humano. A través de ecuaciones diferenciales, estos modelos mantienen estrechas similitudes con los modelos de redes usados en disciplinas como el medio ambiente, para medir, por ejemplo, el impacto en salud de la contaminación del aire. Aunque se ha publicado algún trabajo de modelos matemáticos dinámicos sobre tabaquismo[11], éstos no se han incorporado en las evaluaciones económicas debido a su complejidad, y por lo tanto no conocemos con certeza el impacto negativo de los efectos externos en el tabaco.

Necesidad de considerar los efectos externos en las políticas públicas

La evaluación económica es una herramienta útil para medir el impacto de las políticas públicas ya que provee información sobre los costes y beneficios desde la ótica social.

La importancia de los efectos externos de ciertos comportamientos, tanto positivos como negativos, han sido reconocidos en el campo de la salud, aunque han sido excluidos de la evaluación económica debido a su difícil valoración y metodología y, por tanto, desconocemos si su consideración o la falta de ésta ha ejercido más o menos influencia en el proceso de toma de decisiones.

En cambio, parece claro que podríamos dejar de promover políticas socialmente beneficiosas de deshabituación tabáquica si no incorporamos los efectos externos en nuestras evaluaciones económicas, debido a que nos alejaríamos del conocimiento de verdadero impacto social de dichas medidas, no sólo ya en los fumadores sino en toda la población, si sólo consideramos el beneficio y el coste privado de los programas. Es importante valorar los efectos externos desde una perspectiva social si deseamos evitar evaluaciones económicas de las intervenciones de salud pública incompletas que lleven a tomar decisiones poco apropiadas. A pesar de que existen algunas lagunas de conocimiento metodológico, en España tenemos que hacer un esfuerzo para empezar a valorar los efectos externos e incluirlos dentro de la información relevante a aportar en el proceso de la toma de decisiones. De este modo, una mejor aproximación a la valoración del impacto social de las políticas públicas podrán servir de guía a nuestros deseados sanitarios.

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Appendix 2.1 Review of external effects on different disciplines

Aim

The aim of this preliminary review was to identify which disciplines conduct research related to external effects. The objectives were to detect types and categories of external effects used in the literature.

Methods

This section highlights how the search was conducted.

Search strategy and search terms

A search for textbooks was conducted from October to December 2006 through Brunel University and London School of Economics Library. In addition, some recommendations from experts on the field were given.

Search terms at *Brunel University Library*: "Externalities"; "Externalities Economics"; "Spillovers"; "Economics of Environment"; "Economics of transports"; "Economics of education"; "Economics of Energy"; "Economics of Agriculture"; "Economics of telecommunications"; and, "Crime prevention economic aspects".

Search terms used at *London School of Economics Library*: "Externalities".

Search terms used to search in *google scholar* (http://scholar.google.com/): "Externalities"; "Externalities Economics"; "Spillovers"; "Economics of Environment"; "Economics of transports"; "Economics of education"; "Economics of Energy"; "Economics of Agriculture"; "Economics of telecommunications"; "Crime prevention economic aspects"; "types of externalities"; "externalities, environment"; "externalities, transports"; "externalities, education"; "externalities, energy"; "externalities, agriculture"; "externalities, telecommunications"; and, "externalities, crime prevention economic aspects".

Selection criteria

Books that satisfied the following criteria were selected for review: (a) related to external effects, spillovers or externalities; or (b) focused on economics of some particular areas with good evidence of external effects; and, (c) dataset having smoking specific indicators.

Results

Nine areas were detected to have conducted research about external effects. These areas comprised: agriculture, environment, innovation, technology, telecommunications, network, transport, education and health. Moreover, two types of external effects were identified: positive, related to social benefits, and negative, related to social costs. Finally, external effects were grouped into two main categories: technological and pecuniary external effects

Appendix 2.2 Vaccination programme

Consumption		Production	
Positive effects	**Negative effects**	**Positive effects**	**Negative effects**
Herd-immunity effect: whole population coverage due to an individuals' vaccine	Opposite to herd-immunity effect: bacteria spread across population affecting people's health	GPs not related with the vaccination programme would be attending less patients and increasing their quality of work	Lower 'quality of work' from reception personnel because of attending more new patients for vaccination program
Increases awareness for other vaccines	Higher risk to get an imported disease (from immigration)	Increasing capacity to deal with other patients and increasing the quality of life from rest of patients	Monopoly pricing could increase prices and leave poor patients out of the vaccination program
Satisfaction from colleagues due to you are taking part of a societal decision	Moral hazard	Vaccination programmes are contributing to change national priorities on health	Differences on quality of care provided by hospitals personnel due to some of them are participating in vaccination programmes and some are not
Less traffic jams and less air pollution near the hospital due to less people travelling there	Contraindications of the vaccine due to over-vaccination of the population	Increase in the vans or lorries manufacture and work due to higher demand to carry the vaccines to the hospitals	Higher vaccines' prescription increase the use of computers and therefore computer systems workers have more work to do

Appendix 2.3 Hospital infections

Consumption		Production	
Positive effects	**Negative effects**	**Positive effects**	**Negative effects**
Infection-control initiatives (such as asking healthcare professionals who were in contact with, or whether they washed their hands, etc)	Collaborating to develop cross-infections	Screening programs of high-risk patients to transmit germs	Higher exposure to hazards from surgeons
Help to prevent the spread infection due to an improvement on the immunization system	Higher morbidity and mortality risk of other people attending the hospital	Infection surveillance program (infection control; prevention and early detection of outbreak and the assessment of infection rates over time)	Multi-resistant infections
Health seeking behaviour instead of risk taking behaviour	Increasing resistances to antibiotics	Hospital Infection Control Network (establishment of an infection control network within a group of community hospitals associated with decreasing in infection rates)	Lower quality in hospital resources due to extra expenses in adequate supplies/equipment to live with an hospital infection

Appendix 2.4 Addictive behaviour interventions

Consumption		Production	
Positive effects	**Negative effects**	**Positive effects**	**Negative effects**
Alcohol campaigns			
Reducing crime rates (mortality rate)	Increasing number of aggressions due to anxiety	GPs not related with the campaign attend less patients and increase their quality of work	Cost of opportunity to invest hospital money in alcohol campaigns and not into other programmes is affecting other's people health
Improve quality of life of other people due to a decrease number of aggressions related to alcohol consumption	Increasing risk of Adverse Drug Reactions	Decreasing on suicide rate	Lower research on health because of lower benefits on statins production
Lower risky behaviour (unprotected sex)	Lower QALYS for relatives because of higher risk of participants osteoporosis and bone loss	Better quality of health services due to lower intoxication cases	-
Smoking			
?	Passive smoking	tobacco companies and the economy of countries which produce tobacco	?
?	Smoking during pregnancy		?
?	Smoking behaviour transmission		?
Food habits			
Higher QALYs for the family due to making a personal change on others health	Increase number of aggressions due to anxiety	GPS not related with the campaign are attending less patients and increasing their quality of work	Cost of opportunity to invest hospital money in behaviour changes and not to other programs is damaging health of other ill people
Reduced risk for disease	Lower QALYS to other people due to his/her no satisfaction	Decrease on mortality and morbidity of the country (implementing use of condoms)	?
Benefit to others due to adherence to long term medications	Lower QALYs due to the discontinuation on the behaviour change	Better quality of care due to lower number of ill people	?
Food habits			
Lower rates of premature death	Increase in the anorexic and bulimic rate	GPS not related with the campaign are attending less patients and increasing their	Cost of opportunity to invest hospital money in improve food habits and not to other

Consumption		Production	
Positive effects	**Negative effects**	**Positive effects**	**Negative effects**
		quality of work	programs is damaging health of other ill people
Lower drugs intake, so avoiding interactions between drugs due to healthy food habits	Consequences of psychological problems due to instability of changing food habits	?	?
Better QALYs for participants and their families due to increment physical activity	Lower QALYS to other people due to his/her no satisfaction with food	?	?

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Appendix 3.2 Search strategy and search terms of systematic review of external effects valuation methods

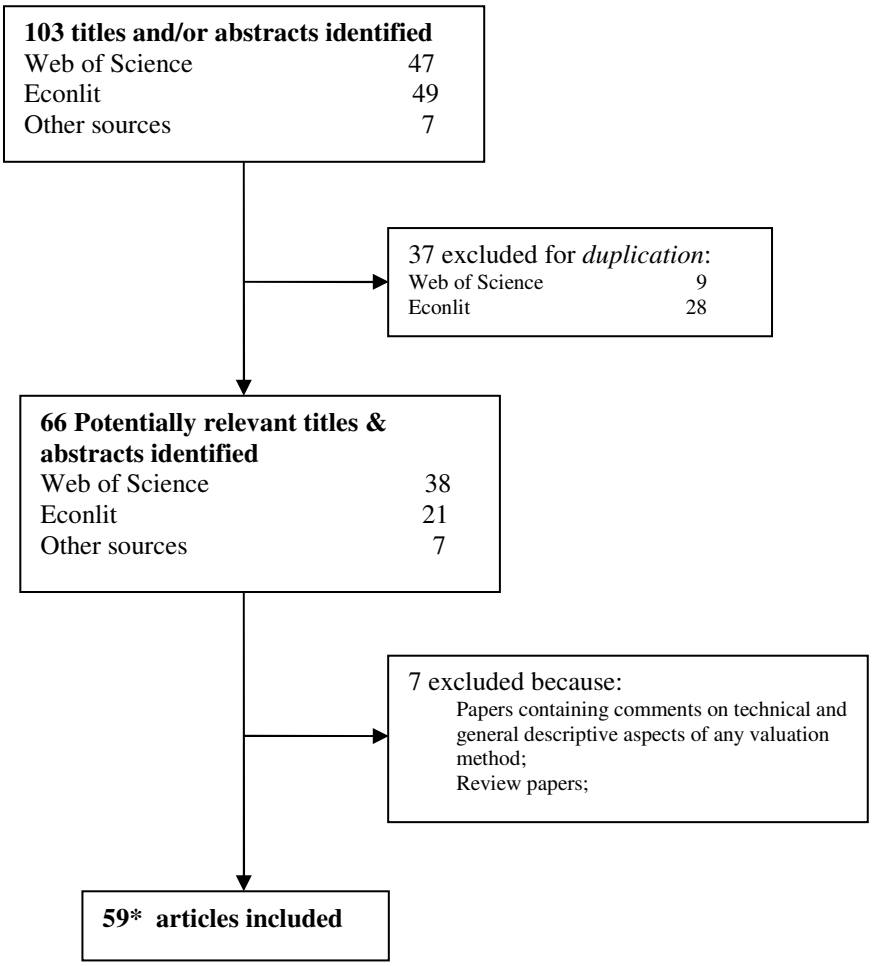
Database	*Search terms*	*Hits*	**Selected papers**
Web of Knowledge	TI=((field search term)[71] and ("cost-benefit" or "costbenefit" or "cost benefit" or "cost-effectiveness" or "costeffectiveness" or "cost effectiveness" or "economic* valuation" or cost* or valu* or "critical appraisal") and ("pecuniary external*" or "technological external*" or "knowledge external*" or "network external*" or "external*" or "spillover*" or "spill-over*"))	47	29
Econlit	TI= (field search term) AND "cost-benefit" or "costbenefit" or "cost benefit" or "cost-effectiveness" or "costeffectiveness" or "cost effectiveness" or "economic* valuation" or cost* or valu* or "critical appraisal" AND "pecuniary external*" or "technological external*" or "knowledge external*" or "network external*" or "external*" or "spillover*" or "spill-over*"	49	23
Other sources		7	7
TOTAL		103	59

[71] 'health*' for health field, 'education*' for education field, 'transport*' for transport field, 'network*' for network field, 'telecomm*' for telecommunications field, 'technolog*' for technology field, 'innovati*' for innovation field, 'environm*' for environment field, 'agricultur*' for agriculture field;

Appendix 3.3 Review questions

Headings	Review questions
Specification and categorisation of external effects	1. PIC (personal identification code) 2. LSIC (literature search identification code) 3. Title 4. Authors 5. Year of publication 6. Year of study 7. Source 8. If question number 7=4, specify 9. Field 10. Paper's objective 11. Why is important to study the external effects in this study? 12. Categorization of external effects according to the author/s' criterion (open text). (i.e. Congestion) 13. If 12=6, specify 14. Description of external effects according to author/s of paper 15. Type of externality/ies valuated 16. Consumption or Production side 17. Why is important to focus on external effects on this side of the market in this study? 18. Categorization of externality/es valuated (according to my own definition) 19. If question number 15≠5, How well do they fit in my definitions? 20. Does the paper cite other authors for the same external effect?
Impact and measures	21. Is this paper identifying and/or measuring impact/s of external effects? 22. Identification of impact/s 23. Measurement of impact/s
Valuation approach	24. Is this paper assigning monetary values to the impact/s of external effects? 25. If 22=1, describe methods to assign monetary values to impacts (according to Eshet et al., 2005) 26. If question number 23=8, specify 27. Valuation methods' description 28. Do they specify a formula to quantify the monetary valuation of impacts? 29. If question number 26=1, specify formula 30. If question number 26=1, description of formula's variables 31. Data source for the formula's variables 32. Type of data of the study 33. If question number 31=1, cite references from this extra estimates 34. Are the valuations of external effects used to do a cost-benefit analysis according to this paper? 35. If question number 33=1, which country?
Main findings and given critics	36. Paper's strengths stated by the author 37. Paper's limitations stated by the author 38. Main conclusions of the paper
Application to health	39. What interesting ideas I can get from this paper? 40. Paper's gradation for containing useful ideas for application to health

Appendix 3.4 Study selection process for systematic review of external effects valuation methods



* 53 articles were included from the literature review and 6 papers were added from experts' recommendations

Appendix 3.5 Included papers in the literature review

Baublys A, Isoraite M. Improvement of external transport cost evaluation in the context of Lithuania's integration into the European Union. A Transnational Transdisciplinary Journal, 2005; 25(2): 245-259.

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Appendix 3.6 Summary of external effects papers reviewed

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
Tegtmeier, E.M.; Duffy,M.D. (Rw 38)	2004	negative	Value lost of water, soil and air resources, wildlife and ecosystem biodiversity and, human health	Water resources: a)treatment of surface water for microbial pathogens (microorganisms in livestock); b)facility infrastructure needs for nitrate treatment; c)facility infrastructure needs for pesticide treatment; Soil resources: a)cost to water resources; b)cost to replace lost capacity of reservoirs; c)water conveyance costs; d)flood damages; e)damages to recreational activities; f)cost to navigation:shipping,dredging; g)Instream impacts:commercial fisheries,preservation; h)off-stream impacts:industrial users, steam power plants; Air resources: a)cost of greenhouse gas emissions from cropland; b)cost of greenhouse gas emissions from livestock production; Wildlife and ecosystem biodiversity: a)honey bee and pollination losses from pesticide use; b)loss of beneficial predators by pesticide applications; c)fish kills due to pesticides; d)fish kills due to manure spills; e)bird kills due to pesticides; Human health • (pathogens): a)cost of illnesses caused by common foodborne pathogens; b)cost to industry to comply with HACCP rule; • (pesticides): a)pesticide poisonings and related illnesses;	Water (costs of treatment to control major pollutants): • Pathogens: annualised national cost of implementing surface water treatment rule*% of damage associated to these pathogens; • Nitrate: cost for water treatment facilities to meet federal nitrate standards* % of nitrate pollution is due to agriculture; • Pesticide: cost for treatment facilities to meet Safe Drinking Water Act*% of pesticides (something in between the % of existing pesticides and % of conventional pesticide usage); Soil resources: • Water industry: % that cropland contributes o total suspended solids*water withdrawn for public supply from surface water sources (litres per day)*treatment costs (per million litres); • Reservoirs: %loss of total national capacity (between % of the nation´s water storage capacity lost annually and the average storage loss from sediment depletion)*per thousand cubic metres replacement value*% of sediment from cropland; • Conveyance: cost for sediment removal and maintenance to prevent local flooding*% for the contribution of sediment from cropland; • Flood damages ,recreational activities, navigation, commercial fisheries and preservation and, off-stream costs: total erosion effects*% damage due to cropland; Air resources: net emissions of carbon dioxide equivalents*market price carbon dioxide equivalents*% of this cost from crop production or livestock sources; Wildlife and ecosystem biodiversity: • Honey bee and pollination losses: colony losses, reduced honey production and crop pollination and the cost of bee rentals; • Loss of beneficial predators: cost of additional	secondary

[72] Valuation approaches: CV (Contingent Valuation); CHM (Choice Modelling Methods); HP (Hedonic Price Method); AB (Averting Behaviour Method); CI (Cost of Illness); HP (Health Production Function); TC (Travel Cost Method).

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
					applications of pesticide due to drops in the population of beneficial insects and crop losses associated with secondary pests; • Fish kills due to pesticides: fish deaths per year due to pesticides and values of freshwater fish, reflecting commercial hatchery production costs of various fish species*cost in $ per fish; • Fish kills due to manure spills: (info on feedlot spills and associated fish kills in 10 states for 3 years=rough proxy for a national estimate)*cost in $ per fish; • Bird kills due to pesticides: number of birds exposed to pesticides*% of birds dying*value of bird's life (using lowest value from cost per bird watching, hunting costs per bird felled and the cost of rearing and releasing a bird to the wild); Human health: • Pathogens o Foodborne illnesses: annual costs for bacteria damage estimates*% of health costs attributable to agricultural production; o Cost to industry to comply with HACCP: industry costs for meat and poultry plants to comply with HACCP regulations*% of health costs attributable to agricultural production; • Pesticides o Pesticide poisonings: costs of pesticide poisonings and deaths based on hospitalizations, outpatient treatment, loss of work and fatalities due to accidental poisonings and treatment costs for pesticide-induced cancers (based in part on speculation regarding the incidence of illness and death);	
Brisson,M.; Edmunds, W.J. (Rw 39)	2004	positive	Value created on altruism due to varicella vaccination	The vaccine may derive benefit from knowledge that by being vaccinated they will not infect other children; they estimated whether individuals derive benefit from not infecting others because they are immunised;	• CV and standard gamble questionnaire: o CV: the respondents were given a description of a child with chickenpox; initially respondents were asked to assume that their child has chickenpox and that a drug exists which can cure their child immediately; They then elicited the maximum the respondent is willing to pay for the drug using a bidding algorithm. In the second section of the CV questionnaire,	primary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
					respondents were asked the maximum they were willing to pay to vaccinate their child against chickenpox; Respondents were given randomly one of 4 different contingent valuation questionnaires; The value parent's put on preventing their child infecting others (altruism) was measured by comparing the WTP from questionnaires stressing this effect to those in which the effect was not mentioned; o SG: a separate group of respondents were asked to imagine that their child is in an imaginary health state for 15 years; the duration of disease was chosen so that parents would trade risks of death for intervention and it is the time-span of childhood. Apart from the duration of disease, the health profile is identical to the description of chickenpox; the only attribute varied in the SG questionnaire was altruism: in half of the questionnaires altruism was included by stressing that treatment will prevent the child from giving the disease to other children. In the remainder there were no mention of knock-on effects;	
Van de Vijver,M.; Vos,B. (Rw 40)	2006	positive	Benefit created by the additional activities that result from the JSF programme within and outside the Dutch aerospace industry	Knowledge creation and innovation (and use of this knowledge in other settings); from the consumer electronics industry (electric shaving) to the aerospace industry. The improved and adjusted production technology is now used for machining of blisks in the JSF project and can also be used in the future in automotive and medical systems industries; Urenco Aerospace developed technology on extreme loading of thermoplastics. This technology can also be used in other industries. The material that is used for these applications is Carbon Fibre Reinforced Plastics (CFRP); TNO, the Netherlands organizations for applied scientific research, developed specific knowledge in the JSF programme to improve video resolution techniques. They can also use this knowledge in security purposes. TNO also developed new knowledge in the field of noise nuisances, which can be used in the development of industrial zones and the design of airports. Employment effects (how many more people are contracted?); Estimated total revenues related to the JSF programme;	Knowledge expanded= valuation method not specified but monetary valuated; Employment=not monetary valuated; Revenue (revenue for the aerospace industry=(number of hours needed for one shipset*total number of shipsets)/annual workable hours per employee; (Maintenance, Repair and Overhaul activities are not included in the estimates);	primary (through interviews)
Jaffe,A.B. (Rw 41)	1986	positive	Value created on R&D due to the proximity of the firms technology space	Weighted sum of other firms' R&D, with weights proportional to the proximity of the firms in technology space; This measure spillovers using a cost function approach and time-series data for the chemical industry;	Not monetary valuated;	secondary
Castronova, E. (Rw 42)	2006	negative	Value of real-money trade (RMT) lost within the current	Consumer and surplus loss as the change in demand and supply times the current subscriber base (marginal effects)	Total Marginal external costs: consumer and surplus loss (as the change in demand and supply) Consumer surplus: n subscribers*(RMT elasticity of	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
			online game market		subscriptions*subscription fee)*12 months (because we want annual data) Producer surplus: n subscribers*(RMT elasticity of subscriptions*subscription fee)*12 months (because we want annual data) Total external cost= total marginal external costs*RMT elasticity total external costs	
Beuthe,M.; Degrandsart ,F.; Geerts,J-F.; Jourquin,B. (Rw 43)	2002	negative	[73]Value lost due to air pollution, accidents, noise and road damages	[74]Effects of: Air pollution (millionECU per gram); Congestion (source of inefficiency of the transport system): cost function expressed in millionECU per t-km; ; Accidents (social cost for accidents between vehicles=between vehicles and pedestrians or cyclists; expressed in millionECU per t-km; Noise (estimated either through a statistical analysis linking the rents paid with different characteristics of housing or by costing the reparative expenditures);expressed in millionECU per t-km;	Air pollution=concentration per gram of pollutant*population*mortality rate*value of life[75] Congestion=loss of time for trucks travelling along the road during peak hours*truck flows* value of time; • Loss of time=speeds on road during peak hours and outside peak hours are computed using a flow speed relation. The difference between these speeds translates into a loss of time for trucks travelling along this road during peak hours; • Value of time=all the costs linked to the operation of a truck (labour, fuel, insurance, maintenance and vehicle cost)=inventory cost of the goods transported which varies with the value of the commodities and the loading of the vehicles; Accidents: • Between vehicles=(WTP for cancelling the risk of an accident for the user=WTP for cancelling the risk of an accident for the closest relations=cost per vehicle made of the costs of police, ambulance (cold blood cost))*traffic flow*risk of accidents; • Between vehicles and pedestrians or cyclists=(WTP for cancelling the risk of an accident for the user=WTP for cancelling the risk of an accident for the closest relations=cost per vehicle made of the costs of police, ambulance (cold blood cost))*total number of km by pedestrians and cyclists*risk of accidents; Noise: estimates which are averages of various studies relying	secondary

[73] Many of these cost estimates are based on market prices and costs rather than on WTP;
[74] In general, a static methodology is applied in this paper (this means that not analyse the flows' impact on the costs of a link use and the resulting spread of the traffic over different routes like in a spatial equilibrium model;
[75] All the computed costs of illnesses not inducing death are based on market prices and costs: cost of medicines, ambulance, hospital, and medical services. A WTP estimate is only used for the value of life in case of death.

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
					on either of linking the rents paid with different characteristics of housing or costing the reparative expenditures;	
de Dios Ortuzar,J.; Cifuentes,L. A.; Williams,H. C.W.L. (Rw 44)	2000	negative	Value lost due to road accidents and air pollution	Effect of road fatality risks (health effects) and pollution-related mortality risks (health effects);	Road accidents: CHM (respondents were invited to choose between two alternative states of the highway on the basis of three attributes: travel time, accident risk and toll charge); Air pollution: CV (WTP for small reductions in the risk of death);	primary
Snowball,J. D.; Antrobus,G. G. (Rw 45)	2001	benefit	Value created by arts to the lower income and education groups in South Africa	Effect of Standard Bank National Arts Festival in Grahamstown	CV(after being given certain basic information about the cost of the Festival and the level of government sponsorship, Grahamstown respondents were asked in a closed-ended, yes or no, question whether they would be willing to pay an extra R5 in taxes per month to support the Festival, first non-liable and then liable)	primary
Gray,R.; Malla,S. (Rw 46)	1998	benefit	Value of health costs saved due to reduce saturated fat acid consumption (SFA)	External portion of the CHD costs reported associated with consumption of butterfat to calculate a per-unit externality (kilograms of fat reduced);	External cost savings=costs of annual CHD reduction due to a reduction in SFA (from literature)*(% of costs being external to the individual (assumption)); Kilograms of SFA consumed by the population=population*SFA per individual; Per-unit externality=External cost savings/kilograms of SFA consumed by population; External cost saved=per-unit externality*reduced kilograms of SFA consumed by the population;	secondary
Pretty,J.N.; Brett,C.; Gee,D.; Hine,R.E.; Mason,C.F. ; Morison, J.I.L.; Raven,H.; Rayment,M .D.; van der Bijl,G. (Rw 47)	2000	negative	Value of agricultural lost due to environmental and health effects	Effects on the treatment or prevention costs (those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state); Administration and monitoring costs (those incurred by public authorities and agencies for monitoring environmental, food and health parameters);	Environment: water, air, soil and biodiversity and landscape[76]; • Water: Cost of remove pathogens from water (pesticides, nitrate, phosphate and zoonoses)=annual operating costs*% assumed to be agricultural treatment cost; Cost to pay for restoring water courses (eutrophication and pollution incidents)=costs incurred to restore rivers to their pre-incident condition; Monitoring and advice on pesticides=pesticide monitoring in food and livestock and on surface and groundwater sites=costs in providing advice; • Air: marginal external costs from methane, nitrous oxide and carbon dioxide (adopted from ExternE	secondary

[76] All this data is adopted from the literature;

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
					project:CV (WTP)); External costs of ammonia: CV (WTP) using the more conservative value of life year (from literature); • Soil: Damage caused by soil erosion: costs estimated from soil carried off farms by water or wind blocks ditches and roads, damages property, induces traffic accidents, increases the risk of floods, and pollutes water through sediments and associated nitrate, phosphate and pesticides; Organic matter and carbon dioxide losses; • Biodiversity and landscape: Costs of wildlife and habitat losses=costs or restoring species and habitats under the Biodiversity Action Plans (BAPs) as a proxy; Costs of hedgerows and drystone walls=amount that farmers receive for replacing hedgerows and drystone walls under agri-environment schemes used as a proxy; Cost of agricultural biodiversity=not possible to put a cost on these losses; • Human health: Pesticides (acute effects)=(value of a symptom-day*(number of farmers are off work for one day=those are off half a day))*GP consultation cost; Pesticides (chronic effects)=not included; Nitrate=assumed zero; Cost of food poisoning=(lost wages=consultations with doctors=hospital beds)*% poisoned people from UK farming; Antibiotic resistance=impossible to estimate; BSE and CJD(transmissible disease occurring in animals and humans)=total costs BSE*% belonging to farming;	
Gulli,F. (Rw 48)	2006	negative	Value of gas-fired distributed generation (decentralized supply) lost due to non-greenhouse emissions	Environmental damage: pollution concentration*population*dose-response function; Using the ExternE methodology (bottom-up approach): a)determining the emissions for each stage of the fuel cycle (from the production of primary input to the output production); b)simulating the dispersion of the pollutants both on a local and	CV (WTP or WTA)	Secondary (ExternE data)

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
				regional scale; c)identifying all the receptors; d)calculating the impact (by applying the "dose-response" functions); The pollutants taken into consideration are solid, liquid and gaseous residues. The main impact is due to the emissions of CO2,SOx,NOx and particulate (PM10); The damage taken into consideration includes the effects on public health, agriculture, forests (acid rain), the ecosystem in general, materials (deterioration of buildings and monuments) and the damage related to global warming due to greenhouse gas emissions; Dose-response functions provide the marginal damage caused by increment of concentration due to plant emissions (USD/Kg);		
Rey,F.J.; Martin-Gil,J.; Velasco,E.; Pérez,D.; Varela,F.; Palomar,J. M.; Dorado,M.P . (Rw 49)	2004	negative	Value lost due to environmental damage of a heat pump	Eco-indicator methodology: evaluate the environmental damage weighting human health, ecosystem and resources. • Human health: expressed as DALY (Disability Adjusted Life Years). It links health effects to DALYs, using estimates of the number of Years Lived Disabled, and Years of Life Lost; Inorganic substances (respiratory effects): emissions to the air; • Ecosystem: quality are expressed in relation to the species that have disappeared in a certain area and period, mainly vascular plants and simple organisms; Damages to ecosystems needs to introduce the following impact categories: ecotoxicity, acidification/eutrophication, and land use. For ecotoxicity, they use the unit PAFm2yr, meaning the Potentially Affected Fraction (PAF)of species in relation to the concentration of toxic substances per area and year. For acidification and eutrophication we use the unit PDFm2yr, meaning the Potentially Disappeared Fraction of plant species (PDF) per area and year. For land use, we also use the PDFm2yr as unit; Carcinogenesis (emissions to the air); Climatic change (emissions to the air); • Resources: Waste heat per Kg of extracted material (surplus energy); Combustibles (mining:petroleum, coal and natural gas); EPS2000 methodology: this method evaluates the impact over the environment via its impact on one or several safe guard subjects, that is, human health;	Eco-indicator methodology: Unit named Eco-indicator point (the absolute value of the points is not very relevant, as the main purpose is to compare relative differences between products or components); EPS2000 methodology: is expressed in environmental load units (ELU), equivalent to the Euro;	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
				The impact categories identified are: human health (including human diseases), ecosystem production capacity (including information relative to crop, fish/meat, and wood yield decrease), abiotic stock resources, and biodiversity (including the extinction of species); Damage categories: • Resources (mining); • Life expectancy (emission to the air); • Severe unhealthy conditions (emission to the air); • Moderate discomfort (emissions to the air); • Moderate unhealthy conditions (emissions to the air);		
Wattage,P.; Soussan,J. (Rw 50)	2003	positive and negative	Value created by the System Rehabilitation Project, a water control structure, to the environmental development projects	Not specified	Net present value (NPV): the result of discounting and summing of annual net benefits stream overtime over the lifetime of the project; NPV=(NDB-DBP=ENB)*e^rt; NDB=net development benefits (difference between benefits and costs of development over time); DBP=disbenefits as a result of the project (estimated using the survey information); ENB=environmental benefits (CV method);	secondary
Hamacher, T.; Sáez,R.M.; Aquilonius, K.; Cabal,H.; Hallberg,B.; Korhonen,R.; Lechón,Y.; Lepicard,S.; Schleisner, L.; Schneider,T.; Ward,D. (Rw 51)	2001	negative	Value of environment lost due to a fusion power plant	• The external effects due to energy consumption for the production and transportation of the materials, the traffic accidents and the occupational accidents during the production processes; • Plant construction: o External costs of SO2,NOx and CO2 emissions (Euro/t CO2); o Increase in traffic during the construction phase; o Increase in road accidents, due to increase in traffic, leads to deaths and injuries of the public involved in the accidents. The number and severity of the accidents are estimated using an estimation of the total amount of materials necessary to be transported together with the national road and rail accident statistics; o Occupational accidents during the construction of the plant and components are based on the expected investment cost, which lead to an estimation of the value for the person years, and the accident statistics for the different branches involve; • Normal operation: o Impacts due to the emissions and the effluents of radioactive isotopes, the impacts due to the occupational	* Methods not specified; • Construction: o Emissions of the transport; o Road accidents; o Occupational accidents; • Power plant operation: o Routine releases; o Occupational exposure; o Other occupational impacts; • Power generation; • Decommissioning: o Emissions of the transport; o Traffic accidents; o Occupational accidents; • Recycling: o Emissions of the transport; o Traffic accidents; o Non radioactive dust emissions; o Radioactive emissions; o 14C emissions; • Site restoration:	secondary (ExternE data)

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
				radioactive exposure and other 'normal' occupational accidents; • Decommissioning[77] and recycling: o Human health impacts due to release of dust and radioactivity from the recycling plant; o Death and health impacts of the decommissioning workers (number of person-years was based on estimated decommissioning years; and the number of expected accidents were based on experience from fission plants); o Road and rail accidents; • Waste disposal: o 14C releases from final repositories; o 94NB releases from final repositories; • Intense fusion economy: o Radioactive emissions in normal operation and from the final repository; • Accidents (input/output analysis): o Acute and chronic health effects on different geographical scales; o Economic losses due to food bans; o Economic disturbances due to relocation of the population; o General risk aversion of the population;	o Emissions; o Traffic accidents; • Waste disposal; Human life is assessed by CV (WTP/WTA): • WTP for a reduction in the risk of death. The 'value of statistical life' is calculated by dividing the cost of the measure to reduce the risk by the reduction in the risk of death; • WTA compensation for a higher risk; • WTP or WTA a higher risk as evaluated from interviews or questionnaires;	
Nishi,J.; Tanaka,T.;Seiki,T.;Ito, H.;Okuyama,K. (Rw 52)	2000	positive	Value created on exterior environment	• Stop a development that would obscure or make unsightly their favorite view;	• Emailed questionnaires where respondents were asked how much money they would pay to stop a development that would obscure or make unsightly their favorite view;	primary
Niskanen,A. (Rw 54)	1998	positive and	Value created of reforestation (carbon	• Benefits in erosion control: the amount of soil erosion was estimated with the modified universal soil loss equation	• Benefits in erosion control: replacement cost method (used to estimate the on-site costs of soil erosion; This	secondary

[77] Decommissioning includes all activities starting with the decontamination and demolition of the plant, waste treatment, including recycling, and transport of radioactive waste to final repositories;

Authors	Year	Consequences				
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		negative	sequestration and increased erosion control) and value lost of reforestation (water consumption and nutrition loss in harvesting) in Thailand	(MUSLE) (Thai baht ha^-1); • Costs of nutrient loss in harvesting: nutrients accumulated in and removed with felled trees (teak, eucalypt and cassava: Thai baht ha^-1); • Costs of transpiration: depends on climatic factors (radiation, relative humidity, temperature, wind speed); physiological response mechanisms; canopy structure; and the availability of soil water to roots (Thai baht ha^-1); • Benefits in carbon sequestration (Thai baht ha^-1);	involved pricing the amount of commercial fertilizers that were needed to replace lost nutrients in eroded material); • Costs of nutrient loss in harvesting: replacement cost technique; • Cost of transpiration: transpiration ratio (basal area of the tree at breast height) and water use efficiency approaches (describe the volume of water in liters that is consumed by a plant during the growing season per kilogram of dry matter produced; • Benefits in carbon sequestration: method used by Nabuurs and Mohren (1993) based on the assumption that the estimation of carbon sequestration of the trees' different structures is possible when the annual stem volume increment in known;	
Parfomak, P.W. (Rw 55)	1997	negative	Value of environment lost due to power plant emissions	• Coal uncontrolled emissions (lbs k Wh^-1); • Coal SO2 controlled emissions (lbs k Wh^-1); • Natural gas steam (lbs k Wh^-1); • Natural gas combined cycle (lbs k Wh^-1);	Externality cost (1994¢ kWh^-1)=Cost of emissions (1994$ lb^-1)*emissions (lbs kWh^-1);	secondary
Torfs,R. (Rw 56)	2007	negative	Value of environmental health lost due to air pollution and noise	• PM10 acute effects (10µg/m3): o Non accidental mortality; o Respiratory hospital admissions; o Cardiovascular hospital admissions; o Use of bronchodilators against asthma; o Prevalence of acute bronchitis; • PM2.5 chronic effects (10µg/m3): o Cardio-respiratory mortality; o Mortality due to lung cancer; • PM10 chronic effects (10µg/m3): o Incidence of chronic bronchitis; • Oxone (50µg/m3): o Non accidental death; o Days with restricted activity; o Respiratory hospital admissions (15-64) (65=); o Exacerbation of extreme asthma; o Symptom days; • UV radiation/stratospheric ozone: o Death due to melanoma cancers; • Benzene: o Death due to leukaemia; o Non fatal leukaemia; • PAHs:	• Concentration response function or unit risk factor=CV (WTP) • Results: External cost per DALY;	secondary (ExternE data)

Authors	Year	Consequences				
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				○ Mortality due to lung cancer; • As: ○ Mortality due to lung cancer; • Ni: ○ Inhalation and decrease of IQ; ○ Ingestion and decrease of IQ (µg/year); • Noise: ○ IHD Mortality; ○ Cardiovascular hospital admissions (IHD); ○ Serious nuisance; ○ Sleep disturbance; • Exposure: health changes and mortality risks: ○ DALYs: YLL = YLD YLL=number of deaths *disability weight*standard life expectancy at age of death in years L; YLD=number of incident cases*disability weight*average duration of disability in years L; The number of cases (N) attributable to outdoor air pollution or noise is estimated by using the 'at least' approach. The required data components are the exposure-response function, the frequency of the health outcome and the level of exposure;		
Godoy,R.; Contreras, M. (Rw 57)	2001	positive	Value created on tropical forest due to schooling	• Annual value of lower tropical deforestation due to one additional year of a household head's schooling ($); • $ that households should receive each year for saving the forest so the rest of the world can enjoy its benefits;	• Annual value of externality=average area of old-growth forest cleared by a household each year*mean total value of a rain forest excluding food, raw materials, and recreation ($)*annual value of the positive externality produced by education (%); • Additional environmental externality from not cutting the fallow forest= average area of old-growth forest cleared by a household each year*mean total value of a rain forest excluding food, raw materials, and recreation ($)*% of area reduction of cut fallow forest of one more year of schooling;	primary (household survey)
Viswanathan,S. (Rw 59)	2005	positive	Consumers' utility derived from the bundle, and consumers' utility derived from the network of consumers who purchase from the same firm;	• Two period model (in which a firms' consumer base (demand) in Period I confers utility to the firm's consumers in Period II - the value to a consumer being directly proportional to the number of consumers her firm has in Period I;	Not specified	Not specified

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Lechón,Y.; Cabal,H.; Sáez,R.M.; Hallberg,B.; Aquilonius, K.; Schneider,T.; Lepicard,S.; Ward,D.; Hamacher, T.; Korhonen,R. (Rw 60)	2003	Negative	Value lost due to electricity generation by different fuel cycles;	Emissions of the transport; o Road accidents; o Occupational accidents; • Recycling: o Emissions of the transport; o Road accidents; o Non radioactive dust emissions;Non radioactive dust emissions; o Radioactive emissions; o C-14; • Site restoration : o Emissions; o Traffic accidents; • Waste disposal; • Accidents;	Not specified	secondary
Park,G.; Park,Y. (Rw 61)	2003	positive and negative	Value created and lost on productivity and labour due to information and communications (IC) technology on other industrial sectors	• Positive and negative impact are specified in terms of productivity and employment; • They divide the IC industry into IC-machinery sector and IC-service sector, assuming that these two sub-sectors are considerably different to each other in terms of knowledge contents and flow pattern. In order to measure the inter-industrial spillover effect, other industries are classified into 17 different sectors; • They identify specific effects of IC technology on individual industries; • They measure the spillover effect of IC technology on production cost (cost function) and labour demand (labour price function) of other industrial sectors;	• Not specified;	secondary
Saelensminde,K. (Rw 62)	2004	positive and negative	Value created and lost of insecurity and health effects due to changes from travel by car to cycling or walking	• Benefits: o Traffic accidents resulting in injury: will remain unchanged; o Travel time: travel times for pedestrians and cyclists remain unchanged because of the walking and cycle tracks. They assume that travel times for car drivers who do not substitute walking or cycling for driving are reduced in cities with traffic congestion; o Insecurity: included as a cost of NOK 2 per kilometre; o Less severe diseases and aliments and long-term absence/disability; o External costs of road transport: CO2 emissions, local emissions to air, noise, congestion, and infrastructure costs;	• Methods not specified. Unit: NOK million(NOK 1=USD 0.14) o Accidents (assumed no change); o Travel time (assumed no change); o Reduced insecurity for current pedestrians; o Reduced insecurity for current cyclists; o Reduced insecurity for new future pedestrians; o Reduced insecurity for new future cyclists; o Reduced costs for transporting school children; o Reduced costs related to less severe diseases and aliments and less short-term absence; o Reduced costs related to severe diseases and aliments ; o Reduced external costs of motorized road transport;	secondary
Baublys,A.;	2005	negative	Value lost on	• External and infraestrucutre costs of a heavy vehicle moving on	• Methods not specified:	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
Isoraité,M. (Rw 63)			transport sector due to air pollution, climate changes, infrastructure and noise emission costs	a motorway at 100km/h under the conditions of non-intensive traffic (€): o Air pollution: costs related to health and harvest damages; o Climate changes: floods and harvest damages; o Infraestructure; o Noise emission costs;	o Air pollution; o Climate changes; o Infrastructure; o Noise emission; o Road accidents; o Congestion; o General;	
Gibbons,E.; O'Mahony, M. (Rw 64)	2002	negative	Value lost on environment due to transport activities	• Congestion: longer journey times, increased fuel consumption and greater wear and tear on vehicles. Congestion function to describe how average speed is influenced by traffic flow. The congestion function allows the time loss suffered by other roads users to be computed if an additional passenger car unit (PCU) joins the traffic flow; • Air pollution: take into account the impact of pollutant emissions on local concentration levels and refer to the external costs of air pollution on human health, materials, crops and global warming. The values are calculated for car, bus and train. The values shown for the car are in EURO per vkm, while the values for the public transport modes are in EURO per passenger km; • Accidents: what society would be prepared to pay to reduce the risk of an accident; • Noise: cost of noise generated by road traffic;	• Marginal external congestion cost= the congestion function is combined with information on the value of time (cost of an additional PCU kilometre); • Air pollution=CV (WTP/WTA); obtained by ExternE project; • Accidents=CV (WTP/WTA); The WTP of relatives and friends of the victim to avoid the accident was not included in the cot estimate; • Noise=it is calculated through an algorithm. The total external noise cost was calculated by multiplying the monetary value per dB by the noise level above the threshold of 50 dB(A) by the length of road where a noise externality is generated. The monetary value of noise was calculated at 0.6 EURO per 1dB(A) per kilometre;	secondary
Forkenbrock,D J. (Rw 65)	2001	negative	Value lost of freight train transportation due to accidents, emissions and noise	• Accidents: 3 primary categories of accidents=collisions at highway-rail grade crossing, persons struck by a train at other locations, and mishaps involving the train alone; o Fatalities: o Injuries: o Property damage: estimate of the value of property damage to other vehicles involved in crashes with trains at highway-rail grade crossings • Emissions: Air pollution: volatile organic compounds (VOC), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter under 10 µm in aerodynamic diameter (PM10) (emission rates per ton-mile); Emission costs (cents per ton-mile); o Greenhouse gases: CO2 (cents per ton-mile); • Noise: o social cost of noise per ton-mile of transportation service in rural areas;	• External cost of accidents=numbers of fatal, personal injury, and property damage accidents*the appropriate per-event cost-the amount of compensation paid by the particular mode; o Per-ton-mile external cost=external cost of accidents/ number of ton-miles; o Property damage=pProperty damage for non-crossing rail accidents (other than to trains) is comparatively minor and ignore the costs of such damage; • Emissions: emission rates*emission costs; • Noise: same value as applied for trucks; adopted from the literature;	secondary

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Spadaro,J.V.; Rabl,A.; Jourdain,E.; Coussy,P. (Rw 67)	1998	negative	Value lost due to air pollution of road transport	• Source: gasoline cars with and without three-way catalytic converter and diesel cars; • Emission factors: benzo-a-pyrene (BaP) (in g/km); The calculation of emissions has been done by dividing the journey into six sections representing different traffic conditions, driving cycles and meteorological conditions; • Impacts (Impact Pathway approach: exposure-response function): Health: restricted activity days, chronic bronchitis, respiratory problems, cough, chronic bronchitis in children, chronic sore throat, respiratory hospital admissions, cerebrovascular hospital admissions, cancers and chronic mortality; o Agricultural crops: SO2; o Forests: Acid rain; o Materials: Acid rain;	CV (WTP to avoid the impacts): ECU per case;	Secondary (ExternE project)
Mayeres,I.; Ochelen,S.; Proost,S. (Rw 68)	1996	negative	Value lost due to cars, trucks and urban public transport modes	• Congestion: o Congestion function: expresses the minutes needed to drive 1km in a certain period as a function of the million passenger car units (PCU) per hour at that moment in the city; o Time costs: time loss suffered by the other road users if an additional PCU joins the traffic flow; • Pollution: effects on o Health: mECU/g VOC(volatile organics compound); o Vegetation: SO2 and NOx (mECU/g); o Materials; o Aquatic ecosystems; o Visibility; o Climate: global warming (mECU/g); • Accidents: marginal social accident cost (MSAC) of a car is the derivative of the total accident cost (TAC) with respect to the number of car km; A distinction is made between fatal accidents, accidents with serious injuries, accidents with light injuries and accidents with only material damage; (ECU or million ECU); • Noise: effect on the noise level of an additional car km; They assume that the average street in Brussels has a U-shape; (mECU per vehicle km); Index for noise used is the energy mean sound level over a given period=53.9 = 10log (flow of light vehicles in veh/h = flow of heavy vehicles in veh/h) – 10log of width between the facades (in metres) = correction	• Congestion: not described; • Pollution: o Health (CV): mortality; morbidity (respiratory hospital asmission; emergency room visit; symptoms of chronic bronchitis; symptoms of chronic cough; restricted activity day; minor restricted activity day; asthma attack; and symptom days; o Vegetation: direct effect of SO2 on wheat, barley rye and oats (national and transnational); effect of NOx on O3 on wheat (national); o Global warming: coastal defence; dryland loss; wetland loss; ecosystem loss; agriculture; forestry and fishery losses; gains and losses in the energy and water supply; life and morbidity effects; air pollution damages; migration costs and an estimate of natural hazard damages; • Accidents: CV o MSAC=(WTP to avoid an accident of type n = WTP of the relatives and friends of the victim to avoid an accident of type n = pure economic costs (net output losses, ambulance costs, medical costs, etc))*probability that an accident of severity n occurs between transport modes I and j and in which i is the victim*number of vehicle km travelled by transport mode; • Noise: Hedonic housing market method	secondary

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				factor for speed, which means that 1dB is added for each 10km/h above a speed of 60km/h;	○ Total external noise cost for Brussels=monetary value * noise level above the threshold of 50 * number of road km where a noise externality is generated (we assumed 500km supra); ○ To compute the resulting marginal external noise cost (MENC) in the reference equilibrium, we derive the total external noise cost function with respect to the number of vehicle km;	
de Dios Ortuzar,J.; Rizzi,L.I. (Rw 69)	2007	negative	Value placed for improving urban road safety, better air quality and increasing levels of quietness due to the provision of urban transport	• Urban road accidents: human capital approach (value of a life saved given by the present value of the expected income flow the individual would have earned, had she not died); Linear indirect utility functions; • Local air pollution: a realistic way of 'offering' distinct atmospheric conditions consisted in presenting different residential locations associated with different air quality levels; Although there are many factors influencing housing choice behaviour, it was considered reasonable to include only accessibility to work and accessibility to study (expressed in minutes of travel time for each individual in the household) and the rent paid (CH$); • Quietness: to value reductions in urban noise levels; attributes chosen for the experiment were the rent or mortgage paid, noise level, travel time to work and sun orientation; The authors tested presenting the noise variable in relation to recalled levels at different intersections in Santiago (e.g. some objectively louder than others); Using a 10-point scale;	• Urban road accidents: CHM (stated choice experiment; Discrete Choice Modelling); Through a multinomial logit and mixed logit it is possible to obtain value of travel time and the subjective value of accident reduction; • Local air pollution: SP; Through a multinomial logit and mixed logit it is possible to obtain WTP values for travel time to work by individual h from location I and, travel time to study by individual h from location i; • Quietness: CHM (Discrete Choice Modelling); Through a multinomial logit and mixed logit it is possible to obtain WTP values for noise level and travel time to work;	Primary data (first senior management staff of private and public institutions)
Friedrich,R. ; Bickel,P. (Rw 70)	2001	negative	Value lost of environment due to transports	• Health impacts: exposure-response for acute and for chronic effects of air pollution; Gaseous pollutants: Ozone, SO2, CO and NO2; chronic mortality effects: the years of life lost (YOLL) attributable to air pollution were estimated by linking the regression estimates from literature with the populations-at-risk and age-specific death rates in four European countries (Germany, Italy, Netherlands, UK), using life table methods; • Impacts on building materials: loss of mechanical strength, leakage and failure of protective coatings due to degradation of materials; A dose-response function links the dose of pollution, measured in ambient concentration and/or deposition, to the rate of material corrosion • Impacts on terrestrial ecosystems: effects on the physical structure of the landscape (such as direct loss of land and habitat fragmentation, of the land used solely for transport), effects of management of the transport route and adjacent land	• CV: WTP for environmental benefit or WTA payment in lieu of environmental harm; • Health impacts: ○ Ashmatics: bronchodilator usage, cough and lower respiratory symptoms (wheeze); ○ Elderly 65=: congestive heart failure; ○ Children: chronic cough; ○ Adults: restricted activity days, minor restricted activity days and chronic bronchitis; ○ Entire population: chronic mortality, respiratory hospital admissions, cerebrovascular hospital admissions, symptom days, cancer risk estimates and acute mortality; • Building materials: in order to be able to calculate costs a damage function needs to be obtained. A physical damage function links the rate of material corrosion (due to the	Secondary (ExternE project)

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				(including cutting and clearing vegetation, salting and drainage) and, effects produced by use of the transport system (for example the impacts of atmospheric emissions from the transport vehicles and dispersal of organisms); Only the localised are studied, where the impacts are concentrated by the use of fixed routes such as roads; • Global warming: three uniformly-mixed gases – carbon dioxide, methane, nitrous oxide – and two region-specific gases-nitrogen (from aircraft) and sulphur, which influence ozone and sulphate aerosol concentrations, respectively;	pollution exposure given by the dose-response function); • Global warming: damage costs; morbidity risks are valued based on the value of a life year lost;	
Forkenbrock,D.J. (Rw 71)	1999	negative	Value lost of truck freight transportation due to accidents, emissions, noise and, unrecovered costs associated with the provision, operation, and maintenance of public facilities	• Accidents (fatalities, injuries, and property damage): costs of deaths, injuries and property damage; • Emissions (air pollution and greenhouse gases): o Air pollution: is needed the amount of air pollution associated with a unit of travel by different types of vehicles operating under different conditions and, the dollar value of damage to human health and other things of value – animals, crop, yields, building and structures, and scenic views; o Greenhouse gases: CO2 emission; • Noise: to associate the noise level in decibels above an established noise threshold with average changes in property values. Average property value changes per decibel increase can then be tied to the noise generated by a particular type of vehicle operating at various distances from the property; • Unrecovered costs associated with the provision, operation, and maintenance of public facilities (primarily roads and bridges): assess which vehicle classes, on balance, overpay and which underpay relative to other classes;	• Accidents: WTP for risk reduction; Per ton-mile external cost of general freight trucking=amount of compensation paid by affected trucking companies; External cost=total cost of society- Per ton-mile external cost of general freight trucking; • Emissions: o Air pollution: emission factors (g per mile)*costs (dollars)=costs of air pollution per vehicle-mile; Damage cost function to value damage to materials; o Greenhouse gases: quantity of diesel fuel burned (CO2 emissions)*cost per ton=cost to society of CO2 emissions per ton-mile shipped by truck; • Noise: not specified; • User charge underpayment: estimates of the magnitude of government subsidies to freight trucks are based on the equity ratios (user charges paid / cost responsibilities) produced by the Federal Highway Cost Allocation Study (Federal HCAS);	secondary
Turtós Carbonell,L.; Meneses Ruiz,E.; Sánchez Gácita,M.; Rivero Oliva,J.; Díaz Rivero,N. (Rw 72)	2007	negative	Value lost on health due to atmospheric emissions of electricity generation	• Health impacts: Year of Life Lost (YOLL) approach; the loss of life expectancy is a meaningful indicator; o Mortality impact: acute and chronic impact; specific exposure-response functions; proxies used: chronic mortality in adults and acute mortality; o Morbidity impact: cost of an acute crisis of asthma; proxies used: chronic bronchitis in adults, hospital admissions for respiratory causes, restricted activity days in adults, emergency room visits, and acute asthma crisis (asthmatic population);	• Mortality and morbidity costs: not specified; unit costs in EU (USD 2002 per case or YOLL);	secondary

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Houndekon, V.A.; De Groote,H.; Lomer,C. (Rw 73)	2006	negative	health costs to non-farming members of the community, costs covered by communal health centres, health costs to farmers' children and, externalities of livestock losses	• livestock losses: farmers and pastoralists were asked to recall the number of animals with pesticide intoxication thay had observed in their herds over the last five years, and how many of those animals died;	• Losses were valued at market price, and divided by the average number of hectares treated by the farmers (multiplying the mortality by the number of animals per farm and by their average values);	Mixed (primary and secondary)
Houndekon, V.A.; De Groote,H.; (Rw 74)	1998	negative	Value lost on health, animals and environment due to chemical pesticides	• Human health: impact on respiratory system, neurological system, skin, eye and the gastro-intestinal system; studied by a statistical model (logit model); The independent variables are individual characteristics, indicators of exposure to pesticides, and other factors that might influence health; • Livestock losses: number of animals with pesticide intoxication they had observed in their herd over the last five years, and how many of those animals died; • Destruction of obsolete pesticides: cost of cleaning up obsolete pesticides;	• Human health: o Health costs=expenses of medical services (medications or consultation fees)=loss of productive work time; • Livestock losses: (total number of animals intoxicated and how many of those died*market price of those animals)/number of hectares treated during that year in that region; • Obsolete pesticides: average cost of destroying obsolete pesticides per litre (obtained from a destruction project already existing) / hectare treated;	primary and secondary
Brisson,M.; Edmunds, W.J. (Rw 76)	2004	positive	Value created on altruism due to varicella vaccination	• The vaccine may derive benefit from knowledge that by being vaccinated they will not infect other children; they estimated whether individuals derive benefit from not infecting others because they are immunised;	• CV and standard gamble questionnaire: o CV: the respondents were given a description of a child with chickenpox; initially respondents were asked to assume that their child has chickenpox and that a drug exists which can cure their child immediately; They then elicited the maximum the respondent is willing to pay for the drug using a bidding algorithm. In the second section of the CV questionnaire, respondents were asked the maximum they were willing to pay to vaccinate their child against chickenpox; Respondents were given randomly one of 4 different contingent valuation questionnaires; The value parent's put on preventing their child infecting others (altruism) was measured by comparing the WTP from questionnaires stressing this effect to those in which the effect was not mentioned; o SG: a separate group of respondents were asked to imagine that their child is in an imaginary health state for 15 years; the duration of	primary

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					disease was chosen so that parents would trade risks of death for intervention and it is the time-span of childhood. Apart from the duration of disease, the health profile is identical to the description of chickenpox; the only attribute varied in the SG questionnaire was altruism: in half of the questionnaires altruism was included by stressing that treatment will prevent the child from giving the disease to other children. In the remainder there were no mention of knock-on effects;	
Henderson, V(Rw 77)	1997	positive	Value created on employment levels due to increased concentrations of own industry activity	• To estimate the nature, magnitude and timing of dynamic externalities, and presents industry specific estimates for five industries: through a model of local individual industry employment, using variables such as: o Concentration of own industry country employment; o Non diversity index; o Market variables: ▪ Wages; ▪ Metro area employment, excluding county own industry employment;	• Not calculated;	secondary
European Comission, DG Environmen t (Rw 80)	2000	positive and negative	Value created and lost on environment due to landfill disposal and incineration of waste	• Incineration: o <u>Air emissions</u>: o Particulates: mortality and morbidity; ecosystem; and, damage to buildings; o NO2: forest dieback and damage to buildings; aerosols (mortality and morbidity); O3(mortality, morbidity, forest die-back and lower agricultural yield); ecosystem; o SO2: mortality and morbidity; lower agricultural yield; forest die-back; damage to buildings; ecosystem; o CO: climate effect; mortality and morbidity; o VOCs: mortality and morbidity; effects of O3; o CO2: climate effect; o HCI and HF: morbidity; acidification; o Dioxins: mortality and morbidity; ecosystem; o Heavy metals: mortality and morbidity; ecosystem; › Wastewater emissions: ecosystem and mortality and morbidity; o Solid waste residues from incineration plants: bottom ash; flue gas cleaning residues; composition of solid waste	*Reporting several studies with different methods each to valuate external effects • Incineration: o External costs of air emissions; o External costs of emissions to water and soil; o External benefits; o External costs of disamenity effects; • Landfill disposal: o External costs of air emissions; o External costs of emissions to water and soil; o External benefits; o External costs of disamenity effects;	secondary

Authors	Year	Consequences				
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				residues; emission to air; o Energy recovery: in the form of electricity and/or heat; o Disamenity impacts: nuisance caused as a result of the presence of an incineration plant including noise, dust, odours, visual pollution (particularly the smoke stack), and the national presence of vermin; o Risk of accidents: contact with auxiliary materials; fire in the silo; fire in the dioxin filter; leaks from high pressure feed-water and steam system; overheating; explosive matter in the waste; leak of ammonia; contact with flue gas residues; • Landfill disposal: o Timing of emissions from landfills: landfill strategy; final storage quality; and timeframe; o Air emissions: CO2 climate effects; CH4 climate effects; CO2 and CH4 ecosystem; VOCs mortality and morbidity; dust and emissions resulting from using landfill gas; o Emissions to soil and water: leachate; o Land use: externality per se; o Displaced impacts: net energy recovered; o Disamenity impacts; o Risk of accidents: explosions and leachate emissions;		
Rabl,A.; Spadaro,J.V.; Desaigues, B. (Rw 81)	1998	negative	Value lost of environment and health due to municipal solid waste incinerators	• Air pollution: Particles, NO2, SO2 (kg/person-year); • Health impacts: o morbidity: acute and chronic effects; Number of asthma attacks due to this O3, using dose-response functions; o mortality;	CV • PM10 rural; • PM10, typical urban; • PM10, Paris • SO2 via sulfates; • NO2 via nitrates; • NO2 via ozone;	secondary
Jacobsson,F.; Carstensen, J.; Borgquist,L. (Rw 82 (22))	2005	positive	Value created for someone's health due to an altruistic behaviour	• respondents willingness to pay for someone else's possibility to be cured from each health state: seven hypothetical health states with different severity levels;	• The respondents drew a line from each box representing a health state to a box representing the amount of money the respondent was willing to pay for someone else's possibility to be cured from each health state. The method was similar to payment cards. This type of open-ended question was also used to get as much information as possible from each respondent;	primary
Krewitt,W.; Friedrich,R.; Heck,T.; Mayerhofer,P. (Rw	1998	positive	Value created on environment and health due to a reduction of SO2 and NOx emissions	• Human health: impact on o Mortality o Morbidity (respiratory symptom days, asthma attacks, or respiratory hospital admissions; • Materials: impact on replacement frequency of zinc, galvanised	• Human health: o Mortality: Value of Statistical Life (VSL), indicating WTP for a reduction of (a small) risk; o Morbidity: WTP and cost of illness of the overall health related damage costs;	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
84(25))				steel, limestone, mortar, sandstone, paint, and rendering for utilitarian buildings; • Crop production: impact on wheat, barley, potato, rye, oats, and sugar beets;	• Agriculture: direct effects of SO2 on crop yield; The costs of changing the amount of lime needed to deal with acidification of agricultural soils, and the benefits of N deposition as fertiliser has been estimated; The estimated yield cross is valued with world market prices to obtain resulting damage costs. Costs of liming and benefits of oxidised N deposition are calculated from market prices for lime and ferlitiser; • Building materials: effect of SO2 and wet acid deposition on corrosion valued using market prices; the material inventories are quantified in terms of the exposed material area from representative buildings;	
Brisson,M.; Edmunds, W.J (Rw 85(7))	2003	positive	Value created on health due to routine mass vaccination	• Effect of Herd-immunity on the dynamics of infection using routine varicella vaccination: the rate at which susceptible become infected is assumed to be a function of the number of infectious individuals in the population at a given point in time, multiplied by the effective contact rate between susceptible and infectious individuals; The impact of herd-immunity effect on the incidence of infection can be visualized as the difference between the static model (that containing the herd-immunity effect) and the static one (where the force of infection or pre-susceptible rate of infection remains constant through time);	• Not calculated;	secondary
Pillet,G., Zingg,N., Maradan,D. (Rw 86)	2001	positive and negative	Value lost and created on environment, societal and spatial structures of a region or country, welfare of people due to actions of agricultural business	• Landscape image: landscape unkeep and structuring; • Recreation: rural sightseeing, recreation and sports; • Education: education (values); • Well-being health: noise; • Animal well-being: detention condition; • Human environment: infrastructure damages (roads, railways, etc); • Resources: soil (landslide and erosion), water (pollution and eutrophication) and air (pollution, contamination); • Natural patrimony: fauna, flora and habitats, diversity and environmental domains (soil and water protection); • Climate: micro-climate, CO; • Natural hazards: avalanches;	• CV, TC or HP; • Benefits and costs o Amenities (landscape upkeep and structuring, rural sightseeing); o Costs (pollution correction) – only costs; o Natural patrimony (recreational areas, water pollution and distribution, fauna and flora); o Climate, health, hazards (diversity and CO2 production/absorption); • Examples of values used for appraising external costs and benefits of agriculture: o Landscape: WTP in Germany for landscape upkeep; o Recreation: TCM estimating relation between recreation and agriculture in Italy; o Soil protection: expenses in CH to maintain soil fertility; o Diversity: WTP for biodiversity in Swiss Jura Mountains; • Costs: o Nitrates: Cost to equip STEPs for denitrification;	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
					○ Phosphates: Cost of chemicals used to precipitate in STEPs;	
Hyojin Jeong,M.A. (Rw 87)	2004	negative	Value lost on water quality due to agricultural practices (pesticide application and tillage practice)	• Water quality aspect: pesticide contamination level is measured as micrograms per litre in finished public surface water; It is derived by summing contamination levels of seven commonly applied pesticides;	• External cost of Pesticide contamination= average annual pesticide contamination level* annual chemical cost per million gallons of water treated; • Water quality aspect=average annual pesticide contamination level in finished surface water as a measure of water quality; • Water treatment cost effect=annual chemical cost per million gallons of water treated as a measure of water treatment costs;	primary and secondary
Gulli,F. (Rw 91)	2002	negative	Value lost on environment due to CO2 emissions	• Based on dose-response approach: pollution * concentration * population * dose-response function; • Civil sector: fuel oil, diesel and, methane; • Industrial sector: fuel oil, and methane; • Transport: petrol and diesel oil; • Thermoelectric generation: Carbone, fuel oil and methane;	• Not specified;	secondary
Matthews,H .S. (Rw 95)	1999	negative	Value lost on environment due to air pollution	• Carbon Monoxide; • Nitrogen oxides; • Particulate matter; • Sulphur Dioxide; • Volatile Organic Compounds; • Global Warming Potential (in CO2) equivalent; (all in metric tons)	• Estimated external cost ($ / metric ton of air emissions)= emissions * median estimate of dollar damage;	secondary
dey Chaudhury, P. (Rw 98)	2006	negative	Value lost on environment and health due to transport emissions	• Accidents ○ Risk that he/she himself/herself may be killed or severely disabled in which case his/her family and friends will experience the costs of grief and suffering; ○ Risk that the operator may kill or injure someone else, such as pedestrian or cause damage to someone else's vehicle or property; • Fatalities; • Injuries; (on the rail and road modes for the three of them) • Human health: noxious pollutants, noise pollution, climate change, ecological damage, etc.	• Accidents, fatalities and injuries (in rupees) 'gross output' (or 'human capital') approach. The major component of the cost of an accident involving a fatality is the discounted present value of the victim's future output (or income) foregone as a result of his premature death. In the case of individuals whose services are not marketed imputations are typically made for such services. An allowance is then made for various other economic effects, such as vehicle damage, police and medical costs. The gross output approach can thus be seen as an attempt to measure the impact of death or injury on current and future levels of national output, broadly construed to include various non-marketed services; • Human health: not specified;	secondary
de Nocker,L., Vergote,S.,	1998	negative	Value lost on environment due to airborne pollutants	• Air pollution; • Human health; ○ Chronic mortality: KECU per year of life lost;	• Air pollution (including global warming)= emission*monetary value; • Human health (market prices or WTP): takes into account	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
Vinckx,L., Wouters,G. (Rw 99)			from passenger cars and public transport	• Agriculture; • Materials; • Ecosystems; o Ecological impacts; o Global warming;	the loss of income and the value people attach toa reduced mortality risk; The estimation takes into account the estimated number of years lost;	
Bickel,P., Friedrich,R. (Rw 100)	1997	negative	Value lost due to road and rail transport	• Accidents: impairment of life and health; Only personal injury is considered; • Air pollution: health effects and impairment of materials and vegetation; • Noise: human well-being on the psychological and on the physical level; • Land use: use of the surface and functions of the ground; • Barrier effects: human communication and biodiversity;	• Accidents: o human capital approach (monetary valuation oh health impairment includes rehabilitation costs as well as the costs of lost production due to injuries and fatalities; rehabilitation costs comprise average costs of medical treatment, emergency service, police and legal activity per killed or inured person; Costs of lost production are estimated based on the national income per person of employable age and year); o WTP (provides an indicator for the subjective value which individuals put on the risk of losing their life in an accident); o Damage costs like costs of medical treatment, emergency service, police, and legal activity have to be taken into account as well as the net losses for society due to lost production; • Air pollution: WTP from ExternE project; • Noise: o WTP which can be subdivided into two categories: one using results of studies based on the HP, the other using the CV; o Quantifying health effects by means of dose-response relationships; • Land use: opportunity costs are calculated for the case that the land used for traffic would be used for farming, housing, or recreation; • Barrier effects: only time losses of pedestrians are taken into account (use subways or traffic lights and waiting for a possibility to cross lead to time losses;	secondary
Mayeres,I., van Dender,K. (Rw 101)	2001	negative	Value lost on transport due to congestion, air pollution (including global warming), noise, accident and road damage costs;	• Congestion: o Change in resource costs of other vehicles due to the decrease in speed caused by the additional vehicle; o The time losses of all other road users due to the decrease in speed caused by the additional vehicle; o Air pollution (including global warming): Damage to the rest of society and to future generations; effects on health,	• Congestion: time and operation costs of the road users; o Marginal external congestion cost=time losses suffered by other road users*number of km in a period by mode j of transport*value of marginal time saving per passenger or per tonne per hour; o Value of marginal time savings=stated preference method;	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
				vegetation, materials, visibility, ecosystems, etc. (exposure-response relationships); The impacts considered are: health, materials soiling, materials, visibility, crops, forests, ecosystems, fisheries, climate change; • Accident costs: Cost of the increased accident risk = direct economic costs associated with average accident risk; • Noise: Damage to the neighbourhood; effect on the noise level of an additional vehicle-km; index used is the energy mean sound level; • Road damage costs: increased repair cost of the road borne by the government; They arise when the passage of trucks causes damage to the road surface; Two types distinguished: the increased repair cost of the road, borne by the government and the increased vehicle operating costs for the other road users;	• Air pollution: o The impacts valued are: health, materials soiling, materials, crops, and climate change; o Marginal external air pollution costs=emission factors*damage cost per g of pollutant emitted; o Damage cost per g of pollutant emitted from ExternE project data; • Accident costs: o Marginal external accident costs=pure economic costs (net output loss, ambulance costs, police and medical costs) borne by the rest of society*probability that an accident of severity n occurs between transport modes j and v and in which j is the victim (accident risks); o Pure economic costs=output loss=police and medical costs-discounted consumption; • Noise: function that relates the noise level in a street to the traffic flow; o Monetary valuation: hedonic housing market method; o Total external noise cost=monetary value for dB*noise level above the threshold established*number of road km where a noise externality is generated; • Road damage costs: o increased repair cost of the road=fraction of the average repair cost allocated over the total number of equivalent standard axles; o the increased vehicle operating costs for the other road users=are negligible;	
Roebeling,P. (Rw 102)	2006	Positive and negative	Value created from terrestrial sediment water pollution and value lost on marginal marine costs from water pollution;	• Terrestrial benefits: Marginal benefits from water pollution are obtained by computing the shadow value for sediment loads at the margin; • Marine costs: The effects of water pollution in the GBR-lagoon on reef quality and fish stocks are estimated using results from research performed by AIMS, GBRMPA, the Reef-CRC and results from research performed in other parts of the world;	• not specified	-
Fernandez, L. (Rw 103)	2006	negative	Value lost on forest and soil resources due to changes on property rights;	• impact on future generations of current use, thereby internalizing the social externality of individual household use of a rotating common property forest resource;	• not specified	-
LeClair,M.	2006	Positive	Value lost on	• Negative (agricultural or mineral in nature): land degradation	• (8) The most common is to utilize some measure of the	secondary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
S.; Franceschi, D. (Rw 104)		and negative	environment and value created on preservation of indigenous and cultural goods;	and species extinction (timber, sugar), excess use of a critical resource (rice), or outright pollution/poisoning of the environment (gold); Positive: usually involve preservation of indigenous culture or techniques of production (handicrafts);	premium consumers would be willing to pay for a substitute product that does not have the negative externality attached to it (or, in the case of positive externalities, does have the benefit imbedded. For negative spillovers, such as environmental damage, this is likely to produce, at best, a lower boundary for the valuation placed upon elimination of the externality; • (8) A value can also be placed upon externalities by measuring the cost of undoing a negative, or achieving a positive, spillover; • (8) A third means of measuring external costs and benefits is to examine the magnitude of public expenditures that are undertaken to achieve the same outcome, as this may best reflect the public's valuation of these goals; • (9) Estimates of what consumers would be willing to pay to purchase Green Products that reduce pollution;	
Janic,M. (Rw 105)	2007	negative	Value lost on environment due to a road transport network	• Air pollution: • Congestion: delays imposed on other vehicles; • Noise pollution: decline productivity and adverse health effects; • Traffic accidents: damage and property loss the network operators and third parties, in addition to the loss of life and injuries to the affected people;	• External cost (road network)= o frequency*external cost per frequency; o demand / (load factor*vehicle capacity) * external cost per frequency;	secondary
Owen,A.D.; (Rw 108)	2006	negative	Value lost due to electric power generation	• Damage caused to health and the environment by emissions other than those associated with climate change: o damage from acid rain and health damage from oxides of sulphur and nitrogen from coal-fired power stations; o power industry accidents (whether they occur in coal mines, on offshore oil or gas rigs, in nuclear plant, on wind farms or at hydro plants); o visual pollution; o noise; • Net costs of climate change attributable to greenhouse gas (and particularly CO2) emissions: o Flooding; o Changes in agriculture pattern; o Other effects;	• WTP to avoid damage arising from the emissions	secondary
de Beer,P.; Friend,F. (Rw 109)	2006	negative	Value lost on environment and human beings, their property and their welfare due to operations and products by	• Environmental degradation for which firms are not legally liable; • Adverse impacts on human beings, their property and their welfare that cannot always be compensated for through legal systems;	• Not specified	primary

Authors	Year	Consequences				
		Type	Identification	Measurement (physical effect)	Valuation[72]	Type of data
			industries;			
Blottnitz,H. V.; Rabl,A.; Boiadjiev,D .; Taylor,T.; Arnold,S. (Rw 110)	2006	negative	Value lost of environment due to synthetic nitrogen fertilizer	• Impacts due to fertilizer production (€/kg of pollutant) : o Emission of greenhouse gases; o Other air pollutants (NOx and NH4NO3); • Global warming due to N fertilizer use (€/kg of pollutant); • Health impacts (€/kg of pollutant): methemoglobinemia, a serious and often fatal illness in infants due to conversion of nitrate to nitrite by the body, which can reduce the oxygen-carrying capacity of blood; • Eutrophication (€/kg of pollutant): concentration of the phosphorus, nitrogen and other plant nutrients in an aging aquatic ecosystem, leading to excessive growth of certain species, especially blooms of algae, and creating conditions that interfere with the recreational use of lakes and estuaries, and the health and diversity of indigenous fish, plant and animal populations;	• CV (WTP to avoid damage) Fertilizer: emission value* damage costs of fertilizer; Global warming: emission per kg of fertilizer*damage cost of fertilizer; o Greenhouse gases from fertilizer production; o NOx from fertilizer production; o NH4NO3 from fertilizer production; o N2O from fertilizer in soil; o NH3 emissions from fertilizer in fields; o Eutrophication; o Health (infant mortality due to nitrates in drinking water);	secondary (ExternE project)
Pongthanap anich,T. (Rw 111)	2006	negative	Value lost on environment due to shrimp farming;	• Eutrophication • Abandonend farms: o Abandoned ponds are unsuitabe for raising shrimp or growing economic crops due to high salinity; o Without soil reclamation, salt accumulation will be a point source of surface water and groundwater contamination; o The abandoned pond cannot purify itself without remediation;	• Marginal external costs= Supply - rate of discharge*shadow price of the stock;	Mixed (primary and secondary)
Bond,E.W. (Rw 112)	2006	positive	Value created on cooperation on infraestructure investments due to infraestructure investments	• Changes in world prices: changes in the terms of trade that results from reductions in the transport cost per unit between countries; • Technological spillover from the transport cost function: which allows the level of investments in one country to affect the productivity of investments in the other country;	• Not specified	
Riddel,M.; Schwer,R.K . (Rw 113)	2006	positive	Value created on perceived risks due to nuclear-waste transport;	• Welfare values of reducing nuclear-waste transport risk;	• WTP: to avoid health and safety risks from transport by conducting a conjoint experiment where respondents rank housing choices based on various attributes including the distance from the transport route; WTA: with a contingent valuation model that analyzes household-relocation preferences for an increase in the level of neighborhood health risks from nuclear-waste transport. By using the same sample of households and the same good (housing) under different property-right assignments, they hope to offer estimates that are free of bias arising from uncertainty about the good;	primary

Appendix 3.7 Impact, measures and valuation methods: negative external effects on the consumption side

Impact area	External effect	Measurement	Paper context	Valuation method
Environment	Air pollution	Concentration per gram of pollutant and value of life	Freight transport (Rw 43)	Concentration per gram of pollutant*population*mortality rate*value of life (All the computed costs of illnesses not inducing death are based on market prices and costs: cost of medicines, ambulance, hospital, and medical services. A WTP estimate is only used for the value of life in case of death);
		pollution-related mortality risks (health effects);	Transport in less developed countries (Rw 44)	CV (WTP for small reductions in the risk of death);
		PM10 acute effects (10µg/m3): o Non accidental mortality; o Respiratory hospital admissions; o Cardiovascular hospital admissions; o Use of bronchodilators against asthma; o Prevalence of acute bronchitis; • PM2.5 chronic effects (10µg/m3): o Cardio-respiratory mortality; o Mortality due to lung cancer; • PM10 chronic effects (10µg/m3): o Incidence of chronic bronchitis; • Oxone (50µg/m3): o Non accidental death; o Days with restricted activity; o Respiratory hospital admissions (15-64) (65=); o Exacerbation of extreme asthma; o Symptom days; • UV radiation/stratospheric ozone: o Death due to melanoma cancers; • Benzene: o Death due to leukaemia; o Non fatal leukaemia; • PAHs: o Mortality due to lung cancer; • As: o Mortality due to lung cancer; • Ni: o Inhalation and decrease of IQ; o Ingestion and decrease of IQ (µg/year);	Environmental health decision making (Rw 56)	Concentration response function or unit risk factor=CV (WTP)
		costs related to health and harvest damages;	Transport sector (Rw 63)	Not specified
		take into account the impact of pollutant emissions on local concentration levels and refer to the external costs of air pollution	Urban transport (Rw 64)	CV (WTP/WTA); obtained by ExternE project;

Impact area	External effect	Measurement	Paper context	Valuation method
		on human health, materials, crops and global warming. The values are calculated for car, bus and train. The values shown for the car are in EURO per vkm, while the values for the public transport modes are in EURO per passenger km;		
		• Source: gasoline cars with and without three-way catalytic converter and diesel cars; • Emission factors: benzo-a-pyrene (BaP) (in g/km); The calculation of emissions has been done by dividing the journey into six sections representing different traffic conditions, driving cycles and meteorological conditions; • Impacts (Impact Pathway approach: exposure-response function): o Health: restricted activity days, chronic bronchitis, respiratory problems, cough, chronic bronchitis in children, chronic sore throat, respiratory hospital admissions, cerebrovascular hospital admissions, cancers and chronic mortality; o Agricultural crops: SO2; o Forests: Acid rain; o Materials: Acid rain;	Road transports (Rw 67)	CV (WTP to avoid the impacts): ECU per case;
		effects on o Health: mECU/g VOC(volatile organics compound); o Vegetation: SO2 and NOx (mECU/g); o Materials; o Aquatic ecosystems; o Visibility; o Climate: global warming (mECU/g);	Cars, trucks and urban public transports (Rw 68)	o Health (CV): mortality; morbidity (respiratory hospital asmission; emergency room visit; symptoms of chronic bronchitis; symptoms of chronic cough; restricted activity day; minor restricted activity day; asthma attack; and symptom days; o Vegetation: direct effect of SO2 on wheat, barley rye and oats (national and transnational); effect of NOx on O3 on wheat (national); o Global warming: coastal defence; dryland loss; wetland loss; ecosystem loss; agriculture; forestry and fishery losses; gains and losses in the energy and water supply; life and morbidity effects; air pollution damages; migration costs and an estimate of natural hazard damages;
		Not specified	Urban transport (Rw 99)	(including global warming)= emission*monetary value;
		health effects and impairment of materials and vegetation;	Transport (Rw 100)	WTP from ExternE project;
		(including global warming): Damage to the rest of society and to future generations; effects on health, vegetation, materials, visibility, ecosystems, etc. (exposure-response relationships); The impacts considered are: health, materials soiling, materials, visibility, crops, forests, ecosystems, fisheries, climate change;	Transport (Rw 101)	o The impacts valued are: health, materials soiling, materials, crops, and climate change; o Marginal external air pollution costs=emission factors*damage cost per g of pollutant emitted; o Damage cost per g of pollutant emitted from ExternE project data;
		Not described	Road freight transport (Rw 105)	Not valued
	Noise	Estimated either through a statistical analysis linking the rents	Freight transport (Rw	estimates which are averages of various studies relying on

Impact area	External effect	Measurement	Paper context	Valuation method
		paid with different characteristics of housing or by costing the reparative expenditures	43)	either of linking the rents paid with different characteristics of housing or costing the reparative expenditures;
		IHD Mortality; o Cardiovascular hospital admissions (IHD); o Serious nuisance; o Sleep disturbance; • Exposure: health changes and mortality risks: o DALYs: YLL = YLD o YLL=number of deaths *disability weight*standard life expectancy at age of death in years L; o YLD=number of incident cases*disability weight*average duration of disability in years L; o The number of cases (N) attributable to outdoor air pollution or noise is estimated by using the 'at least' approach. The required data components are the exposure-response function, the frequency of the health outcome and the level of exposure;	Environmental health decision making (Rw 56)	Concentration response function or unit risk factor=CV (WTP)
		Emission costs	Transport sector (Rw 63)	Not specified
		cost of noise generated by road traffic;	Urban transport (Rw 64)	it is calculated through an algorithm. The total external noise cost was calculated by multiplying the monetary value per dB by the noise level above the threshold of 50 dB(A) by the length of road where a noise externality is generated. The monetary value of noise was calculated at 0.6 EURO per 1dB(A) per kilometre;
		social cost of noise per ton-mile of transportation service in rural areas;	rail freight transportation (Rw 65)	same value as applied for trucks; adopted from the literature; HP
		effect on the noise level of an additional car km; They assume that the average street in Brussels has a U-shape; (mECU per vehicle km); Index for noise used is the energy mean sound level over a given period=53.9 = 10log (flow of light vehicles in veh/h = flow of heavy vehicles in veh/h) – 10log of width between the facades (in metres) = correction factor for speed, which means that 1dB is added for each 10km/h above a speed of 60km/h;	Cars, trucks and urban public transports (Rw 68)	Hedonic housing market method o Total external noise cost for Brussels=monetary value * noise level above the threshold of 50 * number of road km where a noise externality is generated (we assumed 500km supra); o To compute the resulting marginal external noise cost (MENC) in the reference equilibrium, we derive the total external noise cost function with respect to the number of vehicle km;
		to associate the noise level in decibels above an established noise threshold with average changes in property values. Average property value changes per decibel increase can then be tied to the noise generated by a particular type of vehicle operating at various distances from the property;	Truck Freight Transport (Rw 71)	HP
		human well-being on the psychological and on the physical level;	Transport (Rw 100)	o WTP which can be subdivided into two categories: one using results of studies based on the HP, the other using the CV; o Quantifying health effects by means of dose-response relationships;
		Damage to the neighbourhood; effect on the noise	Transport (Rw 101)	function that relates the noise level in a street to the traffic flow;

Impact area	External effect	Measurement	Paper context	Valuation method
		level of an additional vehicle-km; index used is the energy mean sound level;		o Monetary valuation: hedonic housing market method; o Total external noise cost=monetary value for dB*noise level above the threshold established*number of road km where a noise externality is generated;
		decline productivity and adverse health effects;	Road freight transport (Rw 105)	o frequency*external cost per frequency; o demand / (load factor*vehicle capacity) * external cost per frequency;
	Congestion	Cost function expressed in million ECU per t-km	Freight transport (Rw 43)	loss of time for trucks travelling along the road during peak hours*truck flows* value of time; • Loss of time=speeds on road during peak hours and outside peak hours are computed using a flow speed relation. The difference between these speeds translates into a loss of time for trucks travelling along this road during peak hours; • Value of time=all the costs linked to the operation of a truck (labour, fuel, insurance, maintenance and vehicle cost)=inventory cost of the goods transported which varies with the value of the commodities and the loading of the vehicles;
		longer journey times, increased fuel consumption and greater wear and tear on vehicles. Congestion function to describe how average speed is influenced by traffic flow. The congestion function allows the time loss suffered by other roads users to be computed if an additional passenger car unit (PCU) joins the traffic flow;	Urban transport (Rw 64)	the congestion function is combined with information on the value of time (cost of an additional PCU kilometre);
		o Congestion function: expresses the minutes needed to drive 1km in a certain period as a function of the million passenger car units (PCU) per hour at that moment in the city; o Time costs: time loss suffered by the other road users if an additional PCU joins the traffic flow;	Cars, trucks and urban public transports (Rw 68)	Not described
		o Change in resource costs of other vehicles due to the decrease in speed caused by the additional vehicle; o The time losses of all other road users due to the decrease in speed caused by the additional vehicle;	Transport (Rw 101)	o Marginal external congestion cost=time losses suffered by other road users*number of km in a period by mode j of transport*value of marginal time saving per passenger or per tonne per hour;
		delays imposed on other vehicles;	Road freight transport (Rw 105)	o frequency*external cost per frequency; o demand / (load factor*vehicle capacity) * external cost per frequency; the external cost in the collection step in zone k is proportional to the frequency of trips dependent on the quantity of loads units, the vehicle capacity and load factor, and the aggregate external cost per trip;
	Emissions	o Air pollution: volatile organic compounds (VOC), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter under 10 µm in aerodynamic diameter (PM10) (emission rates per ton-mile);	rail freight transportation (Rw 65)	emission rates*emission costs;

Impact area	External effect	Measurement	Paper context	Valuation method
		o Emission costs (cents per ton-mile); o Greenhouse gases: CO2 (cents per ton-mile);		
		o Air pollution: is needed the amount of air pollution associated with a unit of travel by different types of vehicles operating under different conditions and, the dollar value of damage to human health and other things of value – animals, crop, yields, building and structures, and scenic views; o Greenhouse gases: CO2 emission;	Truck Freight Transport (Rw 71)	o Air pollution: emission factors (g per mile)*costs (dollars)=costs of air pollution per vehicle-mile; Damage cost function to value damage to materials; o Greenhouse gases: quantity of diesel fuel burned (CO2 emissions)*cost per ton=cost to society of CO2 emissions per ton-mile shipped by truck;
	Climate changes	floods and harvest damages;	Transport sector (Rw 63)	Not specified
	Ecosystem	quality are expressed in relation to the species that have disappeared in a certain area and period, mainly vascular plants and simple organisms; Damages to ecosystems needs to introduce the following impact categories: ecotoxicity, acidification/eutrophication, and land use. For ecotoxicity, they use the unit PAFm2yr, meaning the Potentially Affected Fraction (PAF)of species in relation to the concentration of toxic substances per area and year. For acidification and eutrophication we use the unit PDFm2yr, meaning the Potentially Disappeared Fraction of plant species (PDF) per area and year. For land use, we also use the PDFm2yr as unit; Carcinogenesis (emissions to the air); Climatic change (emissions to the air);	Manufacturing and functioning of a heat pump (Rw 49)	Eco-indicator methodology and, EPS2000 methodology;
		Ecological impacts and global warming	Urban transport (Rw 99)	Not valued
	Resources	Waste heat per Kg of extracted material (surplus energy);	Manufacturing and functioning of a heat pump (Rw 49)	Eco-indicator methodology and, EPS2000 methodology;
	Livestock	farmers and pastoralists were asked to recall the number of animals with pesticide intoxication thay had observed in their herds over the last five years, and how many of those animals died	Pesticide use (Rw 73)	Losses were valued at market price, and divided by the average number of hectares treated by the farmers (multiplying the mortality by the number of animals per farm and by their average values);
		number of animals with pesticide intoxication they had observed in their herd over the last five years, and how many of those animals died;	Pesticide use (Rw 74)	(total number of animals intoxicated and how many of those died*market price of those animals)/number of hectares treated during that year in that region;
	Agriculture	Not specified	Urban transport (Rw 99)	Not valued
	Materials	Not specified	Urban transport (Rw 99)	Not valued
	Destruction of obsolet	cost of cleaning up obsolete pesticides;	Pesticide use (Rw 74)	average cost of destroying obsolete pesticides per litre (obtained from a destruction project already existing) / hectare treated;

Impact area	External effect	Measurement	Paper context	Valuation method
	e pesticides			
	Land use	use of the surface and functions of the ground;	Transport (Rw 100)	opportunity costs are calculated for the case that the land used for traffic would be used for farming, housing, or recreation;
	Barrier effects	human communication and biodiversity	Transport (Rw 100)	only time losses of pedestrians are taken into account (use subways or traffic lights and waiting for a possibility to cross lead to time losses;
Health	Accidents	Social cost for accidents between vehicles = between vehicles and pedestrians or cyclists; expressed in million ECU per t-km	Freight transport (Rw 43)	• Between vehicles=(WTP for cancelling the risk of an accident for the user=WTP for cancelling the risk of an accident for the closest relations=cost per vehicle made of the costs of police, ambulance (cold blood cost))*traffic flow*risk of accidents; • Between vehicles and pedestrians or cyclists=(WTP for cancelling the risk of an accident for the user=WTP for cancelling the risk of an accident for the closest relations=cost per vehicle made of the costs of police, ambulance (cold blood cost))*total number of km by pedestrians and cyclists*risk of accidents;
		Effect of road fatality risks (health effects)	Transport in less developed countries (Rw 44)	CHM (respondents were invited to choose between two alternative states of the highway on the basis of three attributes: travel time, accident risk and toll charge);
		what society would be prepared to pay to reduce the risk of an accident;	Urban transport (Rw 64)	CV (WTP/WTA); The WTP of relatives and friends of the victim to avoid the accident was not included in the cot estimate;
		3 primary categories of accidents=collisions at highway-rail grade crossing, persons struck by a train at other locations, and mishaps involving the train alone; o Fatalities: o Injuries: o Property damage: estimate of the value of property damage to other vehicles involved in crashes with trains at highway-rail grade crossings	rail freight transportation (Rw 65)	numbers of fatal, personal injury, and property damage accidents*the appropriate per-event cost-the amount of compensation paid by the particular mode; o Per-ton-mile external cost=external cost of accidents/ number of ton-miles; o Property damage=pProperty damage for non-crossing rail accidents (other than to trains) is comparatively minor and ignore the costs of such damage;
		marginal social accident cost (MSAC) of a car is the derivative of the total accident cost (TAC) with respect to the number of car km; A distinction is made between fatal accidents, accidents with serious injuries, accidents with light injuries and accidents with only material damage; (ECU or million ECU);	Cars, trucks and urban public transports (Rw 68)	CV o MSAC=(WTP to avoid an accident of type n = WTP of the relatives and friends of the victim to avoid an accident of type n = pure economic costs (net output losses, ambulance costs, medical costs, etc))*probability that an accident of severity n occurs between transport modes I and j and in which i is the victim*number of vehicle km travelled by transport mode;
		(fatalities, injuries, and property damage): costs of deaths, injuries and property damage;	Truck Freight Transport (Rw 71)	WTP for risk reduction; Per ton-mile external cost of general freight trucking=amount of compensation paid by affected trucking companies; External cost=total cost of society- Per ton-mile external cost of

Impact area	External effect	Measurement	Paper context	Valuation method
				general freight trucking;
		impairment of life and health; Only personal injury is considered;	Transport (Rw 100)	o human capital approach (monetary valuation oh health impairment includes rehabilitation costs as well as the costs of lost production due to injuries and fatalities; rehabilitation costs comprise average costs of medical treatment, emergency service, police and legal activity per killed or inured person; Costs of lost production are estimated based on the national income per person of employable age and year); o WTP (provides an indicator for the subjective value which individuals put on the risk of losing their life in an accident); o Damage costs like costs of medical treatment, emergency service, police, and legal activity have to be taken into account as well as the net losses for society due to lost production;
		Cost of the increased accident risk = direct economic costs associated with average accident risk;	Transport (Rw 101)	Marginal external accident costs=pure economic costs (net output loss, ambulance costs, police and medical costs) borne by the rest of society*probability that an accident of severity n occurs between transport modes j and v and in which j is the victim (accident risks); o Pure economic costs=output loss=police and medical costs-discounted consumption;
		damage and property loss the network operators and third parties, in addition to the loss of life and injuries to the affected people;	Road freight transport (Rw 105)	o frequency*external cost per frequency; o demand / (load factor*vehicle capacity) * external cost per frequency;
	Respiratory effects	• Life expectancy (emission to the air); • Severe unhealthy conditions (emission to the air); • Moderate discomfort (emissions to the air); • Moderate unhealthy conditions (emissions to the air) Expressed as DALY (Disability Adjusted Life Years). It links health effects to DALYs, using estimates of the number of Years Lived Disabled, and Years of Life Lost;	Manufacturing and functioning of a heat pump (Rw 49)	Eco-indicator methodology and, EPS2000 methodology;
	Pesticide use	impact on respiratory system, neurological system, skin, eye and the gastro-intestinal system; studied by a statistical model (logit model); The independent variables are individual characteristics, indicators of exposure to pesticides, and other factors that might influence health;	Pesticide use (Rw 74)	Health costs=expenses of medical services (medications or consultation fees)=loss of productive work time;
	Airbone pollutants	Chronic mortality: KECU per year of life lost	Urban transport (Rw 99)	(market prices or WTP): takes into account the loss of income and the value people attach toa reduced mortality risk; The estimation takes into account the estimated number of years lost;
Infrastructure	Motorway costs	infrastructure costs of a heavy vehicle moving on a motorway at 100km/h under the conditions of non-intensive traffic (€):	Transport sector (Rw 63)	Not specified
	Road damage	increased repair cost of the road borne by the government; They arise when the passage of trucks causes damage to the road surface; Two types distinguished: the increased repair	Transport (Rw 101)	o increased repair cost of the road=fraction of the average repair cost allocated over the total number of equivalent standard axles; o the increased vehicle operating costs for the other road users=are

Impact area	External effect	Measurement	Paper context	Valuation method
		cost of the road, borne by the government and the increased vehicle operating costs for the other road users;	negligible;	

Appendix 3.8 Impact, measures and valuation methods: negative external effects on the production side

Impact area	External effect	Measurement	Paper context	Valuation method
Environment	Natural resources	Water resources: a)treatment of surface water for microbial pathogens (microorganisms in livestock); b)facility infrastructure needs for nitrate treatment; c)facility infrastructure needs for pesticide treatment; Soil resources: a)cost to water resources; b)cost to replace lost capacity of reservoirs; c)water conveyance costs; d)flood damages; e)damages to recreational activities; f)cost to navigation:shipping,dredging; g)Instream impacts:commercial fisheries,preservation; h)off-stream impacts:industrial users, steam power plants; Air resources: a)cost of greenhouse gas emissions from cropland; b)cost of greenhouse gas emissions from livestock production;	Agricultural Production (Rw 38)	Water (costs of treatment to control major pollutants): • Pathogens: annualised national cost of implementing surface water treatment rule*% of damage associated to these pathogens; • Nitrate: cost for water treatment facilities to meet federal nitrate standards* % of nitrate pollution is due to agriculture; • Pesticide: cost for treatment facilities to meet Safe Drinking Water Act*% of pesticides (something in between the % of existing pesticides and % of conventional pesticide usage); Soil resources: • Water industry: % that cropland contributes o total suspended solids*water withdrawn for public supply from surface water sources (litres per day)*treatment costs (per million litres); • Reservoirs: %loss of total national capacity (between % of the nation´s water storage capacity lost annually and the average storage loss from sediment depletion)*per thousand cubic metres replacement value*% of sediment from cropland; • Conveyance: cost for sediment removal and maintenance to prevent local flooding*% for the contribution of sediment from cropland; • Flood damages ,recreational activities, navigation, commercial fisheries and preservation and, off-stream costs: total erosion effects*% damage due to cropland; Air resources: net emissions of carbon dioxide equivalents*market price carbon dioxide equivalents*% of this cost from crop production or livestock sources;
		• Coal uncontrolled emissions (lbs k Wh^-1); • Coal SO2 controlled emissions (lbs k Wh^-1); • Natural gas steam (lbs k Wh^-1); • Natural gas combined cycle (lbs k Wh^-1);	Electricity production (Rw 55)	Cost of emissions (1994$ lb^-1)*emissions (lbs kWh^-1); not specified
		Effects on the treatment or prevention costs (those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state); Administration and monitoring costs (those incurred by public authorities and agencies for monitoring environmental, food and health parameters);	Agriculture (Rw 47)	water, air, soil and biodiversity and landscape ; • Water: Cost of remove pathogens from water (pesticides, nitrate, phosphate and zoonoses)=annual operating costs*% assumed to be agricultural treatment cost; Cost to pay for restoring water courses (eutrophication and pollution incidents)=costs incurred to restore rivers to their pre-incident condition; Monitoring and advice on pesticides=pesticide monitoring in food and livestock and on surface and groundwater sites=costs in providing advice; • Air: marginal external costs from methane, nitrous oxide and carbon

Impact area	External effect	Measurement	Paper context	Valuation method
				dioxide (adopted from ExternE project:CV (WTP)); External costs of ammonia: CV (WTP) using the more conservative value of life year (from literature); • Soil: Damage caused by soil erosion: costs estimated from soil carried off farms by water or wind blocks ditches and roads, damages property, induces traffic accidents, increases the risk of floods, and pollutes water through sediments and associated nitrate, phosphate and pesticides; Organic matter and carbon dioxide losses;
		• Water quality aspect: pesticide contamination level is measured as micrograms per litre in finished public surface water; It is derived by summing contamination levels of seven commonly applied pesticides;	Recreational fishing (Rw 87)	• External cost of Pesticide contamination= average annual pesticide contamination level* annual chemical cost per million gallons of water treated; • Water quality aspect=average annual pesticide contamination level in finished surface water as a measure of water quality; • Water treatment cost effect=annual chemical cost per million gallons of water treated as a measure of water treatment costs;
	Wildlife and ecosystem biodiversity	a)honey bee and pollination losses from pesticide use; b)loss of beneficial predators by pesticide applications; c)fish kills due to pesticides; d)fish kills due to manure spills; e)bird kills due to pesticides;	Agricultural Production (Rw 38)	• Honey bee and pollination losses: colony losses, reduced honey production and crop pollination and the cost of bee rentals; • Loss of beneficial predators: cost of additional applications of pesticide due to drops in the population of beneficial insects and crop losses associated with secondary pests; • Fish kills due to pesticides: fish deaths per year due to pesticides and values of freshwater fish, reflecting commercial hatchery production costs of various fish species*cost in $ per fish; • Fish kills due to manure spills: (info on feedlot spills and associated fish kills in 10 states for 3 years=rough proxy for a national estimate)*cost in $ per fish; • Bird kills due to pesticides: number of birds exposed to pesticides*% of birds dying*value of bird's life (using lowest value from cost per bird watching, hunting costs per bird felled and the cost of rearing and releasing a bird to the wild);
		Effects on the treatment or prevention costs (those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state); Administration and monitoring costs (those incurred by public authorities and agencies for monitoring environmental, food and health parameters);	Agriculture (Rw 47)	Costs of wildlife and habitat losses=costs or restoring species and habitats under the Biodiversity Action Plans (BAPs) as a proxy; Costs of hedgerows and drystone walls=amount that farmers receive for replacing hedgerows and drystone walls under agri-environment schemes used as a proxy; Cost of agricultural biodiversity=not possible to put a cost on these losses;
	Shrimp farming	• Eutrophication • Abandonend farms: o Abandoned ponds are unsuitabe for raising shrimp or growing economic crops due to high salinity;	Shrimp farming (Rw 111)	Damage function; Marginal external costs= Supply - rate of discharge*shadow price of the stock;

Impact area	External effect	Measurement	Paper context	Valuation method
		o Without soil reclamation, salt accumulation will be a point source of surface water and groundwater contamination; o The abandoned pond cannot purify itself without remediation;		
	Intense fusion economy	Radioactive emissions in normal operation and from the final repository;	Fusion power plant (Rw 51)	Not specified
	Water quality			
	Forest and soil	impact on future generations of current use, thereby internalizing the social externality of individual household use of a rotating common property forest resource;	Agriculture (Rw 103)	Not valued
Human health	Agriculture	• (pathogens): a)cost of illnesses caused by common foodborne pathogens; b)cost to industry to comply with HACCP rule; • (pesticides): a)pesticide poisonings and related illnesses;	Agricultural Production (Rw 38)	• Pathogens o Foodborne illnesses: annual costs for bacteria damage estimates*% of health costs attributable to agricultural production; o Cost to industry to comply with HACCP: industry costs for meat and poultry plants to comply with HACCP regulations*% of health costs attributable to agricultural production; • Pesticides o Pesticide poisonings: costs of pesticide poisonings and deaths based on hospitalizations, outpatient treatment, loss of work and fatalities due to accidental poisonings and treatment costs for pesticide-induced cancers (based in part on speculation regarding the incidence of illness and death);
		Effects on the treatment or prevention costs (those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state); Administration and monitoring costs (those incurred by public authorities and agencies for monitoring environmental, food and health parameters);	Agriculture (Rw 47)	Pesticides (acute effects)=(value of a symptom-day*(number of farmers are off work for one day=those are off half a day))*GP consultation cost; Pesticides (chronic effects)=not included; Nitrate=assumed zero; Cost of food poisoning=(lost wages=consultations with doctors=hospital beds)*% poisoned people from UK farming; Antibiotic resistance=impossible to estimate; BSE and CJD(transmissible disease occurring in animals and humans)=total costs BSE*% belonging to farming;
	Emissions	• Health impacts: Year of Life Lost (YOLL) approach; the loss of life expectancy is a meaningful indicator; o Mortality impact: acute and chronic impact; specific exposure-response functions; proxies used: chronic mortality in adults and acute mortality; o Morbidity impact: cost of an acute crisis of asthma; proxies used: chronic bronchitis in adults, hospital admissions for respiratory causes, restricted activity days in adults, emergency room visits, and acute asthma crisis (asthmatic population);	Electricity generation (Rw 72)	Not specified
Environment	Plant	External costs of SO2,NOx and CO2 emissions (Euro/t CO2);	Fusion power plant (Rw 51)	Human life is assessed by CV (WTP/WTA):

Impact area	External effect	Measurement	Paper context	Valuation method
and health	construction	o Increase in traffic during the construction phase; o Increase in road accidents, due to increase in traffic, leads to deaths and injuries of the public involved in the accidents. The number and severity of the accidents are estimated using an estimation of the total amount of materials necessary to be transported together with the national road and rail accident statistics; o Occupational accidents during the construction of the plant and components are based on the expected investment cost, which lead to an estimation of the value for the person years, and the accident statistics for the different branches involve;		• WTP for a reduction in the risk of death. The 'value of statistical life' is calculated by dividing the cost of the measure to reduce the risk by the reduction in the risk of death; • WTA compensation for a higher risk; • WTP or WTA a higher risk as evaluated from interviews or questionnaires;
		o Emissions of the transport; o Road accidents; o Occupational accidents;	Electricity generation (Rw 60)	Not specified
	Normal operation	Impacts due to the emissions and the effluents of radioactive isotopes, the impacts due to the occupational radioactive exposure and other 'normal' occupational accidents;	Fusion power plant (Rw 51)	Human life is assessed by CV (WTP/WTA): • WTP for a reduction in the risk of death. The 'value of statistical life' is calculated by dividing the cost of the measure to reduce the risk by the reduction in the risk of death; • WTA compensation for a higher risk; • WTP or WTA a higher risk as evaluated from interviews or questionnaires;
		o Routine releases; o Occupational exposure; o Other occupational accidents;	Electricity generation (Rw 60)	Not specified
		• Environmental degradation for which firms are not legally liable; • Adverse impacts on human beings, their property and their welfare that cannot always be compensated for through legal systems;	Industry (Rw 109)	Not specified
	Decommissioning and recycling	Human health impacts due to release of dust and radioactivity from the recycling plant; o Death and health impacts of the decommissioning workers (number of person-years was based on estimated decommissioning years; and the number of expected accidents were based on experience from fission plants); o Road and rail accidents;	Fusion power plant (Rw 51)	Human life is assessed by CV (WTP/WTA): • WTP for a reduction in the risk of death. The 'value of statistical life' is calculated by dividing the cost of the measure to reduce the risk by the reduction in the risk of death; • WTA compensation for a higher risk; • WTP or WTA a higher risk as evaluated from interviews or questionnaires;
		• Decommissioning: o Emissions of the transport; o Road accidents; o Occupational accidents; • Recycling: o Emissions of the transport;	Electricity generation (Rw 60)	Not specified

Impact area	External effect	Measurement	Paper context	Valuation method
		o Road accidents; o Non radioactive dust emissions;Non radioactive dust emissions; o Radioactive emissions; o C-14;		
	Site restoration	o Emissions; o Traffic accidents;	Electricity generation (Rw 60)	Not specified
	Municipal solid Waste incinerator	• Air pollution: Particles, NO2, SO2 (kg/person-year); • Health impacts: o morbidity: acute and chronic effects; Number of asthma attacks due to this O3, using dose-response functions; o mortality;	Power plants, cars and waste incinerators (Rw 81)	CV
	Emissions (greenhouse)	pollution concentration*population*dose-response function; The damage taken into consideration includes the effects on public health, agriculture, forests (acid rain), the ecosystem in general, materials (deterioration of buildings and monuments) and the damage related to global warming due to greenhouse gas emissions; Dose-response functions provide the marginal damage caused by increment of concentration due to plant emissions (USD/Kg);	Gas-based energy (Rw 48)	WTP or WTA
		• Damage caused to health and the environment by emissions other than those associated with climate change: o damage from acid rain and health damage from oxides of sulphur and nitrogen from coal-fired power stations; o power industry accidents (whether they occur in coal mines, on offshore oil or gas rigs, in nuclear plant, on wind farms or at hydro plants); o visual pollution; o noise; • Net costs of climate change attributable to greenhouse gas (and particularly CO2) emissions: o Flooding; o Changes in agriculture pattern; o Other effects;	Electric power generation (Rw 108)	• WTP to avoid damage arising from the emissions
Infrastructure	Unrecovered costs on provision, operation, and maintenance of public facilities	assess which vehicle classes, on balance, overpay and which underpay relative to other classes;	Truck Freight Transport (Rw 71)	estimates of the magnitude of government subsidies to freight trucks are based on the equity ratios (user charges paid / cost responsibilities) produced by the Federal Highway Cost Allocation Study (Federal HCAS);

Appendix 3.9 Impact, measures and valuation methods: positive external effects on the consumption and production side

Side	Impact area	External effect	Measurement	Paper context	Valuation method
Consumption	Education	Effect of Standard Bank National Arts Festival	Support from low income groups to the festival	Value of arts to society (Rw 45)	CV(after being given certain basic information about the cost of the Festival and the level of government sponsorship, Grahamstown respondents were asked in a closed-ended, yes or no, question whether they would be willing to pay an extra R5 in taxes per month to support the Festival, first non-liable and then liable)
	Health	Reduction on the CHD incidence	Reducing saturated fat acid consumption	Evaluation of agricultural policy (Rw 46)	External cost savings=costs of annual CHD reduction due to a reduction in SFA (from literature)*(% of costs being external to the individual (assumption)); Kilograms of SFA consumed by the population=population*SFA per individual; Per-unit externality=External cost savings/kilograms of SFA consumed by population; External cost saved=per-unit externality*reduced kilograms of SFA consumed by the population;
		Accidents	Value of life saved	Provision of urban transport (Rw 69)	CHM (stated choice experiment; Discrete Choice Modelling); Through a multinomial logit and mixed logit it is possible to obtain value of travel time and the subjective value of accident reduction;
		Herd-immunity	Effect on the incidence of infection	Routine varicella vaccination (Rw 85 (7))	Not valued
		Mortality	Reduction of risk	Sulphur and nitrogen emission (Rw 113)	WTP: to avoid health and safety risks from transport by conducting a conjoint experiment where respondents rank housing choices based on various attributes including the distance from the transport route; WTA: with a contingent valuation model that analyzes household-relocation preferences for an increase in the level of neighborhood health risks from nuclear-waste transport. By using the same sample of households and the same good (housing) under different property-right assignments, they hope to offer estimates that are free of bias arising from uncertainty about the good;
		Morbidity	Respiratory symptom, asthma attacks, respiratory hospital admissions	Sulphur and nitrogen emission (Rw 84)	WTP and cost of illness of the overall health related damage costs;
	Infrastructure	Materials	Replacement frequency of zinc, galvanised steel, limestone, mortar, sandstone, paint, and rendering for utilitarian buildings	Sulphur and nitrogen emission (Rw 84)	effect of SO2 and wet acid deposition on corrosion valued using market prices; the material inventories are quantified in terms of the exposed material area from representative buildings;
	Environment	Make unsightly a favourite view	Stopping a development that would obscure their favourite view	Estimation of the value of the environment in the underground space use (Rw 52)	Emailed questionnaires where respondents were asked how much money they would pay to stop a development that would obscure or make unsightly their favorite view;
		Tropical	Adding one year of schooling	Ways to lower tropical	• Annual value of externality=average area of old-growth forest

Side	Impact area	External effect	Measurement	Paper context	Valuation method
		forest		deforestation (Rw 57)	cleared by a household each year*mean total value of a rain forest excluding food, raw materials, and recreation ($)*annual value of the positive externality produced by education (%); • Additional environmental externality from not cutting the fallow forest= average area of old-growth forest cleared by a household each year*mean total value of a rain forest excluding food, raw materials, and recreation ($)*% of area reduction of cut fallow forest of one more year of schooling;
		Air pollution	Housing choice behaviour considering accessibility either to work or to study	Provision of urban transport (Rw 69)	SP; Through a multinomial logit and mixed logit it is possible to obtain WTP values for travel time to work by individual h from location I and, travel time to study by individual h from location i;
		Noise	Valuing reductions in urban noise levels (quietness)	Provision of urban transport (RW 69)	CHM (Discrete Choice Modelling); Through a multinomial logit and mixed logit it is possible to obtain WTP values for noise level and travel time to work;
		Crops	Wheat, barley, potato, rye, oats and, sugar beets	Sulphur and nitrogen emission (Rw 84)	direct effects of SO2 on crop yield; The costs of changing the amount of lime needed to deal with acidification of agricultural soils, and the benefits of N deposition as fertiliser has been estimated; The estimated yield cross is valued with world market prices to obtain resulting damage costs. Costs of liming and benefits of oxidised N deposition are calculated from market prices for lime and ferlitiser;
	Welfare	Altruism	Benefit from knowledge that by being vaccinated will not infect other children	Vaccination program (Rw 85 (7))	Not valued
			Benefit from possibility to be cured from seven hypothetical different severity levels	Comparison of individual preferences of different health states (Rw 22)	• CV: The respondents drew a line from each box representing a health state to a box representing the amount of money the respondent was willing to pay for someone else's possibility to be cured from each health state. The method was similar to payment cards. This type of open-ended question was also used to get as much information as possible from each respondent;
		Health and safety risk	Reducing nuclear-waste transport risk	Nuclear-waste transport (Rw 113)	WTP: to avoid health and safety risks from transport by conducting a conjoint experiment where respondents rank housing choices based on various attributes including the distance from the transport route; WTA: with a contingent valuation model that analyzes household-relocation preferences for an increase in the level of neighborhood health risks from nuclear-waste transport. By using the same sample of households and the same good (housing) under different property-right assignments, they hope to offer estimates that are free of bias arising from uncertainty about the good;
Production	Knowledge	Innovation and employment	Knowledge expanded from electronics industry to the aerospace industry and, increase in the employment rate in the aerospace industry	Additional activities generated with the F-35 joint strike fighter (JSF) programme (Rw 40)	Knowledge expanded= valuation method not specified but monetary valuated; Employment=not monetary valuated; Revenue (revenue for the aerospace industry=(number of hours needed for one shipset*total number of shipsets)/annual workable

Side	Impact area	External effect	Measurement	Paper context	Valuation method
					hours per employee; (Maintenance, Repair and Overhaul activities are not included in the estimates);
	Innovation	Research and Development (R&D)	Proximity of the firms in technology space	R & D of other firms (Rw 41)	Mean, median and standard deviation of annual spillover pool measured in millions of 1972 dollars (the potential spillover pool is constructed using the proximities as weights in a summation of all other firms' R&D spending;
	Competition between firms	Interactions between firms	Consumers' utility derived from the bundle, and consumers' utility derived from the network of consumers who purchase from the same firm	Interactions between firms in the electronic channel (Rw 59)	Not valued
	Industrial development	Employment	Model of local individual employment, using variables such as: concentration of own industry country employment, non diversity index, market variables, wages and, metro area employment(excluding own industry country employment)	Capital goods industries (Rw 77)	Not valued
	Investment	Infrastructure investment	Level of investments in one country affecting the productivity of investments in the other country	Level of investment in trade-related transport infrastructure (Rw 112)	Not valued

Appendix 3.10 Impact, measures and valuation methods: negative and positive external effects on the consumption and production side

Side	Impact area	External effect	Measurement	Paper context	Valuation method
Consumption	Welfare	Insecurity (=)	Subjective perception of insecurity that influences their choice of transport mode for current and future pedestrians and cyclists	Use of non-motorized transport (Rw 62)	Nor specified
	Health	Accidents (-)	People injured	Use of non-motorized transport (Rw 62)	Nor specified
		Severe diseases and short-term absence (=)	Average wage cost	Use of non-motorized transport (Rw 62)	Nor specified
		Severe diseases and ailments and long-term absence/disability (=)	Risk of premature mortality related to four types of severe diseases or ailments for which has been estimated costs to society in the form of medical costs, treatment costs and potential productivity loss	Use of non-motorized transport (Rw 62)	Nor specified
	Time	Travel time (-)	Travel times for car drivers who do substitute walking or cycling for driving	Use of non-motorized transport (Rw 62)	Nor specified
	Road transport	Emissions (=)	Physical amounts and damafe effects from: CO2 emissions, local emissions to air, sulphur dioxide (SO2), nitrogen oxides (NOX), volatile organic components (VOC and NMVOC), particles with diameter less than 10 µm in diameter (PM10)	Use of non-motorized transport (Rw 62)	Nor specified
		Noise (=)	We measure the physical side of noise as the number of people disturbed by noise and unwanted sounds. The level of noise may be assessed from the average sound levels caused by different transport modes, in populated areas. The measure is decibels (dBA). Theoretically it is possible to link the change in traffic that is necessary for a certain change in dBA and thereby the subjective change in the noise level for the people affected by noise	Use of non-motorized transport (Rw 62)	Nor specified
		Congestion (=)	The total time and driving cost that is charged on the whole system from one extra vehicle entering the system	Use of non-motorized transport (Rw 62)	Nor specified
	Traffic	Wear infrastructure (-)	wear is a function of type of infrastructure traffic volume, weight of vehicle, speed, vehicle type, way of operation etc	Use of non-motorized transport (Rw 62)	Nor specified
		Parking costs (=)	Rental prices companies pay for parking spaces in the different cities	Use of non-motorized transport (Rw 62)	Nor specified

Side	Impact area	External effect	Measurement	Paper context	Valuation method
Production	Environment	Water control structure (=) and (-)	Not specified	System Rehabilitation Project; development project (Rw 50)	Net present value (NPV): the result of discounting and summing of annual net benefits stream overtime over the lifetime of the project; NPV=(NDB-DBP=ENB)*e^rt; NDB=net development benefits (difference between benefits and costs of development over time); DBP=disbenefits as a result of the project (estimated using the survey information); ENB=environmental benefits (CV method);
		Reforestation (eucalyptus)	(=): erosion control and carbon sequestration (-): nutrient loss in harvesting and costs of transpiration due to water consumption	Devastating floods (Rw 54)	• Benefits in erosion control: replacement cost method (used to estimate the on-site costs of soil erosion; This involved pricing the amount of commercial fertilizers that were needed to replace lost nutrients in eroded material); • Costs of nutrient loss in harvesting: replacement cost technique; • Cost of transpiration: transpiration ratio (basal area of the tree at breast height) and water use efficiency approaches (describe the volume of water in liters that is consumed by a plant during the growing season per kilogram of dry matter produced; • Benefits in carbon sequestration: method used by Nabuurs and Mohren (1993) based on the assumption that the estimation of carbon sequestration of the trees' different structures is possible when the annual stem volume increment in known;
		Landfill disposal and incineration of waste	• Incineration: Air emissions (mortality and morbidity; ecosystem; and, damage to buildings), Wastewater emissions (ecosystem and mortality and morbidity); Solid waste residues from incineration plants; Energy recovery; disamenity impacts: nuisance caused as a result of the presence of an incineration plant including noise, dust, odours, visual pollution and the national presence of vermin; Risk of accidents; • Landfill disposal: Timing of emissions from landfills; Air emissions; dust and emissions resulting from using landfill gas; Emissions to soil and water, Land use, displaced impacts: net energy recovered, disamenity impacts, and risk of accidents (explosions and leachate emissions);	Evaluation of waste management policies (Rw 80)	HP, CV, Dose-response functions, and clean-up costs;
		Resources, natural patrimony,	Resources : Soil (landslide and erosion), water (pollution and eutrophication) and air (pollution, contamination); Natural Patrimony: fauna, flora and habitats, diversity and	Agriculture (Rw 86)	• CV, TC or HP; • Benefits and costs o Amenities (landscape upkeep and structuring, rural sightseeing);

Side	Impact area	External effect	Measurement	Paper context	Valuation method
		climate and natural hazards	environmental domains (soil and water protection); Climate: micro-climate, CO; Natural hazards: avalanches;		o Costs (pollution correction) – only costs; o Natural patrimony (recreational areas, water pollution and distribution, fauna and flora); o Climate, health, hazards (diversity and CO2 production/absorption); • Examples of values used for appraising external costs and benefits of agriculture: o Landscape: WTP in Germany for landscape upkeep; o Recreation: TCM estimating relation between recreation and agriculture in Italy; o Soil protection: expenses in CH to maintain soil fertility; o Diversity: WTP for biodiversity in Swiss Jura Mountains; • Costs: o Nitrates: Cost to equip STEPs for denitrification; o Phosphates: Cost of chemicals used to precipitate in STEPs;
		Water pollution	Terrestrial benefits: Marginal benefits from water pollution are obtained by computing the shadow value for sediment loads at the margin •Marine costs: The effects of water pollution in the GBR-lagoon on reef quality and fish stocks	Agriculture (Rw 102)	Not valued
	Technolgy	Diffusion of information and communications (IC) technology on other industrial sectors	Productivity (production cost) and employment (labour demand, labour price function) of other industrial sectors (= and -)	Technology industry (Rw 61)	Not specified
	Infrastrucuctur e	Societal and spatial structures	Roads, railways	Agriculture (Rw 86)	• CV, TC or HP; • Benefits and costs o Amenities (landscape upkeep and structuring, rural sightseeing); o Costs (pollution correction) – only costs; o Natural patrimony (recreational areas, water pollution and distribution, fauna and flora); o Climate, health, hazards (diversity and CO2 production/absorption); • Examples of values used for appraising external costs and benefits of agriculture: o Landscape: WTP in Germany for landscape upkeep; o Recreation: TCM estimating relation between recreation and agriculture in Italy; o Soil protection: expenses in CH to maintain soil fertility; o Diversity: WTP for biodiversity in Swiss Jura Mountains;

Side	Impact area	External effect	Measurement	Paper context	Valuation method
					• Costs: o Nitrates: Cost to equip STEPs for denitrification; o Phosphates: Cost of chemicals used to precipitate in STEPs;
	Welfare	Landscape image, recreation, education, well-being health, animal well-being,	Landscape image: landscape unkeep and structuring; Recreation: rural sightseeing, recreation and sports; Education: education values; Well-being health: noise; Animal well-being: detention condition;	Agriculture (Rw 86)	• CV, TC or HP; • Benefits and costs o Amenities (landscape upkeep and structuring, rural sightseeing); o Costs (pollution correction) – only costs; o Natural patrimony (recreational areas, water pollution and distribution, fauna and flora); o Climate, health, hazards (diversity and CO2 production/absorption); • Examples of values used for appraising external costs and benefits of agriculture: o Landscape: WTP in Germany for landscape upkeep; o Recreation: TCM estimating relation between recreation and agriculture in Italy; o Soil protection: expenses in CH to maintain soil fertility; o Diversity: WTP for biodiversity in Swiss Jura Mountains; • Costs: o Nitrates: Cost to equip STEPs for denitrification; o Phosphates: Cost of chemicals used to precipitate in STEPs;
	Traded goods	Environmental degradation, resource exhaustion, habitat destruction and, positive cultural spillovers	Negative (agricultural or mineral in nature): land degradation and species extinction (timber, sugar), excess use of a critical resource (rice), or outright pollution/poisoning of the environment (gold); Positive: usually involve preservation of indigenous culture or techniques of production (handicrafts)	International trade (Rw 104)	CV and cost of undoing a negative spillover and to examine the magnitude of public expenditures that are undertaken to achieve the same outcome; (8) The most common is to utilize some measure of the premium consumers would be willing to pay for a substitute product that does not have the negative externality attached to it (or, in the case of positive externalities, does have the benefit imbedded. For negative spillovers, such as environmental damage, this is likely to produce, at best, a lower boundary for the valuation placed upon elimination of the externality; • (8) A value can also be placed upon externalities by measuring the cost of undoing a negative, or achieving a positive, spillover; • (8) A third means of measuring external costs and benefits is to examine the magnitude of public expenditures that are undertaken to achieve the same outcome, as this may best reflect the public's valuation of these goals; • (9) Estimates of what consumers would be willing to pay to purchase Green Products that reduce pollution;

Appendix 4.1 Review of incorporation of external effects in economic evaluations of smoking cessation programmes

Aim

The aim of this review was to find an economic evaluation of smoking cessation programmes in the UK setting.

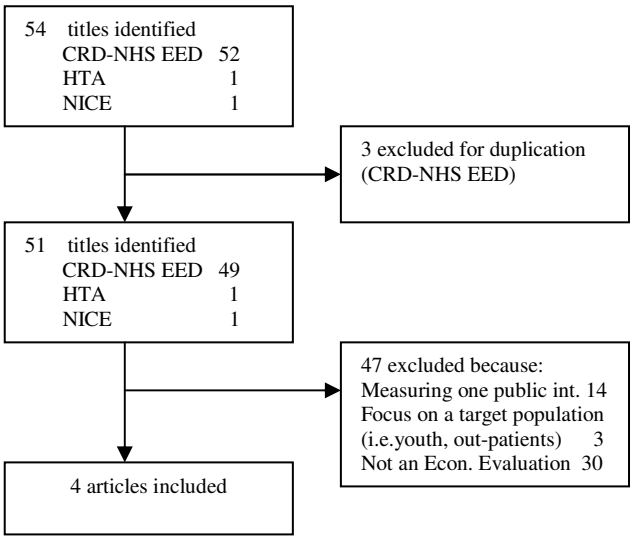
Methods

Search and selection criteria

A review of existing cost-effectiveness studies of smoking cessation interventions was undertaken using CRD (NHS-EED), NICE and Health Technology Assessment (HTA) databases. The search terms used were "cost-effectiveness" or "cost effectiveness" or "economic evaluation" or "intervention*" and "smoking". Studies were included in the cost-effectiveness review if they were economic evaluation which considered the costs and outcomes associated with two or more interventions in the treatment of smoking cessation focused in the general population.

Results

The study selection process for economic evaluation of smoking cessation programmes is represented in next figure.



Four full economic evaluations assessing the cost-effectiveness for smoking cessation interventions were found, one in NICE published literature, and three in CRD (NHS-EED). One of the studies, Salize et al (2009) focused on primary care-based strategies. Hall et al (2005) focused on economic evaluation of two pharmaceutical interventions and one psychological, whereas Mueller-Riemenschneider et al. (2008) focused on economic evaluation of behavioural strategies. Although these three papers met the inclusion criteria, the economic evaluation commissioned by NICE and built by Flack et al (2007) was selected. The reason was that had eleven public health interventions compared, in three different settings: NHS and workplace; workplace; and pharmacist-based. Therefore, it showed a better picture of current public health interventions debated.

Appendix 4.2 Review of economic evaluations of smoking cessation programmes

Aim

The aim of this review was to find an economic evaluation of smoking cessation programmes which incorporated external effects.

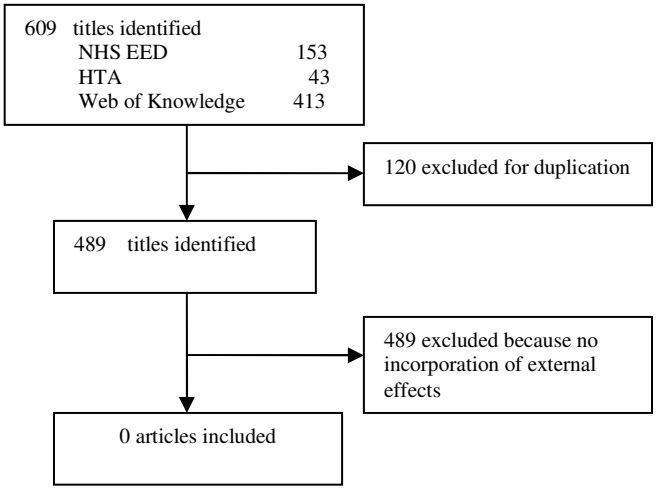
Methods

Search and selection criteria

A review of existing cost-effectiveness studies of smoking cessation interventions was undertaken using CRD (NHS-EED and HTA databases) Web of Knowledge during September 2010. The search term used in the NHS EED and HTA databases was "smoking cessation". However, for the "Web of Knowledge" the terms used were: "smoking cessation" and ("cost-benefit" or costbenefit or cost benefit or cost-effectiveness or costeffectiveness or cost effectiveness or economic evaluation or cost* or valu* or critical appraisal or model). Studies were included if they were economic evaluations of smoking cessation programmes.

Results

The study selection process for economic evaluation of smoking cessation programmes is represented in next figure.



Appendix 4.3 Transition probabilities for mortality by smoking status, age and gender

Age	Smokers		Former smokers		Non-smokers	
	Male	Female	Male	Female	Male	Female
16	0.000402	0.000260	0.000281	0.000182	0.000295	0.000191
17	0.000608	0.000283	0.000426	0.000198	0.000446	0.000208
18	0.000806	0.000309	0.000564	0.000217	0.000591	0.000227
19	0.000766	0.000375	0.000536	0.000263	0.000561	0.000275
20	0.000923	0.000313	0.000647	0.000219	0.000677	0.000230
21	0.000832	0.000334	0.000583	0.000234	0.000610	0.000245
22	0.000973	0.000339	0.000682	0.000237	0.000714	0.000249
23	0.000950	0.000367	0.000665	0.000257	0.000696	0.000269
24	0.000896	0.000345	0.000627	0.000242	0.000657	0.000253
25	0.000990	0.000397	0.000693	0.000278	0.000726	0.000291
26	0.000949	0.000434	0.000664	0.000304	0.000696	0.000318
27	0.000923	0.000413	0.000647	0.000289	0.000677	0.000303
28	0.000984	0.000439	0.000689	0.000307	0.000721	0.000322
29	0.001027	0.000495	0.000719	0.000347	0.000753	0.000363
30	0.001114	0.000545	0.000780	0.000382	0.000817	0.000400
31	0.001131	0.000575	0.000792	0.000403	0.000829	0.000422
32	0.001252	0.000594	0.000877	0.000416	0.000918	0.000435
33	0.001240	0.000636	0.000868	0.000445	0.000909	0.000466
34	0.001270	0.000743	0.000889	0.000521	0.000931	0.000545
35	0.001574	0.000828	0.001124	0.000591	0.000899	0.000473
36	0.001704	0.000922	0.001217	0.000659	0.000974	0.000527
37	0.001823	0.000975	0.001302	0.000697	0.001042	0.000557
38	0.001791	0.001182	0.001279	0.000844	0.001023	0.000675
39	0.002040	0.001238	0.001457	0.000884	0.001166	0.000707
40	0.002233	0.001318	0.001595	0.000941	0.001276	0.000753
41	0.002307	0.001398	0.001648	0.000998	0.001318	0.000799
42	0.002551	0.001604	0.001822	0.001146	0.001458	0.000917
43	0.002985	0.001824	0.002132	0.001303	0.001706	0.001042
44	0.003002	0.002045	0.002144	0.001460	0.001715	0.001168
45	0.003579	0.002397	0.002165	0.001450	0.001767	0.001184
46	0.004003	0.002775	0.002422	0.001679	0.001977	0.001370
47	0.004511	0.003082	0.002729	0.001864	0.002228	0.001522
48	0.004885	0.003339	0.002955	0.002020	0.002412	0.001649
49	0.005424	0.003520	0.003281	0.002129	0.002678	0.001738
50	0.005953	0.003988	0.003601	0.002412	0.002940	0.001969
51	0.006462	0.004290	0.003909	0.002595	0.003191	0.002118
52	0.007083	0.004523	0.004285	0.002736	0.003498	0.002234
53	0.007582	0.005073	0.004587	0.003069	0.003744	0.002505
54	0.008220	0.005414	0.004972	0.003275	0.004059	0.002673
55	0.009025	0.006065	0.005958	0.004003	0.004224	0.002838
56	0.009695	0.006649	0.006400	0.004389	0.004537	0.003112
57	0.011148	0.007187	0.007359	0.004744	0.005217	0.003363
58	0.012040	0.007928	0.007948	0.005233	0.005635	0.003710
59	0.013327	0.008787	0.008797	0.005800	0.006237	0.004112
60	0.015309	0.009936	0.010105	0.006559	0.007164	0.004650
61	0.016731	0.010653	0.011044	0.007032	0.007830	0.004985
62	0.018992	0.011739	0.012537	0.007749	0.008888	0.005494
63	0.020089	0.012821	0.013261	0.008463	0.009401	0.006000
64	0.022815	0.014515	0.015060	0.009581	0.010677	0.006793

Age	Smokers		Former smokers		Non-smokers	
	Male	Female	Male	Female	Male	Female
65	0.024788	0.015770	0.016666	0.010603	0.012500	0.007952
66	0.027133	0.017579	0.018243	0.011819	0.013682	0.008864
67	0.030149	0.019298	0.020270	0.012975	0.015203	0.009731
68	0.033568	0.021754	0.022569	0.014626	0.016927	0.010970
69	0.037351	0.023899	0.025113	0.016068	0.018835	0.012051
70	0.040610	0.026053	0.027304	0.017517	0.020478	0.013138
71	0.045593	0.029528	0.030654	0.019853	0.022990	0.014890
72	0.050793	0.033690	0.034150	0.022651	0.025613	0.016988
73	0.056207	0.037734	0.037790	0.025370	0.028343	0.019028
74	0.063166	0.042403	0.042469	0.028509	0.031852	0.021382
75	0.063717	0.042503	0.046465	0.030995	0.040514	0.027025
76	0.070623	0.047283	0.051502	0.034481	0.044906	0.030065
77	0.078201	0.052398	0.057028	0.038211	0.049724	0.033317
78	0.085962	0.058900	0.062688	0.042953	0.054659	0.037452
79	0.096776	0.064821	0.070574	0.047270	0.061535	0.041216
80	0.105485	0.073101	0.076924	0.053308	0.067073	0.046481
81	0.116436	0.081242	0.084910	0.059246	0.074036	0.051658
82	0.127432	0.091574	0.092929	0.066780	0.081028	0.058227
83	0.136373	0.099383	0.099450	0.072475	0.086713	0.063193
84	0.148824	0.111578	0.108529	0.081367	0.094630	0.070947
85	0.144552	0.109653	0.118775	0.090099	0.111438	0.084534
86	0.165692	0.126041	0.136145	0.103565	0.127735	0.097167
87	0.181541	0.139956	0.149167	0.114998	0.139953	0.107895
88	0.198050	0.155477	0.162732	0.127751	0.152680	0.119860
89	0.215215	0.171825	0.176836	0.141184	0.165913	0.132463
90	0.226968	0.189450	0.186494	0.155666	0.174974	0.146051
91	0.245152	0.207741	0.201435	0.170695	0.188993	0.160151
92	0.269136	0.231570	0.221142	0.190275	0.207482	0.178522
93	0.292858	0.254269	0.240634	0.208926	0.225770	0.196021
94	0.307673	0.276868	0.252807	0.227495	0.237191	0.213443
95	0.342798	0.296317	0.281668	0.243476	0.264269	0.228437
96	0.357484	0.321547	0.293735	0.264206	0.275591	0.247887
97	0.380309	0.344356	0.312490	0.282948	0.293188	0.265471
98	0.404971	0.367641	0.332754	0.302081	0.312200	0.283422
99	0.422426	0.390998	0.347097	0.321273	0.325657	0.301428
100	0.443596	0.417878	0.364491	0.343359	0.341976	0.322150

Appendix 4.4 Population weights by age and gender

Age	Total	Male	Female
16	0.87%	0.43%	0.44%
17	0.87%	0.43%	0.44%
18	0.87%	0.43%	0.44%
19	0.87%	0.43%	0.44%
20	0.87%	0.43%	0.44%
21	0.87%	0.43%	0.44%
22	0.87%	0.43%	0.44%
23	0.87%	0.43%	0.44%
24	0.87%	0.43%	0.44%
25	1.85%	0.93%	0.93%
26	1.85%	0.93%	0.93%
27	1.85%	0.93%	0.93%
28	1.85%	0.93%	0.93%
29	1.85%	0.93%	0.93%
30	2.10%	1.05%	1.05%
31	2.10%	1.05%	1.05%
32	2.10%	1.05%	1.05%
33	2.10%	1.05%	1.05%
34	2.10%	1.05%	1.05%
35	2.09%	1.03%	1.05%
36	2.09%	1.03%	1.05%
37	2.09%	1.03%	1.05%
38	2.09%	1.03%	1.05%
39	2.09%	1.03%	1.05%
40	1.84%	0.92%	0.92%
41	1.84%	0.92%	0.92%
42	1.84%	0.92%	0.92%
43	1.84%	0.92%	0.92%
44	1.84%	0.92%	0.92%
45	1.69%	0.84%	0.85%
46	1.69%	0.84%	0.85%
47	1.69%	0.84%	0.85%
48	1.69%	0.84%	0.85%
49	1.69%	0.84%	0.85%
50	1.83%	0.91%	0.92%
51	1.83%	0.91%	0.92%
52	1.83%	0.91%	0.92%
53	1.83%	0.91%	0.92%
54	1.83%	0.91%	0.92%
55	1.48%	0.73%	0.75%
56	1.48%	0.73%	0.75%
57	1.48%	0.73%	0.75%
58	1.48%	0.73%	0.75%
59	1.48%	0.73%	0.75%
60	1.31%	0.64%	0.67%
61	1.31%	0.64%	0.67%
62	1.31%	0.64%	0.67%
63	1.31%	0.64%	0.67%
64	1.31%	0.64%	0.67%
65	1.18%	0.56%	0.61%
66	1.18%	0.56%	0.61%
67	1.18%	0.56%	0.61%
68	1.18%	0.56%	0.61%

Age	Total	Male	Female
69	1.18%	0.56%	0.61%
70	1.06%	0.48%	0.58%
71	1.06%	0.48%	0.58%
72	1.06%	0.48%	0.58%
73	1.06%	0.48%	0.58%
74	1.06%	0.48%	0.58%
75	0.92%	0.38%	0.54%
76	0.92%	0.38%	0.54%
77	0.92%	0.38%	0.54%
78	0.92%	0.38%	0.54%
79	0.92%	0.38%	0.54%
80	0.57%	0.21%	0.36%
81	0.57%	0.21%	0.36%
82	0.57%	0.21%	0.36%
83	0.57%	0.21%	0.36%
84	0.57%	0.21%	0.36%
85	0.35%	0.10%	0.24%
86	0.35%	0.10%	0.24%
87	0.35%	0.10%	0.24%
88	0.35%	0.10%	0.24%
89	0.35%	0.10%	0.24%
90	0.08%	0.02%	0.06%
91	0.08%	0.02%	0.06%
92	0.08%	0.02%	0.06%
93	0.08%	0.02%	0.06%
94	0.08%	0.02%	0.06%
95	0.08%	0.02%	0.06%
96	0.08%	0.02%	0.06%
97	0.08%	0.02%	0.06%
98	0.08%	0.02%	0.06%
99	0.08%	0.02%	0.06%
100	0.08%	0.02%	0.06%

Appendix 4.5 Description of variables in mortality equation by Flack et al (2007)

Equation variables	Data	Source
A: Mortality odds ratio comparing smokers with former smokers	Mortality rates in relation to smoking status	Doll et al (1994)
B: Mortality odds ratio comparing smokers versus non-smokers	Mortality rates in relation to smoking status	Doll et al (1994)
C: 'Real' mortality by age and gender	Actuary Life Tables	Government Actuary's Department (2004)
D1: Prevalence of smoking by age and gender	Prevalence of smoking	Department of Health (HSE 2004)
D2: Prevalence of former smokers by age and gender	Prevalence of former smokers	Department of Health (HSE 2004)
D3: Prevalence of never regularly smoked by age and gender	Prevalence of never smokers	Department of Health (HSE 2004)

Appendix 4.6 Male mortality rates in relation to smoking status by age

Age at death	Current smoker	Former smoker	Non-smoker
Under 35	0,15	0,10	0,11
35-44	2,80	2,00	1,60
45-54	8,10	4,90	4,00
55-64	20,30	13,40	9,50
65-74	47,00	31,60	23,70
75-84	106,4	77,30	67,40
85 and over	218,70	179,70	168,60

Appendix 4.7 Actuary life tables for mortality rates by age and sex

Age	Male	Female
16	0.000321	0.000210
17	0.000486	0.000229
18	0.000644	0.000250
19	0.000612	0.000303
20	0.000738	0.000253
21	0.000665	0.000270
22	0.000778	0.000274
23	0.000759	0.000297
24	0.000716	0.000279
25	0.000820	0.000318
26	0.000786	0.000348
27	0.000765	0.000331
28	0.000815	0.000352
29	0.000851	0.000397
30	0.000923	0.000437
31	0.000937	0.000461
32	0.001037	0.000476
33	0.001027	0.000510
34	0.001052	0.000596
35	0.001124	0.000590
36	0.001217	0.000657
37	0.001302	0.000695
38	0.001279	0.000842
39	0.001457	0.000882
40	0.001595	0.000939
41	0.001648	0.000996
42	0.001822	0.001143
43	0.002132	0.001300
44	0.002144	0.001457
45	0.002345	0.001548
46	0.002623	0.001792
47	0.002956	0.001990
48	0.003201	0.002156
49	0.003554	0.002273
50	0.003901	0.002575
51	0.004234	0.002770
52	0.004641	0.002921
53	0.004968	0.003276
54	0.005386	0.003496
55	0.005915	0.003832
56	0.006354	0.004201
57	0.007306	0.004541
58	0.007891	0.005009
59	0.008734	0.005552
60	0.010033	0.006278
61	0.010965	0.006731
62	0.012447	0.007417
63	0.013166	0.008101
64	0.014799	0.008994
65	0.016079	0.009772
66	0.017600	0.010893

Age	Male	Female
67	0.019556	0.011958
68	0.021774	0.013480
69	0.024228	0.014809
70	0.026342	0.016144
71	0.029574	0.018297
72	0.032947	0.020876
73	0.036459	0.023382
74	0.040973	0.026275
75	0.045751	0.029814
76	0.050710	0.033167
77	0.056151	0.036755
78	0.061724	0.041316
79	0.069489	0.045469
80	0.075742	0.051277
81	0.083605	0.056988
82	0.091501	0.064235
83	0.097921	0.069713
84	0.106861	0.078267
85	0.118207	0.088763
86	0.135494	0.102029
87	0.148454	0.113293
88	0.161954	0.125857
89	0.175991	0.139091
90	0.185602	0.153358
91	0.200472	0.168164
92	0.220085	0.187454
93	0.239483	0.205828
94	0.251598	0.224122
95	0.280321	0.239866
96	0.292331	0.260289
97	0.310996	0.278753
98	0.331163	0.297602
99	0.345437	0.316509
100	0.362748	0.338268

Appendix 4.8 Prevalence of smoking by age interval and sex

Age	Current smoker (S)		Former (F)		Non-smoker (NS)	
	Men	Women	Men	Women	Men	Women
16-24	0.25	0.29	0.05	0.07	0.69	0.64
25-34	0.37	0.28	0.14	0.16	0.49	0.56
35-44	0.26	0.27	0.21	0.18	0.53	0.55
45-54	0.25	0.25	0.30	0.24	0.44	0.51
55-64	0.19	0.20	0.44	0.30	0.36	0.50
65-74	0.10	0.13	0.56	0.29	0.34	0.57
75 and over	0.07	0.09	0.61	0.34	0.32	0.57
All ages	0.24	0.23	0.29	0.22	0.47	0.56

Appendix 4.9 Description of variables in prevalence equation of Flack et al (2007)

Equation variables	Data	Source
H: Prevalence of each condition by age	Prevalence of LC, CHD, COPD, MI, ST	Forman et al (2003), Allender et al (2006) and Britton (2003)
I: Relative risk of each condition by smoking status (smokers versus former smokers)	Relative risk of LC, CHD, COPD, MI and ST of smokers versus former smokers	Peto et al (2000) and US Department of Health (2004)
J: Relative risk of each condition by smoking status (smokers versus non-smokers)	Relative risk of LC, CHD, COPD, MI and ST of smokers versus non-mokers	Peto et al (2000) and US Department of Health (2004)
D1: Prevalence of smoking by age and gender	Prevalence of smoking	Department of Health (HSE 2004)
D2: Prevalence of former smokers by age and gender	Prevalence of former smokers	Department of Health (HSE 2004)
D3: Prevalence of never regularly smoked by age and gender	Prevalence of never smokers	Department of Health (HSE 2004)

Appendix 4.10 Prevalence of each condition by age and sex

Appendix 4.10.1 Lung cancer

Appendix 4.10.1.1 Prevalence of lung cancer

Age	Prevalence
0-44	0.00%
45-64	0.15%
65+	0.80%
All ages	0.14%

Appendix 4.10.1.2 Relative risk of lung cancer by smoking status

Sex	Smokers	Former smokers	Non-smokers
men	1	0.44	0.03
women	1	0.21	0.05

Appendix 4.10.1.3 Prevalence of lung cancer by smoking status, age and gender

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
16	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
17	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
18	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
19	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
20	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
21	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
22	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
23	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
24	0.00007	0.00006	0.00003	0.00001	0.00000	0.00000
25	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
26	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
27	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
28	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
29	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
30	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
31	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
32	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
33	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
34	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
35	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
36	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
37	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
38	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
39	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
40	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
41	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
42	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
43	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
44	0.00005	0.00006	0.00002	0.00001	0.00000	0.00000
45	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
46	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
47	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
48	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
49	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
50	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
51	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
52	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
53	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
54	0.00383	0.00214	0.00169	0.00045	0.00012	0.00011
55	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
56	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
57	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
58	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
59	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
60	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
61	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
62	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
63	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
64	0.00384	0.00241	0.00169	0.00051	0.00012	0.00012
65	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
66	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
67	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
68	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
69	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
70	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
71	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
72	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
73	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
74	0.02236	0.01007	0.00984	0.00211	0.00067	0.00050
75	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
76	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
77	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
78	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
79	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
80	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
81	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
82	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
83	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
84	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
85	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
86	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
87	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
88	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
89	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
90	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
91	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
92	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
93	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
94	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
95	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
96	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
97	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
98	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
99	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058
100	0.02304	0.01167	0.01014	0.00245	0.00069	0.00058

Appendix 4.10.2 Coronary heart disease

Appendix 4.10.2.1 Prevalence of coronary heart disease

Age	Prevalence
16-24	0.00%
25-34	0.00%
35-44	0.90%
45-54	3.50%
55-64	11.10%
65-74	21.50%
75+	26.40%

Appendix 4.10.2.2 Relative risk of coronary heart disease by smoking status

Smokers	Former smokers	Non-smokers
3.12	1.55	1

Appendix 4.10.2.3 Prevalence of coronary heart disease by smoking status, age and gender

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
16	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
17	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
18	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
19	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
20	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
21	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
22	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
23	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
24	0.00000	0.00378	0.00000	0.00188	0.00000	0.00121
25	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
26	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
29	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
31	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
32	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
33	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
34	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
35	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
36	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
37	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
38	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
39	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
40	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
41	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
42	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
43	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
44	0.01677	0.00747	0.00833	0.00371	0.00538	0.00239
45	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
46	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
47	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
48	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
49	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
50	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
51	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
52	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
53	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
54	0.06416	0.03767	0.03188	0.01871	0.02057	0.01207
55	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
56	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
57	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
58	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
59	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
60	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
61	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
62	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
63	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
64	0.20977	0.11597	0.10421	0.05761	0.06724	0.03717
65	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
66	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
67	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
68	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
69	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
70	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
71	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
72	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
73	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
74	0.44038	0.20962	0.21878	0.10414	0.14115	0.06718
75	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
76	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
77	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
78	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
79	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
80	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
81	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
82	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
83	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
84	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
85	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
86	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
87	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
88	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
89	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
90	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
91	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
92	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
93	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
94	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
95	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
96	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
97	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
98	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
99	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294
100	0.55568	0.41478	0.27606	0.20606	0.17810	0.13294

Appendix 4.10.3 Chronic obstructive pulmonary disease

Appendix 4.10.3.1 Prevalence of chronic obstructive pulmonary disease

Age	Prevalence
0-64	1.00%
65-74	5.00%
75+	10.00%

Appendix 4.10.3.2 Relative risk of chronic obstructive pulmonary disease by smoking status

Sex	Smokers	Former smokers	Non-smokers
Men	1	0.84	0.68
Women	1	0.96	0.92

Appendix 4.10.3.3 Prevalence of chronic obstructive pulmonary disease by smoking status, age and gender

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
16	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
17	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
18	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
19	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
20	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
21	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
22	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
23	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
24	0.013	0.01057	0.01091	0.01015	0.00883	0.00973
25	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
26	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
27	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
28	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
29	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
30	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
31	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
32	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
33	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
34	0.01216	0.01054	0.01022	0.01012	0.00827	0.00970
35	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
36	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
37	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
38	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
39	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
40	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
41	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
42	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
43	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
44	0.01254	0.01054	0.01053	0.01012	0.00853	0.00970
45	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
46	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
47	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
48	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
49	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
50	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
51	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
52	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
53	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
54	0.01236	0.01053	0.01038	0.01011	0.00840	0.00969
55	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
56	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
57	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
58	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
59	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
60	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
61	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
62	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
63	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
64	0.01231	0.01055	0.01034	0.01013	0.00837	0.00971
65	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
66	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
67	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
68	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
69	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
70	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
71	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
72	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
73	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
74	0.06235	0.05306	0.05237	0.05093	0.04240	0.04881
75	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
76	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
77	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
78	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
79	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
80	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
81	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
82	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
83	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
84	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
85	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
86	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
87	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
88	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
89	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
90	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
91	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
92	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
93	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
94	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
95	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
96	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
97	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
98	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
99	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777
100	0.12504	0.10627	0.10504	0.10202	0.08503	0.09777

Appendix 4.10.4 Myocardial infarction

Appendix 4.10.4.1 Prevalence of myocardial infarction

Age	Prevalence
0-54	0.00%
55-64	6.70%
65-74	12.10%

Appendix 4.10.4.2 Relative risk of myocardial infarction by smoking status

Sex	Smokers	Former smokers	Non-smokers
Men	1.6	1.11	1
Women	2.76	1.05	1

Appendix 4.10.4.3 Prevalence of myocardial infarction by smoking status, age and gender

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
19	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
24	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
25	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
26	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
29	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
30	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
31	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
32	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
33	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
34	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
35	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
36	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
37	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
52	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
55	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
56	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
57	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
58	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
59	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
60	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
61	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
62	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
63	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
64	0.09210	0.04250	0.06390	0.01617	0.05756	0.01540
65	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
66	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
67	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
68	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
69	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
70	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
71	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
72	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
73	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
74	0.17246	0.09283	0.11965	0.03532	0.10779	0.03363
75	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
76	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
77	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
78	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
79	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
80	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
81	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
82	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
83	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
84	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
85	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
86	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
87	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
88	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
89	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
90	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
91	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
92	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
93	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
94	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
95	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
96	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
97	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
98	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
99	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555
100	0.17463	0.09811	0.12115	0.03732	0.10914	0.03555

Appendix 4.10.5 Stroke

Appendix 4.10.5.1 Prevalence of stroke

Age	Prevalence
16-24	0.00%
25-34	0.00%
35-44	0.30%
45-54	1.20%
55-64	2.20%
65-74	7.60%
75+	13.30%

Appendix 4.10.5.2 Relative risk of stroke by smoking status

Smokers	Former smokers	Non-smokers
1.37	1.11	1

Appendix 4.10.5.3 Prevalence of stroke by smoking status, age and gender

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
16	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
17	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
18	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
19	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
20	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
21	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
22	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
23	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
24	0.00125	0.00246	0.00101	0.00199	0.00091	0.00179
25	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
26	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
27	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
28	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
29	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
30	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
31	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
32	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
33	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
34	0.00475	0.00367	0.00385	0.00297	0.00347	0.00268
35	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
36	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
37	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
38	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
39	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
40	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
41	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
42	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
43	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
44	0.00367	0.00734	0.00297	0.00595	0.00268	0.00536
45	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
46	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
47	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
48	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
49	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
50	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
51	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
52	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
53	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
54	0.01459	0.01103	0.01182	0.00894	0.01065	0.00805
55	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
56	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
57	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
58	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
59	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
60	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
61	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
62	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
63	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
64	0.02691	0.03095	0.02181	0.02507	0.01965	0.02259
65	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
66	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
67	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
68	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
69	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
70	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
71	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
72	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
73	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
74	0.09473	0.06840	0.07675	0.05542	0.06914	0.04993
75	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
76	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
77	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
78	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
79	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
80	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
81	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
82	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
83	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
84	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
85	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
86	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
87	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
88	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
89	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
90	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
91	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
92	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304

Age	Smokers		Former Smokers		Non-smokers	
	Men	Women	Men	Women	Men	Women
93	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
94	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
95	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
96	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
97	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
98	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
99	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304
100	0.16675	0.11377	0.13510	0.09218	0.12172	0.08304

Appendix 5.1 Search strategy and search terms of passive smoking health effects and mortality review

Search strategy

An established search protocol was used to identify reviews and meta-analysis of risk and mortality of health effects caused by passive smoking. The decision to restrict this to reviews was taken to avoid the maximum variability among estimates, and to introduce sensible average values in the model. Comprehensive searches were conducted using bibliographic databases, bibliographies of relevant reviews and internet sites for epidemiological data on passive smoking in Europe, US and UK. Searches were carried out on May 2009, and involved 3 electronic databases (MEDLINE -Ovid and Pubmed-, Cochrane Library -Wiley Internet version-, and Office of Health Economics Health Economic Evaluation Database –HEED). The World Health Organization (WHO), The Office of Surgeon General US, the Centers for Disease Control and Prevention, and the Information Centre of NHS sites were also consulted by email. This search was restricted to English language, humans, review papers, and without time restrictions and included a combination of text words. The free text terms were "passive smoking", "environmental tobacco smoke", "second hand smoke", "second-hand smoke", "secondhand smoke", "indoor air pollution" and "air pollution". Only the Cochrane reviews results were considered for revision. Search terms were contrived to retrieve papers on risk and mortality of passive smoking health effects.

Databases

Cochrane Library

Cochrane Database of Systematic Reviews

World Health Organization (Internet access)

European data on tobacco (http://data.euro.who.int/tobacco/)

US Department of Health & Human Services (Internet access)

Office of the Surgeon general – data on smoking consequences

(http://www.surgeongeneral.gov/library/smokingconsequences/)

Centers for Disease Control and Prevention (Internet access)

Statistics on smoking

(http://www.cdc.gov/tobacco/data_statistics/sgr/sgr_2006/index.htm)

NHS The Information Centre for health and social care

Publications on smoking (http://www.ic.nhs.uk/pubs/smoking08)

Bibliographic database

MEDLINE (Ovid and Pubmed) – systematic review

Office of Health Economics Health Economic Evaluation Database (HEED)

Search terms

Source - Cochrane Library (Wiley)

#1 "passive smoking in Title, Abstract or Keywords or environmental tobacco smoke in Title, Abstract or Keywords or secondhand smoke in Title, Abstract or Keywords or second hand smoke in Title, Abstract or Keywords or indoor air pollution in Title, Abstract or Keywords in Cochrane Database of Systematic Reviews"

10

Source - Health Economic Evaluation Database

#1 passive smoking and review

4

#2 environmental tobacco smoke and review

1

#3 secondhand smoke and review

0

#4 second-hand smoke and review

0

#5 second hand smoke and review

0

#6 indoor air pollution and review

0

Not possible to limit the search to English language and humans. Restricted search to all type of data. Not possible to restrict it to title abstract & key words.

Source Ovid MEDLINE 2000 to August 2009

1 Passive smoking.mp.or Tobacco Smoke Pollution (7839)
2 Environmental tobacco smoke.mp. (2273)
3 Second hand smoke or second-hand smoke or secondhand smoke).mp. [mp=title, original title, abstract, name of substance word, subject heading word] (725)
4 Indoor air pollution.mp. or Air Pollution, Indoor (6862)
5 4 or 1 or 3 or 2 (14851)
6 Limit 5 to (English language and humans) (10605)
7 Limit 6 to "review articles" (1413)

All titles and abstracts were screened for relevance. Full paper copies of any titles or abstracts judged of potential relevance were obtained. The relevance of each full abstract was assessed. Studies that failed to satisfy all criteria were excluded and the reason for their exclusion recorded. References from searched papers were scrutinized to add relevant references to the search. If no papers were found related either to clinical effects or mortality, experts on smoking in UK suggested data sources.

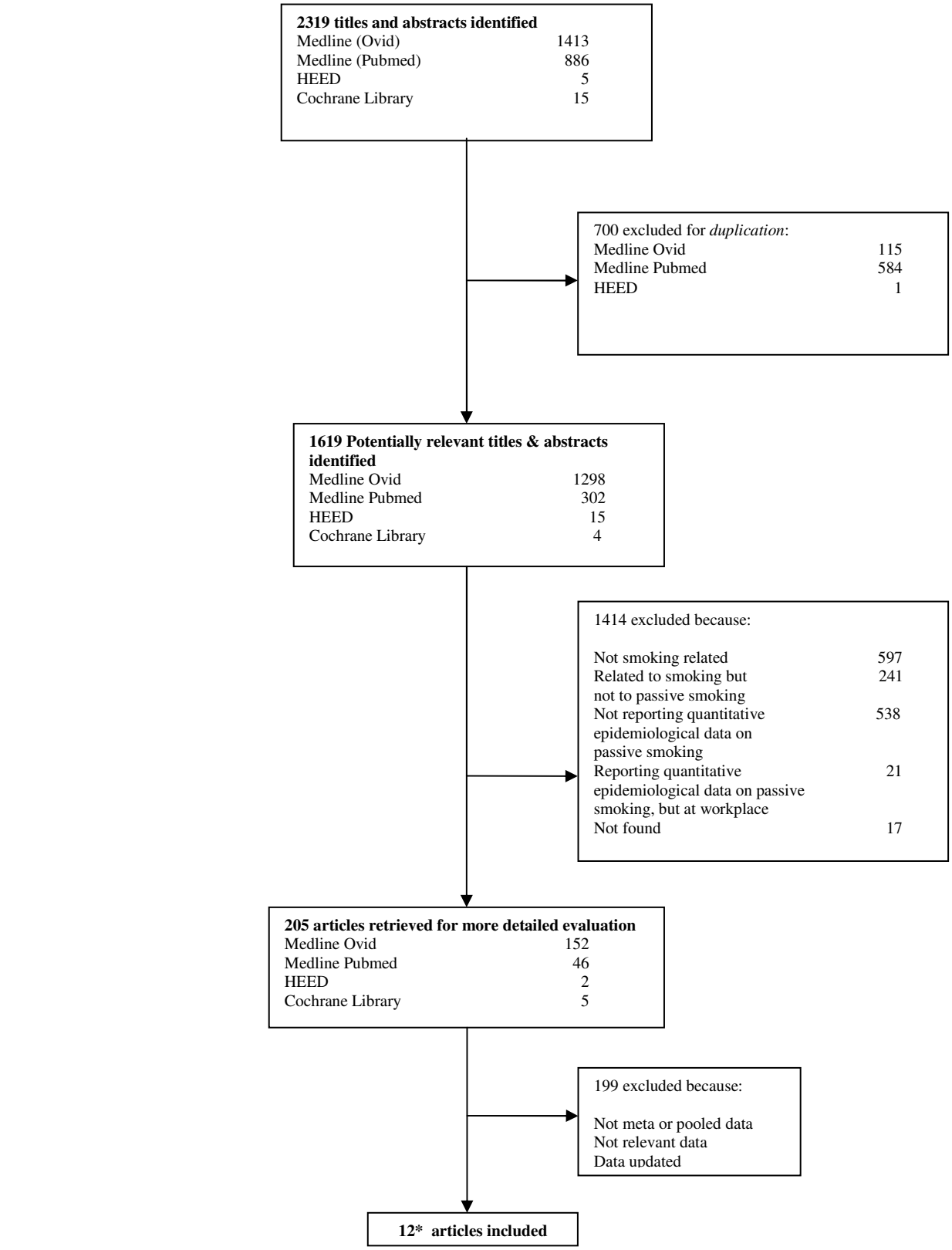
Study selection criteria

A selected paper had to satisfy all the requirements of the following criteria: (a) to present meta-analytic data or pooled data on relative risks or odds ratios of clinical effects on human due to passive smoking; (b) to estimate the causes of mortality among adults passive smokers who have never smoked; (c) be written in English, because there were no resources for translations. Studies were excluded if the data they reported were updated in other papers published in following years or if the epidemiological evidence was reported as not strong enough for clear conclusions.

Data extraction strategy

Data were extracted into two summary tables: one to describe the important health effects of passive smoking in adults and the other to describe the health effects for children.

Appendix 5.2 Study selection process of systematic review for passive smoking health effects



* 6 articles were included from the literature review and 6 papers were added from experts' recommendations

Appendix 5.3 References included in the systematic literature search of health effects of passive smoking

Barnoya J, Glantz SA. Cardiovascular effects of second-hand smoke. Nearly as large as smoking. Circulation, 2005;111:2684-2698.

Cook DG, Strachan DP. Summary of effects of parental smoking on the respiratory health of children and implications for research. Thorax, 1999; 54(4):357-366.

Hackshaw AK, Law MR, Wald NJ. The accumulated evidence on lung cancer and environmental tobacco smoke. British Medical Journal, 1997; 315(7114):980-988.

He J, Vupputuri S, Allen K, Prerost MR, Hughes J, Whelton PK. Passive smoking and the risk of coronary heart disease – a meta-analysis of the epidemiologic studies. The New England Journal of Medicine, 1999; 340(12): 920-926.

Law MR, Morris JK, Wald NJ. Environmental tobacco smoke exposure and ischaemic heart disease: an evaluation of the evidence. British Medical Journal, 1997; 315:973-980.

Leonardi-Bee J, Smyth A, Britton J, Coleman T. Environmental tobacco smoke and fetal health: systematic review and meta-analysis. Archives of Disease Children Fetal Neonatal, 2008; 93:F351-F361.

Li JSM, Peat JK, Xuan W, Berry G. Meta-analysis on the association between environmental tobacco smoke (ETS) exposure and the prevalence of lower respiratory tract infection in early childhood. Pediatric Pulmonology, 1999; 27:5-13.

Pattenden S, Antova T, Neuberger M, Nikiforov B, De Sario M, Grize L, Heinrich J, Hruba F, Janssen N, Luttmann-Gibson H, Privalova L, Rudnai P, Splichalova A, Zlotkowska R, Fletcher T. Parental smoking and children's respiratory health: independent effects of prenatal and postnatal exposure. Tobacco control, 2006; 15:294-301.

Scientific Committee on Tobacco and Health (SCOTH). Secondhand Smoke: Review of evidence since 1998. Update of evidence on health effects of secondhand smoke. UK: Department of Health, 2004.

Taylor R, Najafi F, Dobson A. Meta-analysis of studies of passive smoking and lung cancer: effects of study type and continent. International Journal of Epidemiology, 2007;36(5):1048-1059.

Thun M, Henley J, Apicella L. Epidemiologic studies of fatal and nonfatal cardiovascular disease and ETS exposure from spousal smoking. Environmental Health Perspectives, 1999; 107(6):841-846.

Uhari M, Mäntysaari K, Niemelä M. A meta-analytic review of the risk factors for acute otitis media. Clinical Infectious Diseases, 1996; 22(6):1079-1083.

Appendix 5.4 Mortality transition probabilities for smokers, former smokers, never smokers' non passive and passive

Age	Smokers		Former smokers		Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women	Men	Women	Men	Women
16	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
16.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
17	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
17.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
18	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
18.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
19	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
19.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
20	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
20.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
21	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
21.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
22	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
22.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
23	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
23.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
24	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
24.5	0.000068	0.000059	0.000030	0.000012	1.962085E-06	2.865111E-06	2.432986E-06	3.552737E-06
25	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
25.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
26	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
26.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
27	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
27.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
28	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
28.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
29	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
29.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
30	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
30.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
31	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
31.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
32	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
32.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
33	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
33.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
34	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
34.5	0.000045	0.000059	0.000020	0.000012	1.322742E-06	2.885844E-06	1.640200E-06	3.578447E-06
35	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
35.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
36	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
36.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
37	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
37.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
38	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
38.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
39	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
39.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
40	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
40.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
41	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
41.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
42	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
42.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
43	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
43.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
44	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06

Age	Smokers		Former smokers		Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women	Men	Women	Men	Women
44.5	0.000054	0.000060	0.000024	0.000013	1.612977E-06	2.928342E-06	2.000091E-06	3.631144E-06
45	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
45.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
46	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
46.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
47	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
47.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
48	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
48.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
49	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
49.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
50	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
50.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
51	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
51.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
52	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
52.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
53	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
53.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
54	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
54.5	0.003871	0.002117	0.001703	0.000445	1.143538E-04	1.043277E-04	1.417988E-04	1.293664E-04
55	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
55.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
56	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
56.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
57	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
57.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
58	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
58.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
59	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
59.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
60	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
60.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
61	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
61.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
62	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
62.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
63	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
63.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
64	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
64.5	0.003879	0.002396	0.001707	0.000503	1.148048E-04	1.185546E-04	1.423580E-04	1.470077E-04
65	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
65.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
66	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
66.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
67	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
67.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
68	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
68.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
69	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
69.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
70	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
70.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
71	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
71.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
72	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
72.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
73	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
73.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
74	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04

Age	Smokers		Former smokers		Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women	Men	Women	Men	Women
74.5	0.022434	0.010255	0.009871	0.002154	6.678525E-04	5.081599E-04	8.281371E-04	6.301182E-04
75	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
75.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
76	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
76.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
77	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
77.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
78	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
78.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
79	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
79.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
80	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
80.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
81	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
81.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
82	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
82.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
83	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
83.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
84	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
84.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
85	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
85.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
86	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
86.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
87	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
87.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
88	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
88.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
89	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
89.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
90	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
90.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
91	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
91.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
92	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
92.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
93	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
93.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
94	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
94.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
95	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
95.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
96	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
96.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
97	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
97.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
98	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
98.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
99	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
99.5	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04
100	0.022989	0.011848	0.010115	0.002488	6.843569E-04	5.840074E-04	8.486026E-04	7.241691E-04

Appendix 5.5 Search strategy and search terms of systematic literature review on prevalence, costs and QALYs of passive smoking health effects

Methods

Cochrane Library

Cochrane Database of Systematic Reviews

Health Technology Assessment (Internet access)

Office of Technology Assessment

Office for National Statistics database (Internet access)

National statistics data

Bibliographic database

MEDLINE – systematic review

Office of Health Economics Health Economic Evaluation Database (HEED)

Search terms

Source - Cochrane Library (Wiley)

#1 asthma and children, from 2000 to 2009

52

#2 wheeze and children, from 2000 to 2009

5

#3 cough and children, from 2000 to 2009

16

#4 phlegm and children, from 2000 to 2009

0

#5 breathlessness and children, from 2000 to 2009

0

#6 recurrent otitis media and children, from 2000 to 2009

1

#7 otitis media with effusion and children, from 2000 to 2009

4

#8 acute otitis media and children, from 2000 to 2009

7

#9 glue ear and children, from 2000 to 2009

0

Source - Health Economic Evaluation Database

#1 asthma and children

52

#2 wheeze and children

1

#3 cough and children

9

#4 phlegm and children

0

#5 breathlessness and children

0

#6 recurrent otitis media and children

1

#7 otitis media with effusion and children

5

#8 acute otitis media and children

22

#9 glue ear and children

2

Source Ovid MEDLINE 2000 to August 2009

8 asthma.ti. (50322)

9 wheez*.ti. (1551)

10 cough.ti. (6016)

11 phlegm.ti. (80)

12 breathless*.ti (487)

13 recurrent otitis media.ti. (157)

14 otitis media with effusion.ti. (1045)

15 glue ear.ti. (184)

16 acute otitis media.ti. (1752)

17 prevalence.ti. (56707)

18 (cost* or economic).ti. (75668)

19 (QALY* or utilit* or quality of life or quality-of life or quality adjusted life years or quality-adjusted life years).ti. (35886)

20 1 and 10 (960)

21 limit 13 to last 10 years (626)

22 10 and 2 (56)

23 limit 15 to last 10 years (33)

24 3 and 10 (30)

25 limit 17 to last 10 years (14)

26 4 and 10 (2)

27 limit 19 to last 10 years (0)

28 10 and 5 (0)

29 6 and 10 (3)

30 limit 22 to last 10 years (2)

31 7 and 10 (20)

32 limit 24 to last 10 years (9)

33 10 and 9 (3)

34 limit 26 to last 10 years (2)

35 11 and 1 (434)

36 limit 28 to last 10 years (321)

37 1 and 12 (450)

38 limit 30 to last 10 years (355)

39 11 and 2 (5)

40 limit 32 to last 10 years (4)

41 12 and 2 (8)

42 limit 34 to last 10 years (7)

43 11 and 3 (13)

44 limit 36 to last 10 years (5)

45 3 and 12 (21)

46 limit 38 to last 10 years (18)

47 11 and 4 (0)

48 4 and 12 (1)

49 limit 41 to last 10 years (1)

50 11 and 5 (1)

51 limit 43 to last 10 years (0)

52 12 and 5 (5)

53 limit 45 to last 10 years (4)

54 6 and 11 (2)

55 limit 47 to last 10 years (1)

56 6 and 12 (1)

57 limit 49 to last 10 years (0)

58 11 and 7 (2)

59 limit 51 to last 10 years (2)

60 7 and 12 (3)

61 limit 53 to last 10 years (2)

62 11 and 9 (14)

63 limit 55 to last 10 years (7)

64 9 and 12 (4)

65 limit 57 to last 10 years (3)

66 8 and 11 (0)

67 8 and 12 (0)

68 8 and 10 (0)

Search strategy

A comprehensive search for literature on prevalence, costs and QALYs of passive smoking health effects was conducted. Studies on costs and QALYs were identified from: MEDLINE (Ovid) 2000-July 2009; Office of Health Economics Health Economic Evaluation Database (HEED); Cochrane Library -Wiley Internet version 2000-July 2009; Health Technology Assessment database (HTA); and the National Institute for Health and Clinical Excellence (NICE). An additional search was conducted on the Office for National Statistics database.

This search was restricted to English language, humans, and with no time restrictions, with the exceptions of Medline Ovid and Cochrane Library because of the high number of inputs resulting from the search. Search terms were contrived to retrieve papers on

prevalence, risk and mortality of passive smoking health effects. Details of searches can be found in Appendix 6.8.

All titles and abstracts were screened for relevance. Full paper copies of any titles or abstracts judged of potential relevance were obtained. The relevance of each full abstract was judged according to predefined criteria (see below). Studies that failed to satisfy all criteria were excluded and the reason for their exclusion was recorded. References from searched papers were scrutinized to add relevant references to the search.

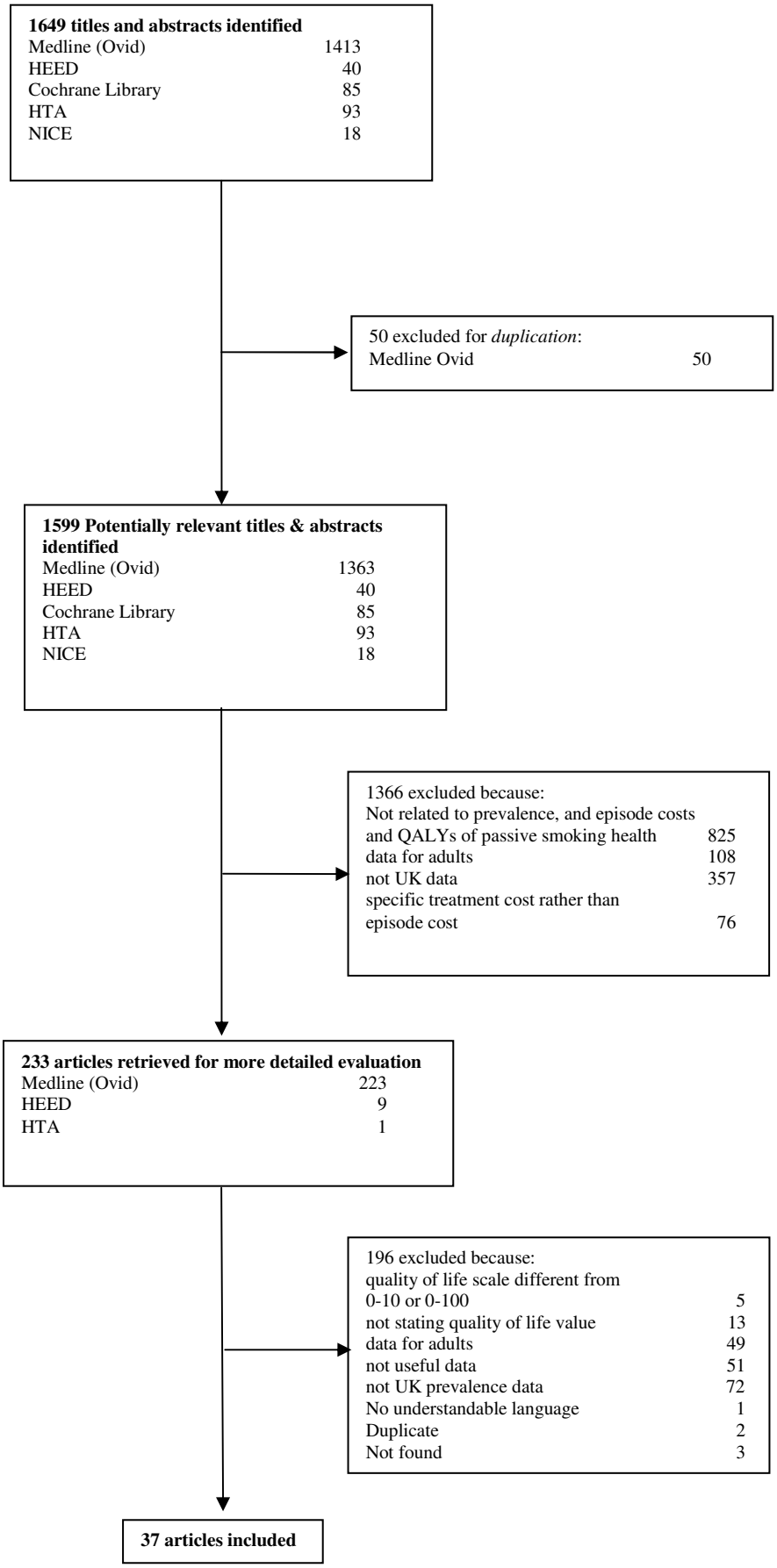
Inclusion criteria

Studies that specify utility values or episode costs of health effects due to passive smoking were included. Studies were excluded if they did not express the costs in terms of cost per episode. The following types of paper were also excluded: papers reporting utilities values in a different scale than 0-10 or 0-100, papers not stating prevalence, not UK estimates on prevalence data, and papers written not in English, because there were no resources for translations.

Data extraction strategy

The data was extracted according to the guidelines produced by the Centre for Reviews and Dissemination (CRD) for the critical appraisal of economic evaluations. Data extraction focused on costs episode and utility values using 0-10 or 0-100 scales.

Appendix 5.6 Study selection process for health effects of passive smoking systematic review



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Appendix 5.8 Selection of datasets for incidence parameter calculation

Methods

This section highlights how the dataset were identified and selected for review.

Search strategy

A search for datasets was conducted in July 2009 in the UK Data Archive (UKDA)[78]. In addition, some institutions were contacted in the search for data.

Table 5.1.1 provides a list of the institutions and individuals who were contacted in the search for data.

Table 5.1.1: List of contacted individuals

Lesley Owen, Analyst, National Institute for Clinical Excellence (NICE), UK
Alison Toczek, NHS Information Centre, UK
Hershbinder Mann, Senior data and support services officer, UK Data Archive, UK
Andy McEwen, Senior research nurse, assistant director tobacco studies, Cancer Research UK Health Behaviour Research Centre, Unicersity College of London, UK
Economic and Social Data service (ESDS), Universities of Essex and Manchester, UK

Selection criteria

Datasets that satisfied the following criteria were selected for review: (a) dataset based on the UK or English general adult (16 years and older) population; (b) data collection conducted from 2000 up to date; and, (c) dataset having smoking specific indicators.

Datasets were also browse by drug abuse, alcohol and smoking subject.

Results

The search strategy identified a total of 30 datasets that were subjected to the selection criteria. All of them were selected for review. None of the data sets had longitudinal data specifically to calculate uptake of smoking. Nonetheless, Lesley Owen, analyst from NICE, advised to follow same proxy as Raikou and McGuire (2008) used to approximate this data. Therefore, the age adults started smoking regularly was used to calculate the number of new smokers, by age, generated in the population. Either the

[78] The UKDA is a custodian of the biggest collection of digital data in the social sciences and humanities in the UK. It is also in charge of the management of the Economic and Social Data Service (ESDS) as a lead collaborator.

HSE or GHS contained this information. But, meanwhile the HSE is designed to monitor trends in the nation's health, the GHS tries to document the major picture of UK households and, to monitor trends in the prevalence of smoking and drinking. Even though that was not possible to cluster the information by households in this last survey because the household member's numbers were changing across survey waves, the information reported by GHS was considered for this analysis. Moreover, Raikou and McGuire (2008) did also consider the same data source for the same analysis.

Therefore, the General Household Survey (2006) was used to calculate the incidence of smoking by age.

Appendix 5.9 Incidence transition probability by age and sex

Age	Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women
16	0,059751	0,037739	0,215350	0,165186
16.5	0,059751	0,037739	0,215350	0,165186
17	0,034373	0,020869	0,128625	0,094240
17.5	0,034373	0,020869	0,128625	0,094240
18	0,041287	0,024961	0,152928	0,111868
18.5	0,041287	0,024961	0,152928	0,111868
19	0,018213	0,012916	0,069798	0,059186
19.5	0,018213	0,012916	0,069798	0,059186
20	0,016238	0,011265	0,062409	0,051779
20.5	0,016238	0,011265	0,062409	0,051779
21	0,014733	0,007702	0,056750	0,035636
21.5	0,014733	0,007702	0,056750	0,035636
22	0,006821	0,005088	0,026582	0,023655
22.5	0,006821	0,005088	0,026582	0,023655
23	0,002463	0,002324	0,009660	0,010861
23.5	0,002463	0,002324	0,009660	0,010861
24	0,003374	0,001885	0,013215	0,008814
24.5	0,003374	0,001885	0,013215	0,008814
25	0,006305	0,004066	0,041718	0,033557
25.5	0,006305	0,004066	0,041718	0,033557
26	0,002069	0,001890	0,013858	0,015727
26.5	0,002069	0,001890	0,013858	0,015727
27	0,002166	0,001258	0,014503	0,010495
27.5	0,002166	0,001258	0,014503	0,010495
28	0,001689	0,001015	0,011322	0,008469
28.5	0,001689	0,001015	0,011322	0,008469
29	0,000593	0,000467	0,003989	0,003902
29.5	0,000593	0,000467	0,003989	0,003902
30	0,003412	0,003551	0,022764	0,029365
30.5	0,003412	0,003551	0,022764	0,029365
31	0,000268	0,000644	0,001806	0,005380
31.5	0,000268	0,000644	0,001806	0,005380
32	0,000773	0,000980	0,005196	0,008182
32.5	0,000773	0,000980	0,005196	0,008182
33	0,000509	0,000320	0,003425	0,002674
33.5	0,000509	0,000320	0,003425	0,002674
34	0,000791	0,000348	0,005317	0,002912
34.5	0,000791	0,000348	0,005317	0,002912
35	0,000883	0,001108	0,009040	0,007657
35.5	0,000883	0,001108	0,009040	0,007657
36	0,000134	0,000221	0,001376	0,001531
36.5	0,000134	0,000221	0,001376	0,001531
37	0,000429	0,000000	0,004407	0,000000
37.5	0,000429	0,000000	0,004407	0,000000
38	0,000177	0,000328	0,001815	0,002270
38.5	0,000177	0,000328	0,001815	0,002270
39	0,000000	0,000000	0,000000	0,000000
39.5	0,000000	0,000000	0,000000	0,000000
40	0,000658	0,001229	0,006748	0,008486
40.5	0,000658	0,001229	0,006748	0,008486
41	0,000000	0,000046	0,000000	0,000319

Age	Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women
41.5	0,000000	0,000046	0,000000	0,000319
42	0,000174	0,000000	0,001784	0,000000
42.5	0,000174	0,000000	0,001784	0,000000
43	0,000000	0,000059	0,000000	0,000406
43.5	0,000000	0,000059	0,000000	0,000406
44	0,000000	0,000000	0,000000	0,000000
44.5	0,000000	0,000000	0,000000	0,000000
45	0,000000	0,000183	0,000000	0,001645
45.5	0,000000	0,000183	0,000000	0,001645
46	0,000333	0,000261	0,002897	0,002345
46.5	0,000333	0,000261	0,002897	0,002345
47	0,000000	0,000117	0,000000	0,001050
47.5	0,000000	0,000117	0,000000	0,001050
48	0,000109	0,000000	0,000949	0,000000
48.5	0,000109	0,000000	0,000949	0,000000
49	0,000000	0,000000	0,000000	0,000000
49.5	0,000000	0,000000	0,000000	0,000000
50	0,000000	0,000313	0,000000	0,002811
50.5	0,000000	0,000313	0,000000	0,002811
51	0,000108	0,000000	0,000938	0,000000
51.5	0,000108	0,000000	0,000938	0,000000
52	0,000000	0,000000	0,000000	0,000000
52.5	0,000000	0,000000	0,000000	0,000000
53	0,000000	0,000000	0,000000	0,000000
53.5	0,000000	0,000000	0,000000	0,000000
54	0,000000	0,000000	0,000000	0,000000
54.5	0,000000	0,000000	0,000000	0,000000
55	0,000146	0,000099	0,001600	0,001099
55.5	0,000146	0,000099	0,001600	0,001099
56	0,000000	0,000000	0,000000	0,000000
56.5	0,000000	0,000000	0,000000	0,000000
57	0,000000	0,000086	0,000000	0,000955
57.5	0,000000	0,000086	0,000000	0,000955
58	0,000000	0,000000	0,000000	0,000000
58.5	0,000000	0,000000	0,000000	0,000000
59	0,000000	0,000000	0,000000	0,000000
59.5	0,000000	0,000000	0,000000	0,000000
60	0,000000	0,000065	0,000000	0,000721
60.5	0,000000	0,000065	0,000000	0,000721
61	0,000000	0,000000	0,000000	0,000000
61.5	0,000000	0,000000	0,000000	0,000000
62	0,000000	0,000078	0,000000	0,000868
62.5	0,000000	0,000078	0,000000	0,000868
63	0,000000	0,000000	0,000000	0,000000
63.5	0,000000	0,000000	0,000000	0,000000
64	0,000000	0,000000	0,000000	0,000000
64.5	0,000000	0,000000	0,000000	0,000000
65	0,000000	0,000000	0,000000	0,000000
65.5	0,000000	0,000000	0,000000	0,000000
66	0,000000	0,000000	0,000000	0,000000
66.5	0,000000	0,000000	0,000000	0,000000
67	0,000000	0,000000	0,000000	0,000000
67.5	0,000000	0,000000	0,000000	0,000000

Age	Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women
68	0,000000	0,000000	0,000000	0,000000
68.5	0,000000	0,000000	0,000000	0,000000
69	0,000000	0,000000	0,000000	0,000000
69.5	0,000000	0,000000	0,000000	0,000000
70	0,000000	0,000076	0,000000	0,000791
70.5	0,000000	0,000076	0,000000	0,000791
71	0,000000	0,000000	0,000000	0,000000
71.5	0,000000	0,000000	0,000000	0,000000
72	0,000000	0,000000	0,000000	0,000000
72.5	0,000000	0,000000	0,000000	0,000000
73	0,000000	0,000000	0,000000	0,000000
73.5	0,000000	0,000000	0,000000	0,000000
74	0,000000	0,000000	0,000000	0,000000
74.5	0,000000	0,000000	0,000000	0,000000
75	0,000000	0,000000	0,000000	0,000000
75.5	0,000000	0,000000	0,000000	0,000000
76	0,000000	0,000000	0,000000	0,000000
76.5	0,000000	0,000000	0,000000	0,000000
77	0,000000	0,000000	0,000000	0,000000
77.5	0,000000	0,000000	0,000000	0,000000
78	0,000000	0,000000	0,000000	0,000000
78.5	0,000000	0,000000	0,000000	0,000000
79	0,000000	0,000000	0,000000	0,000000
79.5	0,000000	0,000000	0,000000	0,000000
80	0,000000	0,000000	0,000000	0,000000
80.5	0,000000	0,000000	0,000000	0,000000
81	0,000000	0,000000	0,000000	0,000000
81.5	0,000000	0,000000	0,000000	0,000000
82	0,000000	0,000000	0,000000	0,000000
82.5	0,000000	0,000000	0,000000	0,000000
83	0,000000	0,000000	0,000000	0,000000
83.5	0,000000	0,000000	0,000000	0,000000
84	0,000000	0,000000	0,000000	0,000000
84.5	0,000000	0,000000	0,000000	0,000000
85	0,000000	0,000000	0,000000	0,000000
85.5	0,000000	0,000000	0,000000	0,000000
86	0,000000	0,000000	0,000000	0,000000
86.5	0,000000	0,000000	0,000000	0,000000
87	0,000000	0,000000	0,000000	0,000000
87.5	0,000000	0,000000	0,000000	0,000000
88	0,000000	0,000000	0,000000	0,000000
88.5	0,000000	0,000000	0,000000	0,000000
89	0,000000	0,000000	0,000000	0,000000
89.5	0,000000	0,000000	0,000000	0,000000
90	0,000000	0,000071	0,000000	0,000460
90.5	0,000000	0,000071	0,000000	0,000460
91	0,000000	0,000000	0,000000	0,000000
91.5	0,000000	0,000000	0,000000	0,000000
92	0,000000	0,000000	0,000000	0,000000
92.5	0,000000	0,000000	0,000000	0,000000
93	0,000000	0,000000	0,000000	0,000000
93.5	0,000000	0,000000	0,000000	0,000000
94	0,000000	0,000000	0,000000	0,000000

Age	Never smokers non passive		Never smokers passive	
	Men	Women	Men	Women
94.5	0,000000	0,000000	0,000000	0,000000
95	0,000000	0,000000	0,000000	0,000000
95.5	0,000000	0,000000	0,000000	0,000000
96	0,000000	0,000000	0,000000	0,000000
96.5	0,000000	0,000000	0,000000	0,000000
97	0,000000	0,000000	0,000000	0,000000
97.5	0,000000	0,000000	0,000000	0,000000
98	0,000000	0,000000	0,000000	0,000000
98.5	0,000000	0,000000	0,000000	0,000000
99	0,000000	0,000000	0,000000	0,000000
99.5	0,000000	0,000000	0,000000	0,000000
100	0,000000	0,000000	0,000000	0,000000

Appendix 5.10 Selection of datasets for passive and non passive prevalence parameters

Methods

This section highlights how the dataset were identified and selected for review.

Search strategy

A search for datasets was conducted in July 2008 in the UK Data Archive (UKDA)[79]. In addition, some institutions were contacted in the search for data.

Lesley Owen, Analyst from National Institute for Clinical Excellence (NICE), was contacted in the search for prevalence data.

Selection criteria

Datasets that satisfied the following criteria were selected for review: (a) dataset based on the UK or English general (children and adults) population; (b) data collection conducted from 2000 up to date; and, (c) dataset having smoking specific indicators.

Datasets were also browse by drug abuse, alcohol and smoking subject.

Results

The search strategy identified a total of 30 datasets that were subjected to the selection criteria. All of them were selected for review. Only one database (Welsh Health Survey (2007)) had data on adults regularly exposed to other people's tobacco smoke at own home, though it was not a requirement being exposed by a member of that household. However, the Health Survey for England (HSE) collects data of adults and children being often near people who smoke at home, though has the same problem of including smokers not from that particular household.

Since the HSE dataset was UK representative and also contained children's data, this was the selected dataset to calculate this model parameter.

[79] The UKDA is a custodian of the biggest collection of digital data in the social sciences and humanities in the UK. It is also in charge of the management of the Economic and Social Data Service (ESDS) as a lead collaborator.

Appendix 5.11 Prevalence of smokers, former smokers and, never smokers' non passive and passive according to HSE (2006)

Population distribution	
Infants (< 2 years)	368
Children (2-15 years)	6889
Adults (≥ 16 years)	14142
TOTAL	21399

Age	CURRENT SMOKERS									FORMER SMOKERS									NEVER SMOKERS									TOTAL		
	PASSIVE			NON PASSIVE			TOTAL			PASSIVE			NON PASSIVE			TOTAL			PASSIVE			NON PASSIVE			TOTAL					
	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot	m	f	tot
16-24	81	95	177	88	115	203	169	211	379	11	15	26	50	66	116	61	81	142	74	71	147	315	400	713	391	471	863	650	794	1444
25-34	87	101	190	207	187	394	294	288	594	6	15	20	185	273	456	191	288	476	22	35	56	352	536	881	374	570	937	862	1148	2010
35-44	106	129	236	227	218	445	333	347	687	18	27	45	263	335	597	281	362	643	25	61	83	540	719	1255	564	781	1338	1183	1494	2677
45-54	89	113	202	160	197	357	249	310	559	30	26	57	280	319	601	310	345	658	29	37	66	456	585	1038	485	622	1104	1050	1279	2329
55-64	75	90	164	140	164	304	215	253	468	39	30	70	484	406	896	524	436	966	18	27	45	367	552	914	385	579	958	1126	1269	2395
65-74	22	36	58	94	81	175	116	117	233	43	21	63	431	298	728	474	318	791	10	21	30	253	477	731	262	498	761	852	933	1785
>75	10	20	31	43	55	98	53	76	128	22	22	43	336	349	681	359	371	725	9	24	33	180	425	609	189	449	642	601	901	1502
All ages	470	585	1057	958	1017	1975	1428	1603	3048	170	156	325	2030	2046	4075	2200	2201	4400	186	276	460	2462	3694	6141	2650	3970	6604	6324	7818	14142

Appendix 5.12 UK national statistics 200780 – general population

Age	Males	Females	Total
0	387490	368252	755742
1	374492	357420	731912
2	366879	349867	716746
3	361908	344186	706094
4	350164	331940	682104
5	339269	324486	663755
6	339165	325821	664986
7	348840	331770	680610
8	358606	342340	700946
9	364536	349347	713883
10	375180	358181	733361
11	372773	355777	728550
12	375786	356911	732697
13	384399	365270	749669
14	390132	369852	759984
15	404902	383424	788326
16	415,336	389,480	804,816
17	410,939	385,903	796,842
18	412,009	387,797	799,806
19	425,520	400,458	825,978
20	423,152	397,038	820,190
21	422,938	405,985	828,923
22	434,506	412,631	847,137
23	427,022	402,710	829,732
24	416,846	397,677	814,523
25	402,328	398,559	800,887
26	413,763	407,342	821,105
27	411,698	406,258	817,956
28	391,325	390,033	781,358
29	372,872	372,086	744,958
30	368,010	365,938	733,948
31	377,902	376,458	754,360
32	386,879	388,176	775,055
33	395,474	398,261	793,735
34	415,719	420,396	836,115
35	434,136	445,657	879,793
36	447,129	457,628	904,757
37	445,709	451,643	897,352
38	456,511	465,385	921,896
39	462,294	467,969	930,263
40	473,564	477,594	951,158
41	469,776	478,334	948,110
42	471,131	481,140	952,271
43	464,077	476,644	940,721
44	453,432	468,339	921,771
45	441,317	455,384	896,701
46	431,496	443,447	874,943
47	415,392	425,614	841,006
48	408,108	416,467	824,575

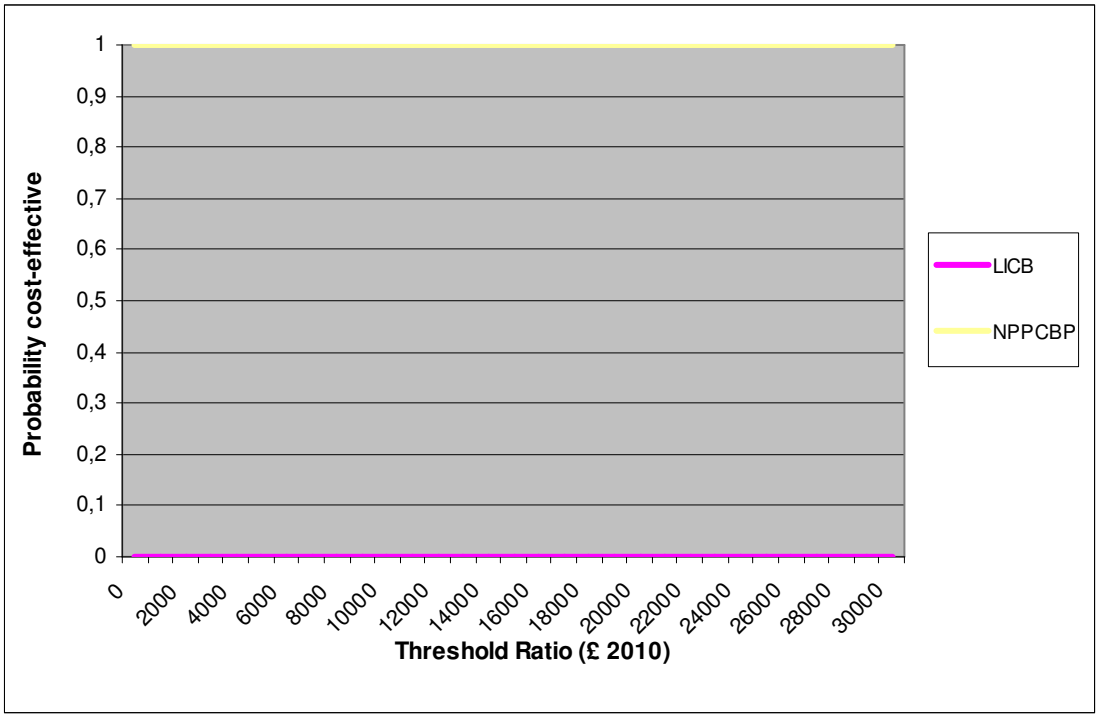
[80] It was the last observed data on the UK national Statistics. From 2008 onwards there was projection data.

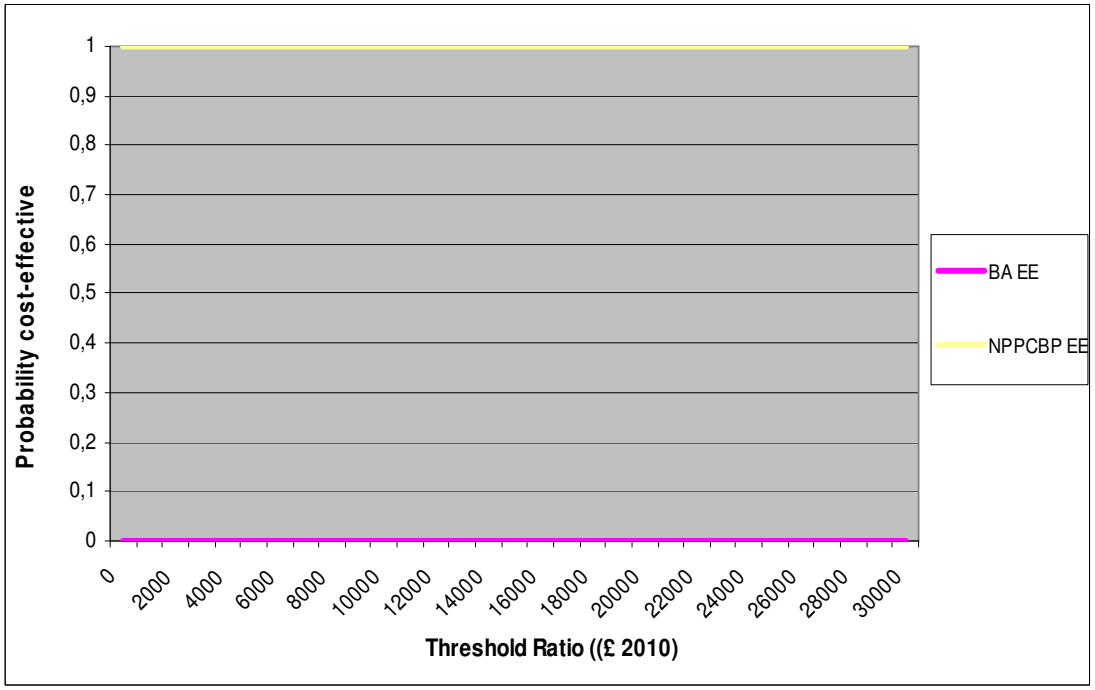
Age	Males	Females	Total
49	402,606	410,398	813,004
50	386,739	395,648	782,387
51	372,588	381,644	754,232
52	362,498	371,245	733,743
53	362,768	372,425	735,193
54	357,758	366,564	724,322
55	353,494	363,546	717,040
56	354,730	365,545	720,275
57	363,135	375,744	738,879
58	374,443	386,134	760,577
59	399,142	412,199	811,341
TOTAL	**23,982,732**	**23,730,367**	**47,713,099**

Appendix 5.13 Standard deviation values for probabilistic analysis of M4 and M5

Variable	Mean	SD calculated	SD reported by study	95% Confidence Interval		Distribution
				Low interval	Upper interval	
Clinic health state (RR)						
LC	1.24	0.12400	-	-	-	lognormal
CHD	1.25	0.12500	-	-	-	lognormal
asthma	1.21	0.06122	-	1.10	1.34	lognormal
wheeze	1.24	0.03571	-	1.17	1.31	lognormal
cough	1.40	0.06632	-	1.27	1.53	lognormal
OME	1.38	0.08163	-	1.23	1.55	lognormal
AOM	1.30	0.15306	-	1.00	1.60	lognormal
Smoking cessation and relapse (rates)						
quit BA	3.00%	0.00300	-	-	-	beta
quit BAS	4.00%	0.00400	-	-	-	beta
quit BASNRT	6.00%	0.00600	-	-	-	beta
quit BASNRTSC	15.00%	0.02551	-	10.00%	20.00%	beta
quit LICB	23.60%	0.01071	-	21.50%	25.70%	beta
quit MICB	31.40%	0.00918	-	29.60%	33.20%	beta
quit NPGC	26.00%	0.02372	-	21.80%	31.10%	beta
quit NPIC	20.00%	0.01276	-	17.60%	22.60%	beta
quit NPNC	15.00%	0.01531	-	11.00%	17.00%	beta
quit NPPC	31.00%	0.03100	-	-	-	beta
quit NPPCBP	44.00%	0.04400	-	-	-	beta
Utilities (Qol values)						
smokers	0.75	0.2500	0.2500	-	-	beta
former smokers	0.78	0.2300	0.2300	-	-	beta
LC	0.58	0.1167	0.1;0.14;0.2;0.0	-	-	beta
CHD	0.80	0.0800	7;0.07;0.12	-	-	beta
COPD	0.73	0.00327	-	(0.771; 0.731;	(0.802; 0.768;	beta
MI	0.80	0.08000	-	0.598)	0.695)	beta
ST	0.48	0.04800	-	-	-	beta
asthma	0.85	0.08500	-	-	-	beta
wheeze	0.95	0.09500	-	-	-	beta
cough	0.76	0.07600	-	-	-	beta
OME	0.70	0.07000	-	-	-	beta
AOM	0.79	0.07900	-	-	-	beta
			-			
Costs (£ 2009)						
Clinic health states						
LC	5912.43	1690.59	-	2599	9226	gamma
CHD	1142.50	114.25	-	-	-	gamma
COPD	995.26	99.53	-	-	-	gamma
MI	2337.67	233.77	-	-	-	gamma
ST	2215.15	221.51	-	-	-	gamma
asthma	85.80	8.58	-	-	-	gamma
wheeze	555.23	55.52	-	-	-	gamma
cough	29.48	2.95	-	-	-	gamma
OME	198.68	19.87	-	-	-	gamma
AOM	117.93	11.79	-	-	-	gamma
Interventions						
BA	7.67	0.77	-	-	-	gamma
BAS	11.47	1.15	-	-	-	gamma
BASNRT	119.41	11.94	-	-	-	gamma
BASNRTSC	132.16	13.22	-	-	-	gamma
LICB	86.21	8.62	-	-	-	gamma
MICB	129.20	12.92	-	-	-	gamma
NPGC	153.46	15.35	-	-	-	gamma
NPIC	102.64	10.26	-	-	-	gamma
NPNC	48.90	4.89	-	-	-	gamma
NPPC	301.48	30.15	-	-	-	gamma
NPPCBP	406.03	40.60	-	-	-	gamma
Indicence	According to age and sex	10% men estimate	-	-	-	beta

Appendix 5.14 Cost-effectiveness acceptability curves for M4 (LICB and NPPCBP) and M5 (LICB EE and NPPCBP EE) compared to no intervention





Appendix 6.1 Search strategy and search terms of systematic literature review on health effects due to smoking during pregnancy

Databases

Cochrane Library

Cochrane Database of Systematic Reviews

National Institute of Clinical Excellence

NHS evidence

Health Technology Assessment (Internet access)

Office of Technology Assessment

The Office of Surgeon General US (Internet access)

Bibliographic database

MEDLINE – systematic review

Office of Health Economics Health Economic Evaluation Database (HEED)

Search terms

Source - Cochrane Library (Wiley)

#1 smok* pregnancy

6

Source – NICE (NHS Evidence)

#1 smoking pregnancy

4033

Source – Health Technology Assessment

#1 pregnancy

0

Source – The Office of Surgeon General US

#1 pregnancy

1

Source Ovid MEDLINE

#1 Smoking pregnancy.m_titl (11)

Source - Health Economic Evaluation Database

#1 smok* pregnancy

0

Search strategy

An established search protocol was used to identify reviews and meta-analysis of health effects risk on pregnant women due to smoking. Comprehensive searches were conducted using bibliographic databases, bibliographies of relevant reviews and internet sites for epidemiological data on passive smoking in Europe, US and UK. Searches were carried out June 2009, and involved 3 electronic databases (MEDLINE -Ovid-, Cochrane Library -Wiley Internet version-, and Office of Health Economics Health Economic Evaluation Database –HEED). The World Health Organization (WHO), The Office of Surgeon General US, the Centers for Disease Control and Prevention, and the Information Centre of NHS sites were also consulted. This search was restricted to English language, humans, review papers, and without time restrictions and included a combination of text words. The free text term used was "smok* pregnan*". Moreover, only the Cochrane reviews results were included for revision. Search term was contrived to retrieve papers on relative risk of smoking during pregnancy health effects.

All titles and abstracts were screened for relevance. Full paper copies of any title or abstract judged to be potentially relevant were obtained. The relevance was judged of each full abstract according to predefined criteria (see below). Studies that failed to satisfy all criteria were excluded and the reason for their exclusion was recorded. References from searched papers were scrutinized to add relevant references to the search.

Selection criteria

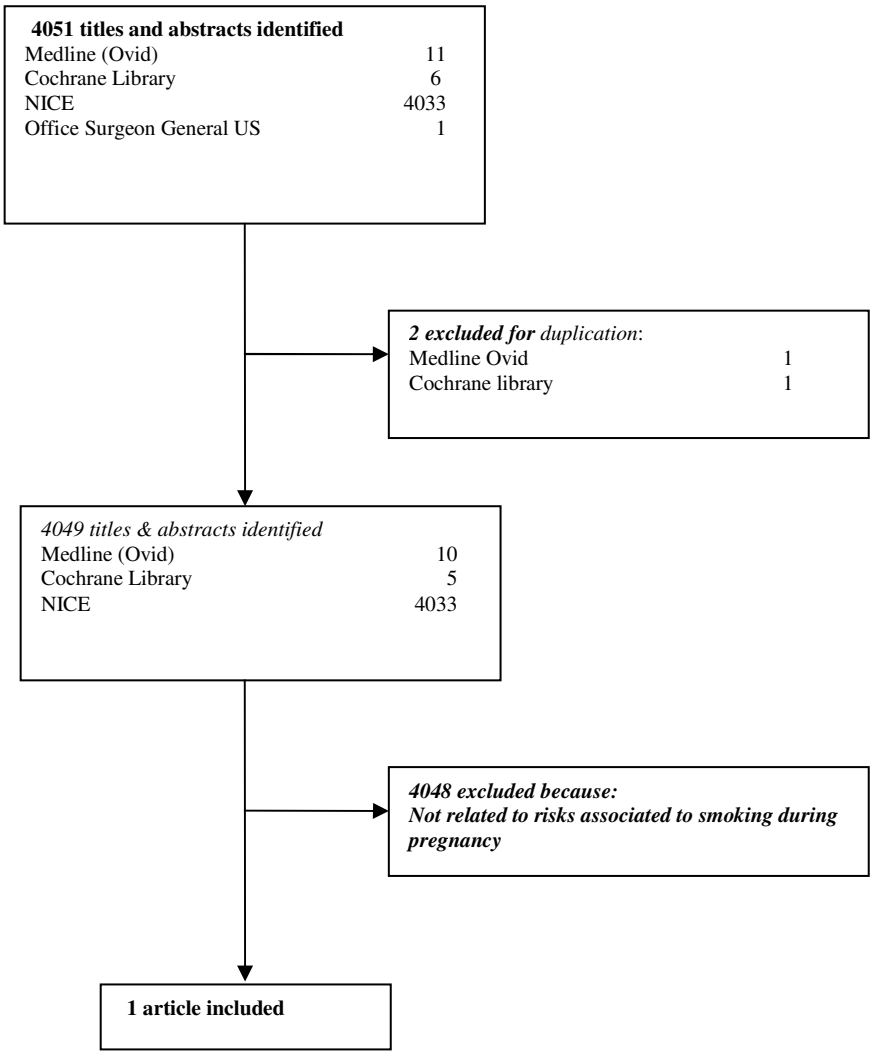
A selected paper had to satisfy all the requirements of the following criteria: (a) to present meta-analytic data or pooled data on relative risks or odds ratios of clinical effects on women due to smoking during pregnancy; (b) be written in English, because there were no resources for translations. Studies were excluded if the data they reported

were updated in other papers published or if the epidemiological evidence was reported as not strong enough for clear conclusions.

Data extraction strategy

Data were extracted into a summary table to describe the important health effects of smoking during pregnancy in women.

Appendix 6.2 Study selection process for smoking during pregnancy papers



Appendix 6.3 Search strategy and search terms of systematic literature review on prevalence, costs and utilities of smoking during pregnancy health effects

Aim

The aim of this systematic review was to identify and critically appraise all published prevalence, costs and quality adjusted life years (QALYs) of the health effects associated with smoking during pregnancy earlier identified, for the purpose of: providing insights into the main cost-effectiveness trade-off relevant to our decision problem.

Search strategy

A comprehensive search for literature on prevalence, costs and QALYs of passive smoking health effects was conducted. Studies on costs and QALYs were identified from: MEDLINE (Ovid) 2000-July 2009; Office of Health Economics Health Economic Evaluation Database (HEED); Cochrane Library -Wiley Internet version 2000-July 2009; Health Technology Assessment database (HTA); and the National Institute for Health and Clinical Excellence (NICE). An additional search was conducted on the Office for National Statistics database.

This search was restricted to English language, humans, and with no time restrictions, with the exceptions of Medline Ovid and Cochrane Library. Search terms were contrived to retrieve papers on prevalence, risk and mortality of passive smoking health effects. Details of searches can be found in Appendix 7.5.

All titles and abstracts were screened for relevance. Full paper copies of any titles or abstracts judged of potential relevance were obtained. The relevance was judged of each full abstract according to predefined criteria (see below). Studies that failed to satisfy all criteria were excluded and the reason for their exclusion was recorded. References from searched papers were scrutinized to add relevant references to the search.

Databases

Cochrane Library

Cochrane Database of Systematic Reviews

National Institute of Clinical Excellence

NHS evidence

Health Technology Assessment (Internet access)

Office of Technology Assessment

Office for National Statistics database (Internet access)

National statistics data

Bibliographic database

MEDLINE – systematic review

Office of Health Economics Health Economic Evaluation Database (HEED)

Contacts

Hema Mistry – Research Fellow from Health Economics Research Group (HERG), Brunel University

Stavros Petrou - Senior Non-Clinical Research Fellow from Health Economics Research Centre (HERC), Oxford University

Search terms

Source - Cochrane Library (Wiley)

#1 ectopic pregnancy, from 1999 to 2009

2

#2 placenta praevia, from 1999 to 2009

1

#3 placental abruption, from 1999 to 2009

1

#4 pre-eclampsia, from 1999 to 2009

19

#5 preeclampsia and children, from 1999 to 2009

0

#6 low birth weight, from 1999 to 2009

41

#7 suddent infant death, from 1999 to 2009

0

Source – NICE (NHS Evidence)

#1 ectopic pregnancy

0

#2 placenta praevia

0

#3 placental abruption

0

#4 pre-eclampsia

0

#5 preeclampsia and children

0

#6 low birth weight

0

#7 suddent infant death

1

Source – Health Technology Assessment

#1 ectopic pregnancy

2

#2 placenta praevia

0

#3 placental abruption

1

#4 pre-eclampsia

14

#5 preeclampsia and children

6

#6 low birth weight

12

#7 suddent infant death

6

Source – Office for National Statistics

#1 ectopic pregnancy

0

#2 placenta praevia

0

#3 placental abruption

0

#4 pre-eclampsia

0

#5 preeclampsia and children

0

#6 low birth weight

0

#7 suddent infant death

3

Source - Health Economic Evaluation Database

#1 ectopic pregnancy

0

#2 placenta praevia

0

#3 placental abruption

0

#4 pre-eclampsia

3

#5 preeclampsia

2

#6 low birth weight

26

#7 sudden infant death

2

Source Ovid MEDLINE 2000 to August 2009

1 ectopic pregnanc*.ti. (3479)

2 placenta praevia.ti. (459)

3 placenta* abruption.ti. (210)

4 pre-eclampsia.ti. (2626)

5 preeclampsia*.ti (3705)

6 low birth weight.ti. (5540)

7 sudden infant death syndrome.ti. (2168)

8 prevalence.ti. (56707)

9 (cost* or economic).ti. (75668)

10 (QALY* or utilit* or quality of life or quality-of life or quality adjusted life years or quality-adjusted life years).ti. (35886)

11 8 and 1 (4)

12 1 and 9 (20)

13 1 and 10 (5)

14 8 and 2 (0)

15 9 and 2 (0)

16 10 and 2 (0)

17 8 and 3 (0)

18 3 and 9 (0)

19 3 and 10 (2)

20 8 and 4 (6)

21 4 and 9 (4)

22 4 and 10 (2)

23 8 and 5 (6)

24 9 and 5 (1)

25 10 and 5 (2)

26 8 and 6 (39)

27 6 and 9 (34)

28 6 and 10 (13)

29 8 and 7 (17)

30 7 and 9 (3)

31 7 and 10 (0)

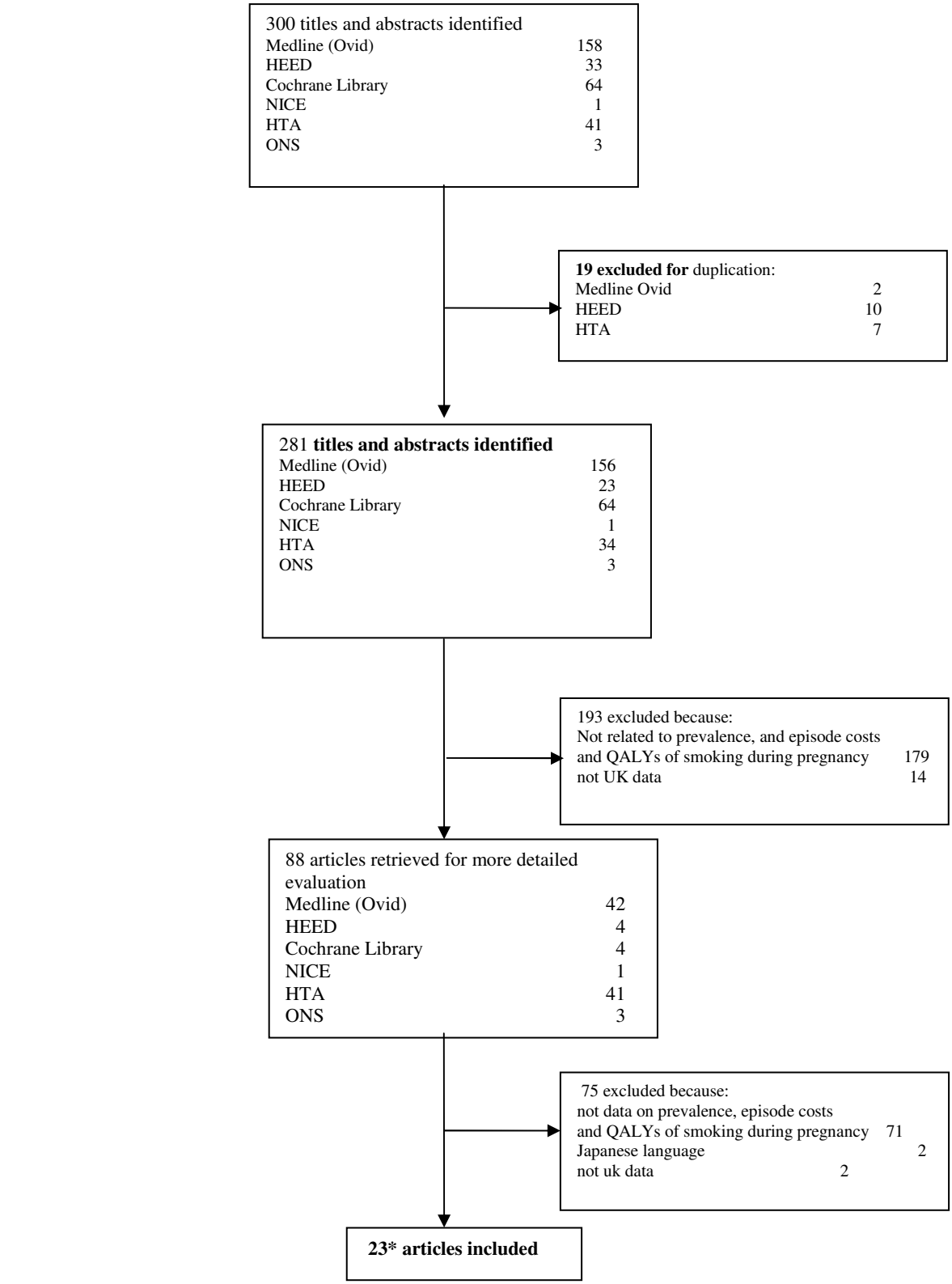
Inclusion criteria

Studies that specify utility values or episode costs of health effects due to smoking during pregnancy were included. Studies were excluded if they did not express the costs in terms of cost per episode. The following types of paper were also excluded: papers reporting utilities values in a different scale than 0-10 or 0-100, papers not stating prevalence, not UK estimates on prevalence data, and papers written not in English, because there were no resources for translations.

Data extraction strategy

The data was extracted according to the guidelines produced by the Centre for Reviews and Dissemination (CRD) for the critical appraisal of economic evaluations. Data extraction focused on costs episode and utility values using 0-10 or 0-100 scales.

Appendix 6.4 Study selection process for smoking during pregnancy prevalence, costs and QALYs



* 13 articles were included from the literature review and 10 papers were added from experts' contacted

Appendix 6.5 References included in the systematic literature search of prevalence, costs and utilities of health effects of passive smoking during pregnancy

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Appendix 6.6 Number of pregnant women according to smoking status and age (HSE, 2006)

Age	Smokers	Former Smokers	Never Smokers		No answer/refused	TOTAL
			Passive	Non passive		
16-24	6.18	2.65	1.05	6.76	2.10	18.74 (794)
25-34	6.77	20.43	2.83	36.46	0.00	66.48 (1148)
35-44	2.39	4.68	0.88	14.68	0.00	22.62 (1494)
All ages	15.33	27.76	4.76	57.90	2.10	107.85 (3436)

Appendix 6.7 Study selection process for smoking during pregnancy papers (Office for National Statistics, the Northern Ireland Statistics and Research Agency, and the National Services Scotland)

2007	England & Wales							Scotland							N. Ireland						
	All ages (ONS London)	Under 20	20-24	25-29	30-34	35-39	40 and over	All ages (GRO Scotland)	Under 20	20-24	25-29	30-34	35-39	40 and over	All ages (NISRA)	Under 20	20-24	25-29	30-34	35-39	40 and over
Singleton	672,528	44,424	129,001	178,714	185,216	110,909	24,264	56,309	4,316	10,771	14,618	15,135	9,625	1,844	23,824	1,392	3,970	6,658	7,015	4,048	741
All multiples	10,471	315	1,233	2,386	3,392	2,516	629	893	36	104	185	281	238	49	362	8	39	78	142	77	18
Twins	10,334	315	1,223	2,361	3,352	2,478	605	882	36	104	182	277	235	48	357	8	39	77	138	77	18
Triplets	135	0	10	25	39	37	24	9	0	0	2	4	3	0	5	0	0	1	4	0	0
Quads	1	0	0	0	1	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0	0
Quins	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sextuplets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total maternities	682,999	44,739	130,234	181,100	188,608	113,425	24,893	57,202	4,352	10,875	14,803	15,416	9,863	1,893	24,186	1,400	4,009	6,736	7,157	4,125	759

2007	UK	UK rate/1000 mats							UK average number of births						
	Total	All ages	Under 20	20-24	25-29	30-34	35-39	40 and over	All ages	Under 20	20-24	25-29	30-34	35-39	40 and over
Singleton	752,661	985	993	991	987	982	978	975	985	992.89	990.52	986.93	981.9	977.8	974.7323
All multiples	11,726	15	7	9	13	18	22	25							
Twins	11,573	15	7	9	13	18	22	24	30.2805	14.22	18.826	25.859	35.68	43.79	48.72028
Triplets	149	0	0	0	0	0	0	1	0.5848	0	0.2067	0.4145	0.668	0.942	2.613905
Quads	3	0	0	0	0	0	0	0	0.0157	0	0	0.0197	0.019	0	0.145217
Quins	1	0	0	0	0	0	0	0	0.0065	0	0	0	0	0.039	0
Sextuplets	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Total maternities	764,387	1000	1000	1000	1000	1000	1000	1000	**1.016**	**1.007**	**1.010**	**1.013**	**1.018**	**1.023**	**1.026**

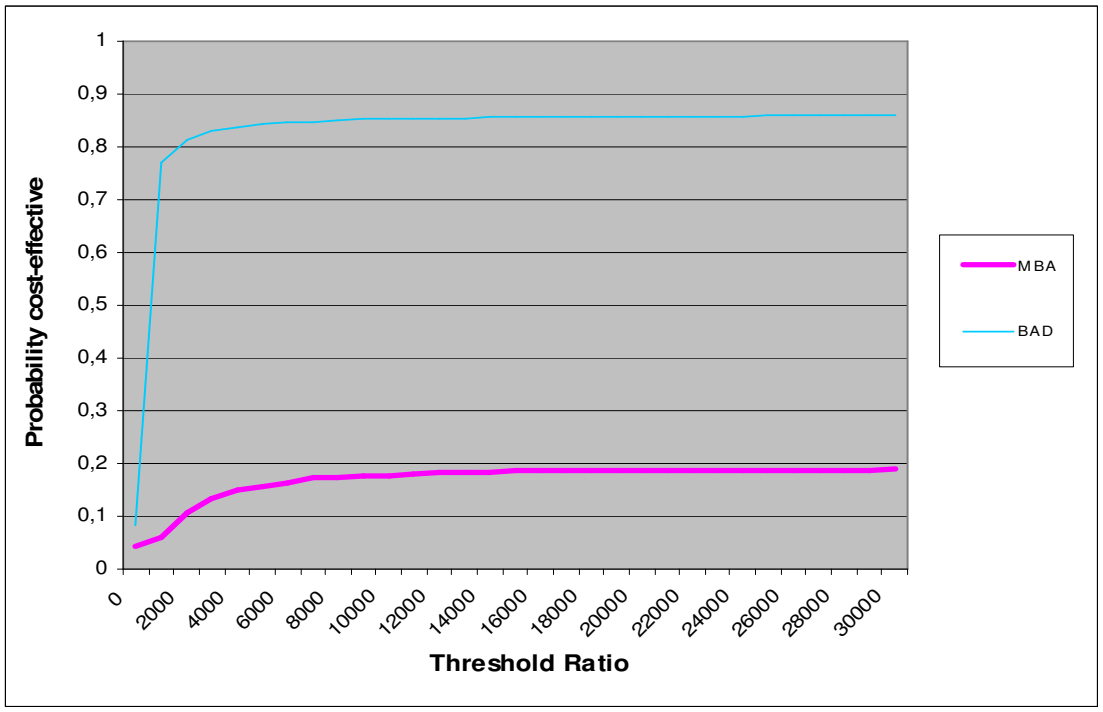
Appendix 6.8 Standard deviation values for the probabilistic analysis of M6 and M7

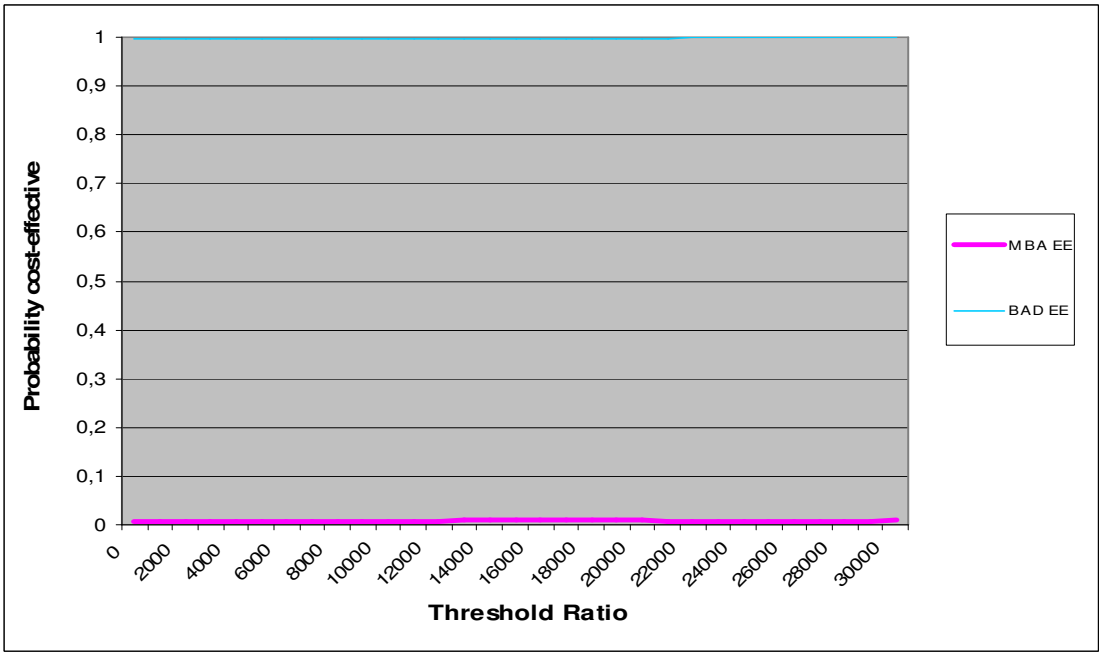
Variable	Mean	SD calculated	SD reported by study	95% Confidence Interval		Distribution
				Low interval	Upper interval	
Clinic health state (RR)						
LBW	1.22	0.07398	-	1.08	1.37	lognormal
SIDS	2.13	0.14541	-	1.86	2.43	lognormal
Smoking cessation and relapse (rates)						
Interventions cessation rate during pregnancy						
quitd_i_MBA	11.60%	0.01160	-	-	-	beta
quitd_i_CC	5.70%	0.00570	-	-	-	beta
quitd_i_HEM	16%	0.03316	-	10%	23%	beta
quitd_i_PCW	18.20%	0.01820	-	-	-	beta
quitd_i_PCB	18.20%	0.01820	-	-	-	beta
quitd_i_NRT	28%	0.01020	-	24%	28%	beta
quitd_i_PC	24%	0.02400	-	-	-	beta
quitd_i_BD	61%	0.06100	-	-	-	beta
quitd_i_BAD	52%	0.05200	-	-	-	beta
Interventions cessation rate after pregnancy						
quita_i_MBA	11.60%	0.01160	-	-	-	beta
quita_i_CC	8.10%	0.00810	-	-	-	beta
quita_i_HEM	13%	0.03316	-	8%	21%	beta
quita_i_PCW	18.20%	0.01820	-	-	-	beta
quita_i_PCB	18.20%	0.01820	-	-	-	beta
quita_i_NRT	21%	0.00765	-	21%	24%	beta
quita_i_PC	24%	0.02400	-	-	-	beta
quita_i_BD	61%	0.06100	-	-	-	beta
quita_i_BAD	52%	0.05200	-	-	-	beta
Utilities (Qol values)						
smokers	0.75	0.2500	0.2500	-	-	beta
former smokers	0.78	0.2300	0.2300	-	-	beta
LC	0.58	0.1167	0.1;0.14;0.2;0.07;0.07;0.12	-	-	beta
CHD	0.80	0.0800	-	-	-	beta
COPD	0.73	0.00327	-	(0.771;	(0.802;	beta
MI	0.80	0.08000	-	0.731;	0.768;	beta
ST	0.48	0.04800	-	0.598)	0.695)	beta
LBW	0.85	0.085	-	-	-	beta
SIDS	0	0	-	-	-	beta
				-	-	
Costs (£ 2009)						
Clinic health states						
LC	5912.43	1690.59	-	2599	9226	gamma
CHD	1142.50	114.25	-	-	-	gamma
COPD	995.26	99.53	-	-	-	gamma
MI	2337.67	233.77	-	-	-	gamma
ST	2215.15	221.51	-	-	-	gamma
LBW	29.48	2.95	-	-	-	gamma
SIDS	3156855.08	315685.51	-	-	-	gamma
Interventions						
MBA	5.00	0.50	-	-	-	gamma
CC	6.84	0.68	-	-	-	gamma
HEM	12.00	1.20	-	-	-	gamma
PCW	361.14	36.11	-	-	-	gamma
PCB	1.14	0.11	-	-	-	gamma
NRT	93.29	9.33	-	-	-	gamma
PC	169.14	16.91	-	-	-	gamma
BD	101.00	10.10	-	-	-	gamma

Variable		Mean	SD calculated	SD reported by study	95% Confidence Interval		Distribution
	BAD	101.00	10.10	-	-	-	gamma
Indicence		According to age and sex	10% men estimate	-	-	-	beta

RR: Relative Risk

Appendix 6.9 Cost-effectiveness acceptability curves for M6 (MBA and BAD) and M7 (MBA EE and BAD EE) compared to no intervention





Appendix 7.1 Search strategy and search terms of review on smoking dynamic models

Databases

Cochrane Library

Cochrane Database of Systematic Reviews

Bibliographic database

Web of Knowledge

ECONLIT

MATHSCINET

NHS EED

HEED

Search terms

Source - Cochrane Library (Wiley)

#1 "smok* behaviour in Title, Abstract or Keywords or dynamic in Title, Abstract or Keywords or extern* in Title, Abstract or Keywords in Cochrane Database of Systematic Reviews"

0

Source – Web of Knowledge

#1 title=smoking* and ("cost-benefit" or "costbenefit" or "cost benefit" or "cost-effectiveness" or "costeffectiveness" or "cost effectiveness" or "economic* valuation" or cost* or valu* or "critical appraisal" or "model")) and ("pecuniary external*" or "technological external*" or "knowledge external*" or "network external*" or "external*" or "spillover*" or "spill-over*")

1

Source ECONLIT

#1 title=smoking* and "cost-benefit" or "costbenefit" or "cost benefit" or "cost-effectiveness" or "costeffectiveness" or "cost effectiveness" or "economic* valuation" or cost* or valu* or "critical appraisal" or "model")) and ("pecuniary external*" or

“technological external*” or “knowledge external*” or “network external*” or “external*” or “spillover*” or “spill-over*”)

1

Source MATHSCINET

#1 (smoking) and (model* or external*)

6

Source NHS EED

#1 (smoking*) and (dynamic*)

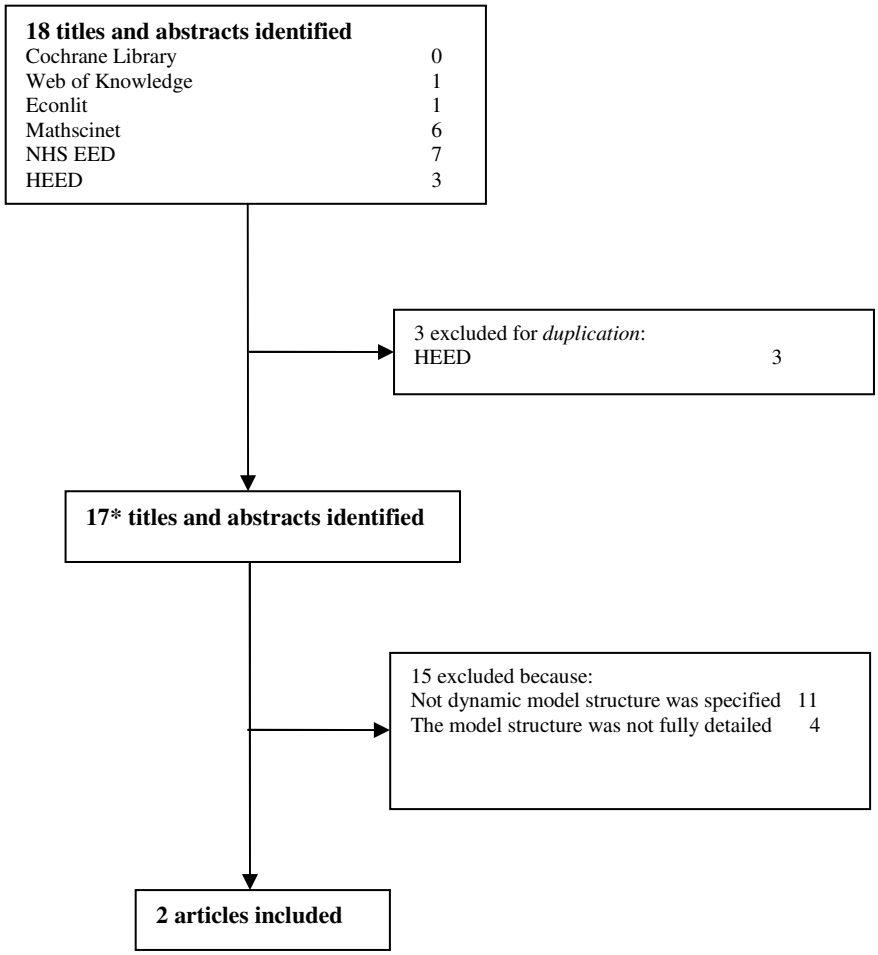
7

Source HEED

#1 (smoking*) and (dynamic*)

3

Appendix 7.2 Study selection process for smoking dynamic models



* Two papers were derived from references

Appendix 7.3 References included in the systematic literature search on smoking dynamic models

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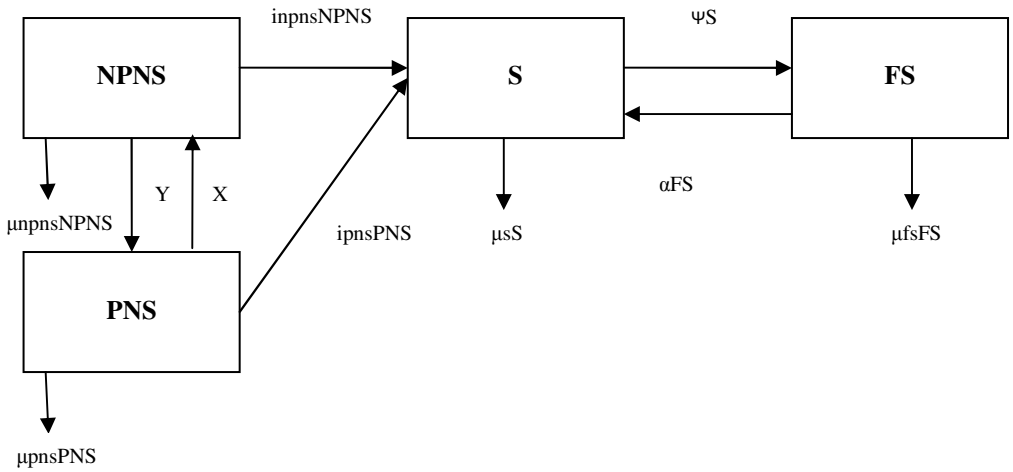
Appendix 7.4 Flow diagram for a conventional transmission dynamic model (Susceptible-Infected-Recovered (SIR) model)

An adaptation of this SIR model to my conventional markov-type approach would need: (a) no additional recruitment of individuals or new groups of population will be entering into the model.; (b) *Potential Smokers* group would be divided in non-passive (NPNS) and passive never smokers (PNS); and, (c) the *Temporary quitters* and *Permanent Quitters* group would be combined in the former smokers category (FS) and therefore, only one quitting rate for former smokers would be required.

Therefore, the new SIR model will be represented as Box A7.4.

Box A7.4 Structure of an adaptation of a smoking SIR health states model



Definition of parameters and variables:

NPNS	≡Non-passive never-smokers
PNS	≡ Passive never-smokers
S	≡Smokers
FS	≡Smokers who quit smoking (former smokers)
inpns	≡rate at which non-passive never-smokers can acquire smoking habits (and become smokers) via contacts with smokers
ipns	≡rate at which passive never-smokers can acquire smoking habits (and become smokers) via contacts with smokers
Ψ	≡quit rate
α	≡rate of revert to smoking when you are a former smoker (relapse rate)
μnpns	≡mortality rate for non-passive never smokers
μpns	≡mortality rate for passive never smokers
μs	≡ mortality rate for smokers
μfs	≡ mortality rate for former smokers

The set of differential equations for the non-passive and passive never smokers SIR model would be:

dNPNS/dt = - (inpns*NPNS) **-** (μnpns*NPNS) **-** (Y*NPNS) + (X*PNS)

dPNS/dt = - (ipns*PNS) **-** (μpns*PNS) + (Y*NPNS) **-** (X*PNS)

dS/dt = + (inpns*NPNS) + (ipns*PNS) + (α*FS) **-** (ψ*S) **-** (μs*S)

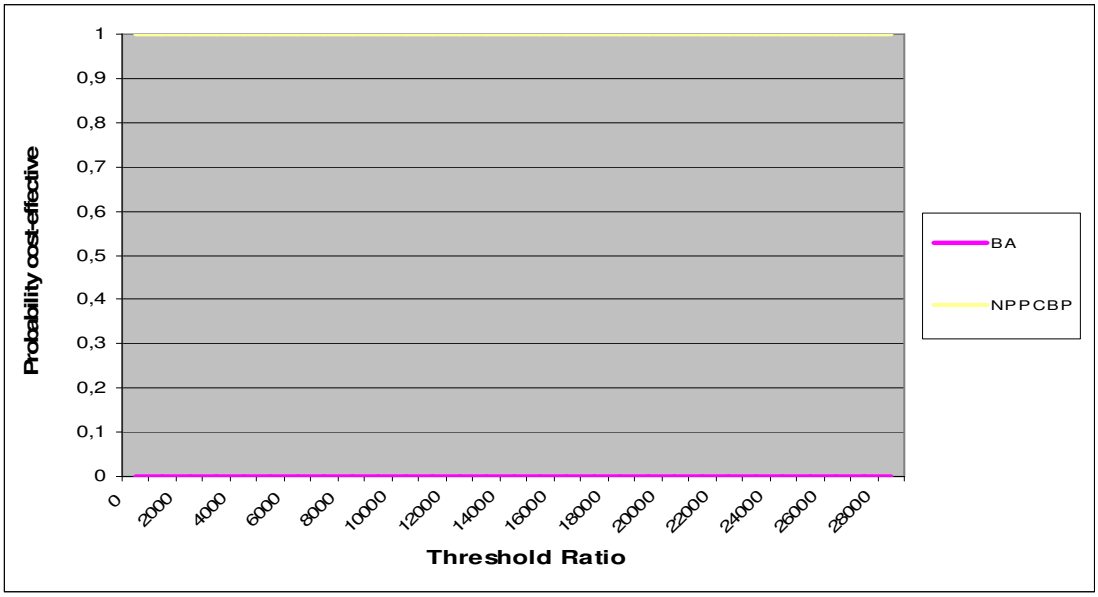
dFS/dt = +(ψ*S) **-** (α*FS) **-** (μfs*FS)

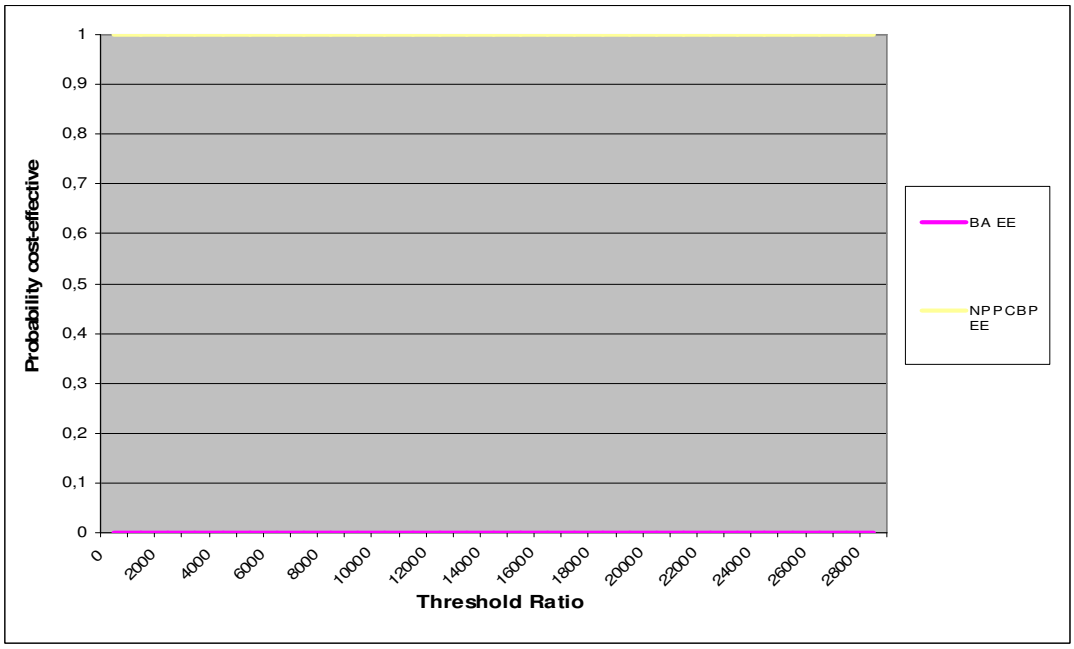
dX/dt = +S*(ψ+ μs)

dY/dt = +(α*FS)

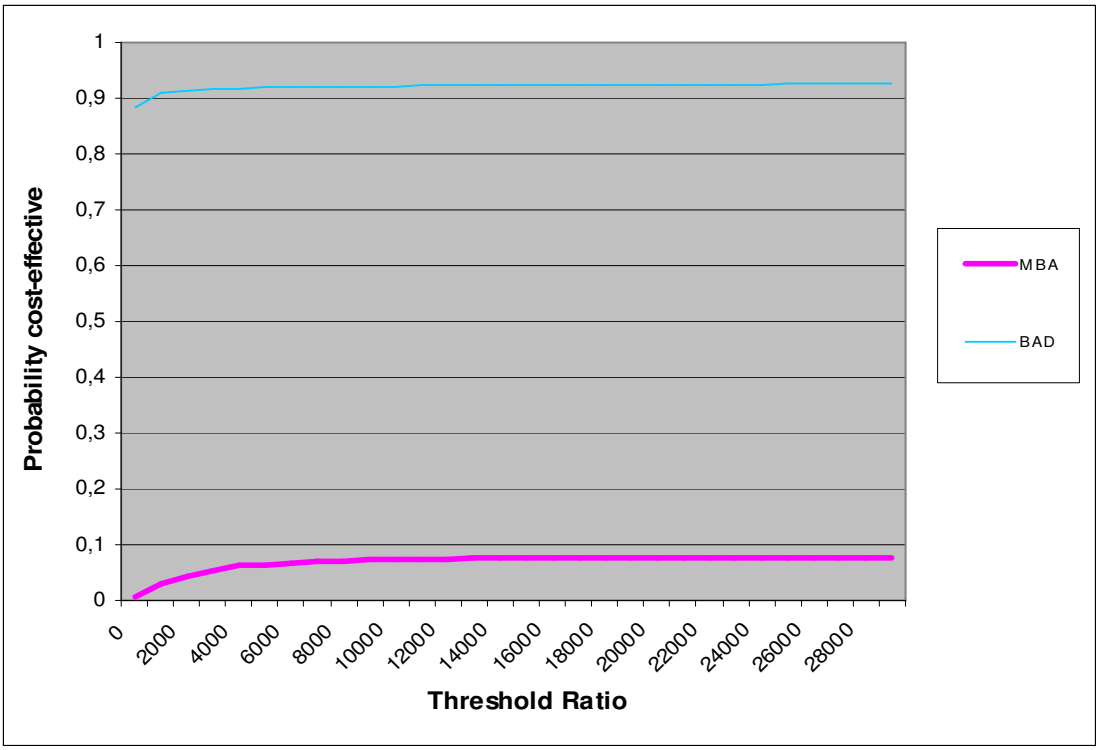
X and Y are both functions of **dS/dt**. For instance, for X as the number of smokers declines, their never-smoking contacts shift from the PNS to the NPNS state (and vice versa); and, for Y, as the number of smokers increases, their never-smoking contacts shift from NPNS to the PNS state.

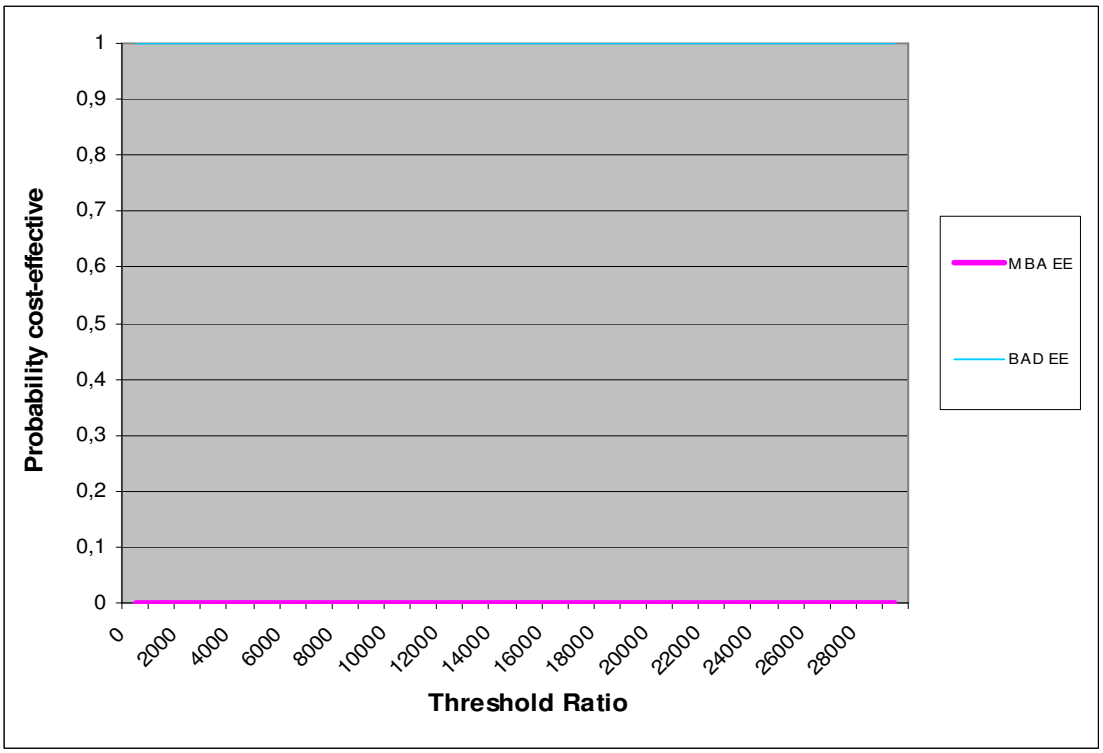
Appendix 7.5 Cost-effectiveness acceptability curves for M8 (LICB and NPPCBP) and M9 (LICB EE and NPPCBP EE) compared to no intervention





Appendix 7.6 Cost-effectiveness acceptability curves for M10 (MBA and BAD) and M11 (MBA EE and BAD EE) compared to no intervention





Appendix 8.1 Summary of population characteristics and analytic horizon of models

Models	Cohort								Sex
	Starting population						Analytic horizon		
	S	FS	NS NP	NS P	Death	TOTAL	Age	Time	
M1	1000	0	-	-	0	1000	16-200	hundred years for each age cohort (i.e. age 16=116; age 45=145, etc)	M&F
M2	1000	0	-	-	0	1000	16-200	hundred years for each age cohort (i.e. age 16=116; age 45=145, etc)	M&F
M3	1000	0	-	-	0	1000	16-100	considering lifetime 100 years (each cohort stops when age 100 years)	M&F
M4	according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000	16-100	considering lifetime 100 years (each cohort stops when age 100 years)	M&F
M5 (EE)	according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000+96.5% of adult smokers' children	16-100	considering lifetime 100 years (each cohort stops when age 100 years)	M&F
M6	Pregnant smokers according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000	16-100	considering pregnancy age from 16 to 44.5 plus five years of children's maximum age	F
M7 (EE)	Pregnant smokers according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000+average number of babies delivered by pregnant adult	16-100	considering pregnancy age from 16 to 44.5 plus five years of children's maximum age	F
M8	according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000	16-100	considering lifetime 100 years (each cohort stops when age 100 years)	M&F
M9 (EE)	according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000+96.5% of adult smokers' children	16-100	considering lifetime 100 years (each cohort stops when age 100 years)	M&F
M10	Pregnant smokers according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000	16-100	considering pregnancy age from 16 to 44.5 plus five years of children's maximum age	F
M11 (EE)	Pregnant smokers according to age prevalence	according to age prevalence	according to age prevalence	according to age prevalence	0	1000+average number of babies delivered by pregnant adult	16-100	considering pregnancy age from 16 to 44.5 plus five years of children's maximum age	F

Appendix 8.2 Summary of parameters and assumptions of models

Models	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	Summary
Discount rate	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	Constant
Background quite rate	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	2% (trans prob and cycle)	Constant
Yearly quitting rates	Adjusted by relapse	Adjusted by relapse	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	adjusted by relapse, trans prob,cycle	no constant
Six monthly quitting rates	not adjusted	not adjusted	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	adjusted by relapse, trans prob	no constant
Relapse rate	not adjusted	not adjusted	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	adjusted by trans prob, cycle	no constant
Condition episode costs	£2006	£2006	£2010	£2010	£2010	£2010	£2010	£2010	£2010	£2010	£2010	no constant
Condition episode utilities	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	according to disease	Constant
Intervention costs	£2006	£2006	£2010	£2010	£2010	£2010	£2010	£2010	£2010	£2010	£2010	no constant
Population weights	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age	according to age	according to age and sex	according to age and sex	according to age	according to age	no constant
Health states	S, FS, D (by age interval and sex)	S, FS, D (by age interval and sex)	S, FS, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	S, FS, NSNP, NSP, D (by age interval and sex)	no constant
Condition Prevalence	S, FS, NS	Given S, FS,NS	Checked S, FS	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	no constant
Mortality	S, FS, NS	Checked S, FS, NS	Checked S, FS, NS	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	Checked and S, FS, NSNP, NSP	no constant
Incidence	-	-	-	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age and sex	according to age and sex	no constant