



Toward a New Comprehensive International Health and Health Care Policy Decision Support Tool

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TABLE OF CONTENTS

1. INTRODUCTION	6
The Chronic Disease Policy Model (CDP 2.0)	8
Key policy questions	9
Outline of this report	10
CHAPTER 2 – THE STATE OF THE ART	11
OECD/WHO/EC workshop on modelling in health	11
Review CDP model activities at the 2011 Expert meeting and identification of future developments .	12
Functional improvements	12
Scope of the model	12
Further reviews of the CDP model	13
Comparative review of health expenditure forecasting methods	13
Microsimulation models	13
Component-based-models	15
Macro-level models	16
Issues faced by model developers	19
International workshop on improving health expenditure forecasting methods	24
Models to evaluate risk factor prevention strategies	24
CHAPTER 3: SCOPE AND KEY FEATURES OF CDP 2.0.....	26
A new architecture	26
Main differences relative to the first version of the CDP model	27
Overall framework of CDP 2.0	28
Why is dynamic microsimulation the right modelling approach for CDP 2.0?.....	28
Key components of CDP 2.0	30
Modelling software for CDP 2.0.....	31
Modgen concepts	32
Why are the simulated lifetimes of individuals realistic?	33
How do we measure and report error?	34
Accessibility and user friendliness.....	35
CHAPTER 4: DEMOGRAPHIC COMPONENTS	36
CHAPTER 5: RISK FACTORS.....	38
How are risk factors incorporated into the model?	39
Alcohol use component.....	40
CHAPTER 6: DISEASES, INJURIES AND MORTALITY.....	42
Diseases essential to the evaluation of policies to control harmful alcohol use	43
How are diseases incorporated into the model?	45
CHAPTER 7: HEALTH SYSTEM PATHWAYS	47
Modelling patient pathways	51

Events in the health care pathway – disease states	55
Events in the health care pathway – outcomes of care	56
Outcomes of care	56
Cost-of-illness in the System of Health Accounts Framework.....	59
National infrastructure for data linkage and analysis.....	67
Sub-national infrastructure for data linkage projects.....	71
Data linkages for public health research and health-care quality monitoring.....	74
CHAPTER 8: BROADER HEALTH AND ECONOMIC OUTCOMES	82
Deaths and life expectancy	83
Prevalence of disability and disability-adjusted life years lived.....	83
Education	84
Participation in the labour force and employment earnings.....	84
CHAPTER 9: EVALUATION OF POLICY ALTERNATIVES	86
CONCLUSIONS	90
Engagement of policy makers.....	90
CDP 2.0 model validation.....	91
Planning for future developments.....	94
Funding.....	95
REFERENCES	96
ANNEX 1: BACKGROUND TO MICROSIMULATION IN HEALTH AT THE OECD.....	104
Introduction.....	104
Early development of the CDP model	104
The epidemiological model.....	105
Exogenous information/input data	107
Cost model.....	107
Main assumptions.....	108
Applications of the CDP model	108
First application: WHO EUR-A Region	108
Second application: individual OECD countries.....	109
Third application: Emerging economies	110
Fourth application: Latin America and South-East Asia.....	110
ANNEX 2: DESCRIPTIONS OF MODELS INCLUDED IN THE 2011 AND 2012 OECD WORKSHOPS	113
Population Health Model (POHEM).....	113
Future Elderly Model (FEM)	117
Archimedes	121
NATSEM-CHE-CoPS Micro-Macro Chronic Disease Prevention Model	122
PRISM – Prevention Impacts Simulation Model.....	126
Multi-level Modular Agent-based Modelling for the Study of Childhood Obesity.....	126
DYNAMO-HIA.....	127
National Heart Forum micro-simulation project.....	127
SESIM-LEV.....	129
Comprehensive Assessment of Reform Efforts (COMPARE).....	134
ANNEX 3: EXPLORATORY ANALYSIS OF THE UNITED STATES MEDICAL EXPENDITURES PANEL SURVEY (MEPS)	138
ANNEX 4: PILOT OF CDP 2.0 – EVALUATION OF ALCOHOL CONTROL POLICIES	145

Modelling prevention policies	154
School-based interventions	157
Fiscal measures	158
Regulation of advertising.....	159
Brief intervention (physician-nurse counselling).....	161
Pharmacological treatment and psychosocial programme for alcohol dependence.....	162
Complete listing of papers included in the policy review	166

Tables

Table 1. Health expenditure forecasting models reviewed	18
Table 2. Leading diseases associated with alcohol use.....	44
Table 3. Classification of CHF patients in 2000.....	53
Table 4. Treatments of interest for new CHF patients in 2000.....	54
Table 5. Direct Costs of NCDs (in constant USD 2010 million).....	60
Table 6. Expenditures for selected diseases, all ages (in US 2010 million USD)	62
Table 7. Expenditures for selected diseases, ages 65 plus (in US 2010 USD)	62
Table 8. Expenditures on Circulatory Diseases - by sub-groups (per-capita, 2010 USD)	63
Table 9. Expenditures on Circulatory Diseases by sub-groups, ages 65 plus (per-capita, 2010 USD)	63
Table 10. Expenditures on Circulatory Diseases by sub-groups and Providers, (per-capita, 2010 USD).	64
Table 11. National data containing records for patients (persons).....	66
Table 12. National number that uniquely identifies patients and the main uses of this number.....	68
Table 13. National data contains a unique patient identifying number that could be used for record linkage.....	69
Table 14. National data contains identifying variables such as name, sex, birth date, and address that could be used for record linkage	71
Table 15. Sub-national infrastructure for data linkage – regional or state-level record-linkage projects by type of data involved.....	72
Table 16. Sub-national infrastructure for data linkage – networks of health care organisations record linkage projects by type of data involved	74
Table 17. National data is used to undertake record linkage projects.....	75
Table 18. National data is used to undertake record linkage projects on a regular basis.....	76
Table 19. Distribution of the regular occurrence of health-related record linkage projects by availability of databases with patient identifiers.....	78
Table 20. Recommendations for gathering evidence of model credibility	92
Table 21. Interventions to tackle noncommunicable disease risk factors: identifying 'best buys'	112
Table 22. Summary of policies to tackle harmful alcohol consumption in OECD countries and partner economies	146
Table 23. List of potential policies options to tackle alcohol consumption.....	155

Figures

Figure 1. Overview of CDP 2.0 Framework.....	30
Figure 2. CDP 2.0 demographic core for Canada – Sample of 1000 simulated lives.....	37
Figure 3. Population attributable fractions (%) and mortality (million deaths) for leading risk factors in high-income countries.....	38
Figure 4. Estimated total deaths (million) by cause in OECD countries	42
Figure 5. Distribution of alcohol mortality and morbidity by category of disease or injury in 2004	43
.....	43
Figure 6. Framework diagram of the health system module (preventing, diagnosing and treating NCDs).....	48
.....	48
Figure 7. Number of countries reporting national data used to conduct record-linkage projects on an occasional and on a regular basis.....	77
Figure 8. Overall casual web in the CDP model.....	106

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1. INTRODUCTION

1. Healthcare systems are large and complex structures. The functioning of these systems is based on hundreds of services, each of which needs a compounded combination of input resources to work. At a higher level, these services are interlinked one to the others and have to interact with a good grade of coordination. Changing demographics and epidemiology of diseases as well as increasing public expectations contribute to modifying over time the way in which health services are delivered, maintaining these structures in a state of continuous transition. Health systems may also face remarkable financial constraints in the near future. OECD countries already spend a sizeable part of resources on health. According to the most recent OECD Health Data, on average 9.5% of GDP is already invested to maintain population in good health with health expenditure that has been projected to increase across OECD countries between 3.5 to 6 percentage points of GDP for the period 2005-2050 (OECD, 2006).
2. Throughout the world, growth in Chronic Non-communicable Diseases (or NCDs) lies at the heart of these health system pressures, with rising numbers of patients as population's age and phenomenal advancements in the technologies and treatments applied to these diseases.
3. Addressing the social and economic burden of NCDs has risen to the top of the global policy agenda. In September 2011, a UN Summit on NCDs focussed on four of the most prominent diseases: cancers, cardiovascular diseases, chronic respiratory diseases and diabetes. The summit resulted in a global strategy to address NCDs in light of concerns about rapid increases in health burden and projected number of deaths from NCDs; concerns about the need for better health promotion efforts and better health-system responses to control this increase; and concerns about the relationship between NCDs and rising health care costs, reduced productivity, poverty and constraints on development (Smith, 2011). In preparation for the summit, the first global ministerial conference on healthy lifestyles and NCDs was organised by the World Health Organisation in April 2011. Ninety ministers and delegations from 167 countries committed to taking "whole of government" and international actions to reduce the burden of NCDs (Smith, 2011).
4. There is a strategic convergence of interests around how to reduce or curb the growth of health care costs. Preventing or postponing disease; better evaluation of the effectiveness of new technologies; as well as improvements in the overall efficiency of the delivery of health care throughout the life course, are three main areas where it is hoped to curb health care spending. In response to pressures, health system reforms and prevention programs are put into place, often with little evidence of effectiveness.
5. The healthcare sector would appear an obvious candidate for the use of computer modelling and for simulation to be employed as a valuable tool to provide sound evidence. Modelling and simulating refer to the imitation of a process and the way in which it works in a bigger environment. The main purpose of employing simulation technologies is to analyze and evaluate "what if scenarios" which, in practical terms, means to predict the likely outcomes produced by a change of any input parameter or by a modification in the process of the system under study by setting-up a simulated reproduction of the environment. In other words, modelling allows to design, validate and implement new ideas without disturbing production processes by manipulating an environment that is not real (it is simulated) but imitates (represents) the real world with real data and actual events. An extraordinary advantage of modelling and simulating is that this has dramatic effects in decreasing costs and unnecessary human efforts compared to experiencing the same

attempts in reality. For instance, Gordon (2001) estimated that, compared to business as usual, the use of simulation analyses may decrease the cost of new project by up to a factor of 10.

6. Advances in computing power and in the availability of health and health-care data, create opportunities for new approaches to empirically estimating the future burden of NCDs and evaluating the policy responses that would be the most effective to mitigate this burden. The advent of inexpensive and powerful computers has stimulated the use of simulation models for health and health care policy (Weinstein, 2006 and Fone, 2003). Modelling in healthcare was first introduced about 30 years ago, but simulation approach has only recently started to gain acceptance as a essential planning approach in the health sector (Fone et al., 2003) becoming a standard part of policy development in some OECD countries (Glied & Tilipman, 2010). Moreover, compared to other disciplines, the use of simulation in healthcare settings has been sensibly slower. A review carried out in 1999 (Jun et al., 1999) identified only 8 studies between 1973 and 1977 and 28 studies between 1993 and 1997. A more recent research performed by Royston (2005) showed that the number of citations had a sizeable increase only after 2000.

7. A number of factors are contributing to the acceptance and use of simulation models. Policy makers have begun to recognize the cost, time and ethical advantages of simulation modelling as against direct experimentation. Modelling can also help generate evidence for or against hypotheses and help investigators to understand the nature of the system under study. Simulating may also suggest new theories, models and hypotheses, based on a systematic exploration of a model's behaviour under both normal and abnormal conditions (Stahl, 2008). Perhaps, most importantly, simulation modelling can aid decision-makers to evaluate the outcomes of different strategies, to explore the consequences of different changes to the system and to predict how the behaviour of the system will change over time. Ultimately, the real advantage of simulation is that it can help to inform and possibly to persuade decision-makers to make the best decisions possible.

8. Existing models tend to have a "disease-specific" or "risk-factor specific" view and fail to account for key interactions and, eventually, fail to reproduce the bigger picture. Perhaps most importantly, models available today are not designed for prioritizing health policies across the whole spectrum of planning, from prevention, to treatment, to long-term care.

9. Computer simulation models enable the evaluation of the impact of health interventions and policies at the level of populations. No single data source, be it experimental or observational, can ever be expected to provide enough information about treatment options, health outcomes, equity and cost-effectiveness when choices have to be made between and among different interventions. Microsimulation methods enable representing the underlying heterogeneity of real populations in a framework synthesizing the best evidence of prevention, diagnosis, treatment and outcomes and, as a result, overcome gaps in existing knowledge. Strengths include enabling a wide set of comparisons to identify the most promising combinations of prevention, diagnosis and treatment approaches for different types of patients; going beyond the follow-up periods of typical clinical trials so that long-term outcomes can be compared; going beyond specially selected or ideal patient populations so that outcomes for typical patients can be assessed; going beyond narrow definitions of study outcomes to outcomes in real-world settings where patients are complex and remain at risk of developing a wide range of disease conditions; and allowing the testing of the potential impacts of policies and practices, through "what if" scenarios before incurring the costs of implementation.

10. While there has been tremendous progress throughout the world in the development of microsimulation models for the evaluation of the comparative effectiveness of approaches to the control and treatment of cancers, the same attention has not yet been given to other leading NCDs. Examples include the use of population-based microsimulation models to support evaluation of the comparative effectiveness of technologies used to diagnose and treat cancers, including comparing imaging methods,

comparing pharmaceuticals, and comparing pharmaceuticals to surgical interventions and also using this evidence to support clinical care guidelines evaluation and to set public reimbursement levels for health services (Rutter, 2011; Miksad, 2011; Zucchelli, 2010). For example, US microsimulation models indicated that computed tomographic colonography (CTC) screening produced only slightly less life years gained than did colonoscopy screening at a substantially lower cost, and with higher potential population participation. These results were a significant factor in the decision of the US Medicare program to reimburse CTC screening (Rutter, 2011).

11. The Canadian Population Health Model (POHEM) is a microsimulation model that perhaps comes closest to reaching this functionality, as it provides guidance on population prevention initiatives as well as clinical prevention and treatment strategies within a single unified empirically-based model for a range of different NCDs including both selected cancers; and acute myocardial infarction and osteoarthritis (Wolfson, 1994; Zucchelli, 2010).

12. Within Europe, there are many helpful models that have been developed, but each focuses on a narrow definition of the problem. For example, Dynamo HIA (Dynamo HIA, 2012), provides a model for the evaluation of the potential impact of risk factor prevention on the burden of CVD. The National Heart Forum in the United Kingdom has built a number of microsimulation models to measure the future impact on health of changes in risk factors. These models also analyse cost effectiveness of interventions to control obesity and tobacco, most notably for the UK Government Tackling Obesities project (McPherson, 2007) and as a comparison of the US and UK (Wang, 2011). The proposed demonstration model as part of the NHF ECONDA project will go further in the design of a model to assess the effectiveness of prevention efforts in clinical practice for cardiovascular disease but will not consider the progression of disease and its treatment.

The Chronic Disease Policy Model (CDP 2.0)

13. Recently, the OECD and the WHO jointly developed a multi-country dynamic microsimulation model (CDP 1.0) which links risk factors to multiple diseases and health outcomes and is used to estimate the cost effectiveness and the distributional impact of a variety of prevention initiatives to increase healthy behaviours and to reduce the prevalence of obesity. Model results were widely publicized through the Lancet as well as OECD and WHO publications (Sassi 2009 and 2010, Cecchini 2010). Further, the model was developed to be shared and has been adopted by several countries to estimate the effectiveness of local policy alternatives. This model represents a “proof of concept” of the potential of computer simulation to benefit policy development across the world. The background and development of CDP 1.0 is presented in annex 1.

14. In March 2011, country representatives participating in an Expert meeting on the Economics of Prevention endorsed a proposal that the OECD and WHO explore the potential to extend this work to develop a simulation model capable of selecting and prioritising efficient portfolios of health and health care policy interventions across all major chronic non-communicable diseases or NCDs. The development of the model was further supported by a grant from the European Commission.

15. *The Chronic Disease Policy Model (CDP 2.0) will be the first computer simulation to dynamically model the complex relationships deriving from interactions between socio-economic factors, epidemiological trends, treatment pathways and the organisation and financing of health care. The model would be designed to consider all major NCDs and to compare the effectiveness of policy interventions at all stages of the process of care, from prevention through to treatment and to long-term care. Further, this simulation model will provide a platform for developing and testing policies in different countries and comparing differences in program effectiveness in different contexts. The simulation technology will be*

extensible to future policy needs and will be freely shared with participating countries, so that they may adopt and enhance the model to make local policy decisions.

Key policy questions

16. The CDP 2.0 modelling platform will be designed to provide participating countries with a virtual population laboratory within which an array of policy questions may be tested in order to compare the effectiveness and cost-effectiveness of various combinations of policy approaches.

17. In broad terms, the model will support research and policy development to address key questions facing countries with a rising burden of chronic disease. These questions include:

- What may be future trends in health care utilisation of populations experiencing single and multiple chronic diseases?
- To address the needs of an aging population, should we invest more in up-stream primary prevention, secondary prevention, down-stream treatments, including new drugs and health technologies, or long-term care provision?
- To what degree does the organisation and financing of care influence future disease burden and health care costs?
- How do different prevention, treatment, and health care financing options affect different socio-economic groups?
- How does the effectiveness of the same policies vary across countries?
- How effective in my country will be innovative policies implemented in another country?
- If my country adopted health-care financing policies in use in another country, how would health outcomes and public health care costs change?

18. The key to the CDP 2.0 framework is that it is also extensible, enabling a closer examination of policy questions for specific areas of policy interest. For example, the CDP 2.0 is currently contributing to the analysis of the comparative effectiveness of policies to mitigate harmful alcohol consumption. For this application, the policy questions are:

- What may be the impact on future mortality and life expectancy of different policies or combinations of policies to control harmful alcohol use?
- What may be the impact on the future burden of diseases and injuries related to harmful alcohol use?
- What could be the future impact on the costs of health care resulting from the implementation of these policies?

19. The policies under consideration include the regulation of the advertising of alcohol products; brief counselling interventions by physicians or nurses; pharmacological and psychosocial treatments for alcohol dependence; and fiscal measures including sales taxes and excise duties.

Outline of this report

20. This report presents the conceptual planning and development work toward the Chronic Disease Policy Model (CDP 2.0). It begins with a review of OECD activities to uncover the state of the art in the development of health policy decision-support models, including two expert workshops and a detailed review of 25 models; followed by an overview of the scope and objectives of CDP 2.0 in chapter three. The demographic components of the model are presented in chapter four. Chapter five discusses the inclusion of health risk factors within the model. The outcomes of the model, including diseases, injuries and mortality are presented in chapter 6. Chapter seven provides a detailed discussion of the inclusion of health-care pathways within CDP 2.0 including exploration of the data environment for the development of pathways and methodological advancements in the estimation of pathways and in the costing of pathways. Chapter 8 discusses modelling broader health and economic outcomes, such as disabilities, education and labour-market participation. Chapter nine discusses how the CDP 2.0 would be used to evaluate the cost-effectiveness of a set of potential policies related to the management of the health system. The report concludes with several key issues in the continued development of CDP 2.0. These include engagement of decision-makers in model development and model use; validation of model results; planning for future developments and securing funding.

CHAPTER 2 – THE STATE OF THE ART

21. Beginning in 2010, the OECD has undertaken three activities to uncover the current state of the art in the development of health policy decision support models. While the use of computer simulation models to support health-policy decision making is relatively new, the OECD review activities have revealed promising approaches that provide insights to support the best-possible design of CDP 2.0. The first was a focussed workshop in 2010, organised by the OECD, WHO and EC, to convene select group of leading modellers to discuss health policy modelling and, in particular, the connection between population health and disease models and the modelling of health systems. This was followed by a critical review of 25 models developed by or used by health policy makers to forecast the future burden of health expenditures and the policy drivers available (Astolfi et al, 2012). Lastly, an international workshop on November 30, 2012 convened leading experts from health and finance backgrounds in government, academia, and international organisations to take stock of progress in health expenditure forecasting and to discuss future directions, in light of policy needs and recent advancements in techniques, detailed data and computing power. This chapter reviews the outcomes of the three exercises as they relate to the objectives of CDP 2.0.

OECD/WHO/EC workshop on modelling in health

22. The OECD, WHO and EC organized a workshop on modelling in health on 29-30 November 2010, which brought together the leading modelling groups worldwide to discuss the directions in which modelling in health and healthcare may develop in the future, given recent advances in modelling approaches and techniques. In particular, participants exchanged views and experiences on critical and emerging issues in the methodology of modelling, from the selection of relevant input data to the assessment of the validity of model outputs, with a special emphasis on linking the modelling of population and disease dynamics with the modelling of health systems.

23. A brief description of each model represented at the workshop is provided in annex 2.

24. The following is a selection of points of greatest potential relevance to the project in question, which emerged from the discussion:

- No single model can incorporate and address all the health and healthcare factors potentially associated with the outcomes of health policies. Different approaches provide distinct advantages and have different drawbacks. Some groups are experimenting with the nesting, or linking, of multiple models. Basically, by using the outputs produced by a first model as inputs to be fed into a second model.
- Some groups are developing reduced versions of their models. One group, in particular, presented an on-line version of their model which incorporates the basic input data required to run a range of simulations that would answer some key policy questions. This approach is a promising way of increasing the use of a model at the local level, without requiring advanced technical expertise.
- A number of risk factors, including obesity, tend to cluster within families and social networks suggesting a role for the social environment in the spread of behaviours closely associated with chronic diseases. This dimension is usually neglected in policy evaluations, because most modelling approaches are not suited to addressing social interactions. A notable exception to this is the agent-based modelling (ABM) approach which provides the flexibility required to

incorporate individual heterogeneity, complex social structures, and a range of dynamic adaptive behaviours.

- According to the ISPOR (International Society for Pharmacoeconomics and Outcomes Research) task force on good research practices in modelling studies (Weinstein, 2003); one of three key areas in assessing the quality of models is validation. Cross-validation (i.e. comparing the inputs and the outputs of different models) is a useful exercise to assess the accuracy and consistency of algorithms and calculations. Cross-analyses were carried out after the workshop to compare the CDP model with the Foresight obesity model, which may serve as an example for further future comparisons.

Review CDP model activities at the 2011 Expert meeting and identification of future developments

25. Results of the workshop with key modelling teams were brought to the OECD Expert Group on the economics of prevention 2011 meeting and possible strategies for further developing OECD policy modelling work, and ways of enhancing the capabilities of the existing CDP model were discussed. Experts agreed that further developments could be pursued in two main directions:

- a) Improvements in model functionality; and,
- b) Expansion of the scope of the model.

Functional improvements

26. Functionality of the version of the CDP model used in early analyses could be enhanced by increasing the usability of the model by less experienced users and reducing the range and complexity of out-of-model estimation steps. The proposed enhancements included:

- i) the implementation of a user-friendly interface to handle at once all different phases of the simulation; this would include the development of a light internet version of the interface, possibly to be made available for access by member countries via the Internet;
- ii) a simplified (automatic) procedure for validating input data which should possibly be incorporated into the interface mentioned above; and,
- iii) the implementation of continuous distributions, instead of categorical distributions, for key variables.

Scope of the model

27. Experts called for an expansion of the scope of the CDP to address a larger number of risk factors for health. In its initial development, CDP captured only some of the interactions between risk factors and diseases, and omitted related diseases that might concur in determining health outcomes and health care costs. In addition, similarly to many existing models, CDP was essentially an epidemiological model, in which the provision of health services was mainly determined by patient demand and coverage represented the only quantified feature of the relevant health system. If a fuller reflection of health care pathways and health system characteristics were incorporated into the model, CPD could prioritise health interventions across the whole spectrum spanning from prevention to treatment and long-term care.

28. In order to overcome some of the above limitations, the expert group identified possible lines of development for the CDP model:

- i) inclusion of new risk factors (e.g. salt, tobacco and alcohol) and diseases (e.g. individual cancers and chronic renal failure);
- ii) accounting for alternative pathways of care;

- iii) developing a health system component which would include health care providers (e.g. differentiating the role primary care providers from hospitals); and,
- iv) enabling the model to project health and economic outcomes into the future

Further reviews of the CDP model

29. Further assessments of the design, input data, key assumptions and performance of the CDP model were undertaken during 2011 through: (a) a detailed review and comparison of the CDP model and the Foresight Obesity model, developed by the UK National Heart Forum (Foresight, 2007), one of the most detailed models available on obesity and related health outcomes and costs; and, (b) two external (peer-) reviews of the architecture, algorithms and performance of the CDP model, conducted by leading experts in the field. The above reviews led to the main conclusion that the next step in the development of the CDP model would require a more extensive re-redesign than originally thought, in order to overcome a number of structural constraints that would prevent a significant expansion, or make such expansion unreasonably difficult. This conclusion paved the way to a new development phase, which effectively started in 2012.

Comparative review of health expenditure forecasting methods

30. The exploration of potential models to support health policy planning widened in 2011/12, at the request of the Health Committee. A comparative analysis reviewed 25 models that were developed by, or used for, policy analysis by OECD member countries and other international organisations (Astolfi et al, 2012). The review focussed on the development of models to forecast health expenditures, as health policy makers are increasingly relying on models to support decision making and there are concerns about health expenditure growth and its long-term sustainability.

31. The review concluded that these models provide some guidance about future health spending but have been weak in their support of decision-making about the policies that could change the future course of health spending. This is not always the case in other areas of policy development, where models are considered necessary before policy changes are made (e.g. road traffic) or at least usual (tax/benefit policy). Instead, we have lots of studies projecting forward health spending, but only a select few have built policy levers into their analysis. It is those few models that provide the greatest insights for the development of CDP 2.0.

32. Forecasting models typically project health expenditure at the level of individuals, groups of individuals or the community as a whole (Hollenbeck, 1995). At the same time, models can focus on specific sections of health expenditure, such as public expenditure, social security, private insurance, or household out-of-pocket payments. By considering both the level of aggregation of the units analysed and the level of detail of health expenditure to be projected, it is useful to identify three broad categories of health expenditure forecasting models. Models focusing on individuals as the unit of analysis for the projection are referred to as micro models. All examples of micro models in this review use microsimulation techniques. Those stratifying sections of health expenditure into groups, or stratifying individuals into groups, or combinations of these two dimensions, are identified here as component-based models. Finally, macro-level models focus on total health expenditure as the unit of analysis. Within this group, some macro-level models (called computable general equilibrium models) project future health expenditure trends within the context of the whole economy.

Microsimulation models

33. ***Microsimulation*** models are powerful tools which allow analysis and testing of relatively detailed “what-if” scenarios resulting from a variety of policy options. The scenarios can be very

informative for policy makers as they may provide information beyond what is available from retrospective population studies. For example, the US Future Elderly Model is a dynamic microsimulation model that investigates the impact of different interventions aimed at influencing the body weight mass index (BMI) of individuals on the potential health and health care expenditure of the future elderly population. BMI interventions explored included a universal strategy that reduces BMI across the population and a targeted strategy aimed at overweight or obese people. The Population Health Model (POHEM), a dynamic microsimulation model developed by Statistics Canada, projects the potential future health, health care utilisation and health expenditure outcomes of leading chronic diseases. It has been used to evaluate the possible impact on acute-care and home-care costs of an out-patient/early discharge strategy for breast cancer surgery patients; as well as the prospective impacts of new drugs and cancer screening.

34. The units of analysis of the microsimulation models are individuals. These individuals can be aggregated into policy-relevant groups and analysed using relevant indicators such as inequality and poverty indices (Zucchelli et al., 2010). For example, outputs of the Future Elderly Model can be expressed as total health expenditures, expenditures by disease category, expenditures by age group, or expenditures by smoking status.

How do microsimulation models work?

35. Microsimulation models reproduce the characteristics and behaviour of a large sample of individuals representing the whole population of interest. Major life-course events can be represented in the lives of the simulated individuals and, in the case of dynamic models, certain characteristics and behaviours can evolve over the life course. Events like pregnancy and birth; exposure to risk factors like hypertension, cholesterol, smoking (initiation and cessation); and changes in weight; as well as the incidence and progression of diseases such as cancer, diabetes or heart disease; can all be associated to simulated individuals with attributions based on risks or probabilities. Events compete to occur in each simulated life and a random component embedded in the models ensures that not all individuals at risk of an event may experience it. Individual life trajectories are simulated until death. Costs can be assigned to interventions associated with the life events that have been simulated to project a future trend in health spending.

36. To test the potential impact of a new policy, the microsimulation model is run twice – once with the base case or status quo scenario and then again with a policy change or variant scenario perturbing the environment in which the individuals operate. These scenarios produce a chain reaction where individuals react to the policy changes first and then, depending on the design of the model, may also react to the reaction of other individuals. The results are the potential future outcome of the reform and are often compared with the base case to evaluate the potential impact of the reform.

Data requirement

37. Microsimulation models require large amounts of data to effectively assemble a sample that adequately represents the whole population of interest and includes all of the characteristics of interest. Data are often gathered from a variety of sources, and sophisticated statistical techniques are often required to standardize the various databases so that they can be used to populate all of the desired attributes of individuals included in the sample. In addition to characterizing the state of the population, For instance, when performing the economic evaluations of cancer control interventions, POHEM typically uses a simulation sample size of one million individuals and draws together information on risk factors; disease incidence by age, gender and cell-type; stage distribution at the time of diagnosis; and the ‘standard’ or typical diagnostic and therapeutic approaches used. Moreover, data on disease progression after initial diagnosis (depending upon age, gender and stage at diagnosis) are required, in addition to follow-up patterns of practice, treatment at relapse, and terminal care. Therefore 23 different datasets are used which

include various cancer registries and hospital registries, data from pharmaceutical associations, population health surveys, screening studies and clinical trials, etc. (Will et al., 2001).

38. For dynamic microsimulation, a second data requirement concerns the design of realistic behaviours for all of the individuals. Degrees of response that individuals may have to changes in an external variable (elasticities) may be estimated through econometric regressions based on the individual's past experiences and choices or may be taken from a review of the health and economic literature (Ringel et al., 2010).

Component-based-models

39. The most widely used class of models is ***component-based-models***. This class includes a large variety of forecasting models that analyse expenditure by financing agents, by providers, by goods and services consumed, by groups of individuals or by some combination of these groups. When expenditures are grouped by financing agents, for example public expenditure, private insurance or out-of-pocket payments, the models often consist of different layers, each of which may use a different technique to project a sub-component of health expenditure. For example, the Actuarial office of the Centers for Medicare & Medicaid Services (CMS/OACT) in the United States models the public and private component separately, where the former is further divided into Medicare and Medicaid.

40. An important sub-class of component-based models is represented by ***cohort-based models***. In cohort-based models, individuals are grouped into cells according to several key attributes. Typically age is the principal criteria used to stratify the population of interest (generally into five-year age cohorts). Further refinements are obtained by sub-dividing the cohorts according to other commonly-used attributes, such as gender, health status, and proximity to death. These models are often referred to as actuarial models or cell-based models, where the term cell identifies the sub-categories into which each cohort is divided.

How do component-based models work?

41. Each cell in the model is associated with an average cost of health goods and services (usually expressed in real terms). Actuarial projections allow predicting the likely evolution of the population and therefore the future number of individuals included in each cell of the model. Future health expenditure is determined by multiplying the average costs by the projected number of individuals included in each cell. More advanced cohort-based models take into account trends in disabilities as well as factors influencing epidemiologic trends such as, individual behaviour and exposure to risks factors (e.g. smoking, obesity, hypertension and cholesterol). Wherever possible, the introduction of medical innovations is considered. To evaluate the impact of policy options, exogenous shocks are introduced. Each cell typically reacts to exogenous shocks by having a number of individuals migrate to another cell.

42. Cohort-based models have been very common over the years, probably because they offer a number of advantages. First, their implementation and maintenance tends to be simple and relatively inexpensive. This is because this class of models can be developed in an interactive spreadsheet, requiring a limited amount of data and generally including only a few parameters. Many of these parameters can be found in the literature, rather than being estimated. Secondly, the impact of policy changes can be assessed easily by simply modifying the policy parameters (Ringel et al., 2010).

Data requirement

43. Component-based models are typically less data demanding than microsimulation models which partially explains their popularity. Basic version of the component-based models typically use health expenditure estimates broken down into major spending categories and age classes. All of these data

requirements are generally recorded in databases in OECD countries and often cover a relatively long time span. Similarly, demographic projections are often regularly produced and updated. However, the development of more sophisticated versions of the component-based models could require additional information, such as health spending broken down by gender and disease categories, by descendent and survivor status or by end-of-life costs. The absence of national data for some models in this review was overcome by using partial information or information from another country and assuming that the same trends could apply to the country analysed. For example, Wanless uses Scottish data that link records of hospitals use with death records and assumes the results would be representative of all of the UK (Wanless, 2002).

Macro-level models

44. *Macro-level models* restrict the analysis to aggregate health expenditures. They are most appropriate for short-term projections in the presence of clear and undisturbed trends and in the absence of structural breaks (Bartosz, 2010). Therefore, these extrapolation methods can benefit from the inertia in the health systems in the short-run (Getzen et al., 1992).

How do macro-models work?

45. Econometric regression analysis is used to fit time-series data. Projections can be based on pure extrapolation of the statistical models fitting the data or they can be based on the projected values of the critical explanatory variables, whenever included. For example, Getzen and Poullier (1992) proposed a simple econometric approach to forecast aggregate health expenditures as a function of past GDP growth and inflation rates. The accuracy of forecasts was then compared to the results obtained from three different pure extrapolation methods (exponential smoothing, moving average and ARIMA methods). The authors concluded that a combination of all four forecasts was more accurate than any one of them in isolation.

46. Within the class of macro-level models are “computable general equilibrium (CGE)” models. These are models that allow for the measurement of broader consequences to the economy resulting from medical spending growth and for feedback or reaction from consumers and producers. They allow assessing the implications of higher levels of medical-care spending and higher governmental health expenditures on economic growth; and identify what are the long-run determinants of medical spending growth. For example, a CGE model could be used to estimate the extent to which increases in medical spending are driven by capital investment in health technologies. The CMS Dynamic Computable General Equilibrium Model represents the U.S. economy as being composed of two markets, health and non-health products, for which aggregate demand and supply are modelled (Borger, 2008). From the demand side, individuals are assumed to maximize their welfare through consumption of both products, subject to their income and savings. The supply side of this CGE model assumes that both medical and non-medical firms maximize profits and that their profits depend on capital and labour costs and tax rates. The model allows for feedback from consumers and producers to rising levels of medical care expenditures and therefore a response to levels of expenditure that negatively affect consumer welfare. These models depend on assumptions of equilibrium that may not account for observed trends and rely on strong simplifying assumptions about the behaviour of individuals, firms and governments.

Data requirements

47. Macro-level models are typically the least demanding in terms of data requirements (Bartosz, 2010). This is particularly the case for pure extrapolation methods which use a single time series and for regression-based models which very often include just a few explanatory variables. The computational and

data requirements for Dynamic Computable General Equilibrium Models, on the other hand, are generally much higher and depend on the specification of the equations included in the model.

48. Overall, it appears that no class of model can be considered as superior to the others and that there is great flexibility within and between models to design platforms to support addressing a variety of policy questions. The choice of platform depends on the policy questions that are the most pressing.

49. Table 1 reports the list of the models reviewed and their main features.

Table 1. Health expenditure forecasting models reviewed

Country	Models reviewed	Class of models	Year
Australia	Australian Institute of Health and Welfare (AIHW)	Component-based	2008
Australia	National Centre for Social and Economic Modelling (NATSEM) Micro-Macro	Combined component-based & macro-level CGE	2002/2009
Australia	Australian Government, Productivity Commission	Macro-level	2005
Australia	Australian Government, The Treasury	Component-based	2010
Canada	Canadian Institute for Health Information (CIHI)	Macro-level	2006
Canada	Parliamentary Budget Officer (PBO)	Component-based	2007
Canada	Statistics Canada /Population Health Model (POHEM)	Microsimulation	1994 onwards
European Union	European Union/Ageing Working Group	Component-based	2012
France	Direction de la recherche, des études de l'évaluation et des stat. (DRESS)	Component-based	2007
France	Sénat	Macro-level	2004
Italy	Ministry of Health/Università di Roma Tor Vergata	Macro-level	2011
Italy	Ragioneria Generale dello Stato	Component-based	2011
Netherlands	Bureau for Economic Policy Analysis (CPB)	Component-based	2010
New Zealand	Ministry of Health and Treasury	Component-based	2004
OECD	Directorate for Social Affairs, Manpower and Education	Macro-level	1992
OECD	Economics Department	Component-based	2006
Sweden	Ministry of Health and Social Affairs	Microsimulation	2010/2011
UK	HM Treasury/ Office for Budgetary Responsibility (OBR)	Component-based	2002
UK	National Heart Forum Microsimulation Model (Foresight)	Microsimulation	2007/2011
USA	Centers for Medicare & Medicaid Services (Component)	Combined component-based & macro-level	annual
USA	Centers for Medicare & Medicaid Services (GE)	Macro-level CGE	2008
USA	Congressional Budget Office (CBOLT)	Combined component-based and microsimulation	annual
USA	The Future Elderly Model (CMS/RAND)	Microsimulation	2004/2011
USA	U.S. Department of Veterans Affairs	Component-based	2008
USA	Comprehensive Assessment of Reform Efforts (COMPARE) (RAND/USDL/USDHHS)	Microsimulation	2010

Issues faced by model developers

50. Each of the three families of models presents challenges to model developers from both limitations in the desired data for model development; as well as limitations associated with the model family and the impact of model assumptions on results (Lorenzoni et al, 2012).

Macro-level models

51. Macro-level models restrict analysis to aggregate health expenditures. They depend on the presence of clear and undisturbed trends and on the absence of structural breaks. Thus they are most appropriate for short-term projections, as the extrapolation methods can benefit from the inertia in the health system.

52. Macro-level models are typically the least demanding in terms of data requirements (Bartozs 2010). This is particularly the case for pure extrapolation methods which use a single time series (Getzen and Poullier, 1992) and for regression-based models which very often include just a few explanatory variables. However, time series need to be relatively long and consistent. The presence of breaks in the series, due to either change in the methodology or to the implementation of specific policies, or to limitations in the availability of data points may harm the results. In addition, the identification of relevant explanatory variables in the regression based model is particularly tricky. In fact, swings from expansion to contraction in health spending (turning points) can be predicted only if explanatory variables are able to anticipate the peaks and troughs.

53. As an example, the Centre for Economic and International Studies (CEIS) at Tor Vergata University in Rome (Italy) has developed a macro-level model with explanatory variables which allows the estimation of future health expenditure by selecting statistically significant explanatory variables, estimating the coefficient of those variables on the basis of historical data from 1969-2009 and making assumptions about the changes in the value of those explanatory variables from 2010-2051 (Atella et al 2011).

54. The computational and data requirements for dynamic computable general equilibrium models (CGE), on the other hand, are generally much higher and depend on the specification of the equations included in the model. CGE models depend on assumptions of equilibrium that may not account for observed trends and rely on strong simplifying assumptions about the behaviour of individuals, firms and governments.

Component-based models

55. Component-based models are the dominant class, accounting for more than half of all forecasting models surveyed in the OECD study. Component-based models are typically more data demanding than macro-level models but less demanding than microsimulation models, and this partially explains their popularity. Basic versions of component-based models typically break down health expenditure into major spending categories and age classes and employ actuarial projections as the main driver of future health spending. The development of more sophisticated versions of these models requires additional information, such as health spending broken down by gender and disease categories, by descendent and survivor status or by end-of-life costs.

56. The implementation and maintenance of component-based models tends to be relatively simple and inexpensive, and they can be integrated into a broader framework that projects other spending; such as social security expenditure (e.g. including pensions). In these models, the impact of policy changes can be assessed by simply modifying the policy parameters that were included.

57. An example of this family of models is given by the OECD Economics Department health expenditure forecasting model (OECD 2006, updated in 2012). To project public health expenditure, per-capita expenditure profiles by age are estimated in the base year for two components: health care;

and long-term care. The per-capita expenditure growth is projected according to specific assumptions about demographic-related factors (i.e. death-related costs; and healthy aging); income elasticity of health expenditure; and a composite residual growth factor that includes health-specific prices and technology. The growth rates are first projected for each country and they are then adjusted to allow for convergence across countries towards a common target.

How could we further develop component-based models?

58. Health expenditure projections by age and gender could be enriched by taking into account the epidemiological projections for a specific set of diseases. A feasible opportunity for model development would be to include leading diseases as individual model components in order to examine and compare expenditure growth patterns by disease, which may well differ as they can be determined by different drivers.

59. The price of health care relative to the general price level was reported as a significant driver of health spending growth. Several models (Goss 2008; CMS-OATC 2010) included excess medical prices among the non-demographic drivers when forecasting current health spending growth and health expenditure as a share of GDP. Other models reviewed ascribe it to the residual category when no measures of health-sector inflation are available. Explicitly modelling health prices and volumes of health care services as independent drivers of expenditure growth would provide insight into drivers of expenditure growth; particularly those related to the intensity of care provision. Development of data that distinguishes health-specific price and volume would be needed.

60. The general consensus is that growth in real spending on health care is mainly the result of the emergence of new technologies and services, and their adoption and widespread diffusion. However, when it comes to measuring how much this factor accounts for growth in health spending, the effect of technological change is often proxied. One proxy is to ascribe technological change to the residual after all other factors have been controlled for (“excess growth”), while another uses a time index to control for the effects of technological change on health expenditures. A data collection strategy to better measure the introduction, adoption and use of new technologies (e.g. therapies, ICTs in health care) represents an important area for development. This strategy should not only predict the level of technological development but also its type (Chandra et al 2011).

61. It has generally been accepted that variations in per capita national income are closely correlated with variations in per capita health spending, and higher levels of GDP contribute to higher levels of spending. One possible explanation for this is that as nations become richer, people place higher value on health and want to spend a larger share of their income on improving their health (Fogel 2008). However, the “income elasticity” varies a lot in empirical results and whether health care is a luxury good or a necessity has not been settled. There is a need for research to unpack the difference between family income growth and family health spending and national income growth and national public health spending in order to make more empirically informed assumptions about “income elasticity”.

62. Focussing on total expenditure, which is public and private health expenditure, and on the relationship between the two will allow estimating – at an aggregate level - the distributional impacts of policies to control health expenditures.

63. Addressing the need to understand how institutional/policy changes influence health spending growth represents another area for model development. This could be done by identifying the relevant macro dimensions that can be used to describe the distinctive features and constraints of a health system in terms of financing and organizational arrangements and then estimating how those features could impact public and private health spending growth.

Component-based models have limitations that will be difficult to address

- It is difficult to explore distributional impacts of different policies to control health expenditure growth without exploding the number of cells in the model.
- There is limited ability to test “what if” scenarios about the impacts of new policies to control expenditure growth.
- The models will only be able to test assumptions about the future burden of disease/health status of the population.
- Estimating the population’s engagement in healthy lifestyles and behaviour and its impact on health expenditures would explode the number of cells in the model.

Microsimulation models

64. Microsimulation models require large amounts of data to effectively assemble a sample that adequately represents the whole population of interest and includes all of the characteristics of interest. Data are often gathered from a variety of sources, and sophisticated statistical techniques are often required to standardize the various databases so that they can be used to populate all of the desired attributes of individuals included in the sample.

65. For example, the US Future Elderly Model (RAND 2011) is a dynamic micro-simulation model that investigates the impact of different interventions aimed at influencing health risk factors, such as body mass, on the potential health and health care expenditure of the future elderly population. It has also been used to assess the impact of the introduction of sets of specific health technologies on future health, health system use and expenditures. The Population Health Model (POHEM) is a dynamic micro-simulation model developed by Statistics Canada. It has been used to evaluate the possible impact on acute-care and home-care costs of an out-patient/early discharge strategy for breast cancer surgery patients, as well as the prospective impacts of new drugs and cancer screening. In addition to characterizing the state of the population, for instance, when performing the economic evaluations of cancer control interventions, POHEM typically uses a simulation sample size of one million individuals and draws together information on risk factors; disease incidence by age, gender and cell-type; stage distribution at the time of diagnosis; and the ‘standard’ or typical diagnostic and therapeutic approaches used. Moreover, data on disease progression after initial diagnosis (depending upon age, gender and stage at diagnosis) are required, in addition to follow-up patterns of practice, treatment at relapse, and terminal care. Therefore 23 different datasets are used which include various cancer registries and hospital registries, data from pharmaceutical associations, population health surveys, screening studies and clinical trials.

66. For dynamic microsimulation, a second data requirement concerns the design of realistic behaviours for all of the individuals over their life course. Estimating relative risks or hazards of transition from one state to another require analysis of longitudinal data or a review of the health and economic literature where relative risks or hazards of transitions have been reported. Degrees of response that individuals may have to changes in an external variable (elasticities) may be estimated through econometric regressions based on the individual’s past experiences and choices or may be taken from the health and economic literature.

How could we further develop microsimulation models?

67. Feasible opportunities for model development within a microsimulation framework include the following.

- Develop models that include leading diseases (those at the top of the burden of disease estimates) in order to capture the major health drivers of expenditure growth.

- Address the need to understand the distributional impacts of policies to control health expenditures by extending the model to describe and project the variability within country populations: by ethnicity, by immigration status, by education, and by family income.
- Include health care pathways including service providers, details about the therapies used and the costs of health care consumed.
- Explicitly differentiate health care paid by public sources, by personal insurance and out of pocket for each family in the model.
- Project total health expenditures, and also life expectancy, healthy life expectancy, and disease burden.

Microsimulation models have limitations that will be difficult to address

- Health system characteristics and policies that determine the supply and provision of healthcare services and may modify diagnostic and therapeutic pathways are difficult to include.
- Components of expenditure growth like administration and research/investments are difficult to include.
- These models are not conceived to explicitly include the broader economic environment in which the “virtual” individuals live.

Could the three families of models be complementary?

68. While many approaches to forecasting health-care expenditures have been around for a very long time, new approaches are appearing on the horizon that take advantage of increases in data granularity and in computing technology to bring a fresh look to the issue of explaining trends in health expenditures. Recent decision-support models offer enhanced opportunity to test policy scenarios and to understand the broader social and economic implications of policy changes. There are emerging systems of models (combined models) where different modelling approaches are designed to work together coherently. In this way, techniques with different strengths are amalgamated and a broader range of policy questions may be explored.

How could a component-based model and a microsimulation model work together?

69. Microsimulation model could be used to test the impact on health expenditures, the health status of the population, the burden of disease, treatments provided, and family’s out-of-pocket share of their health care costs of new policies to, for example:

- Introduce new health services,
- Prevent or postpone disease,
- Cut back on health services,
- Change insurance options, and
- Change the public-private payment split.

70. Projected results of trends in health care consumption, population health status, and health services used could provide important inputs to inform the component-based model in order to develop full forecasts of health expenditures including supply-side factors and components of

expenditure growth, like administration and research investments, that are outside of the microsimulation framework.

71. As an example, the Congressional Budget Office (CBO) has developed a sophisticated long-term model known as CBOLT to analyse the budgetary effects of social security programs in the United States (CBO, 2009). CBOLT is a forecasting platform that amalgamates both component-based or actuarial methods and dynamic microsimulation methods.

How could a macro-level model and a microsimulation model work together?

72. A notable example in that direction is the NATSEM-CHE-CoPS Micro-Macro Chronic Disease Prevention Model (Brown 2009) which combines a microsimulation approach to model the effects of population health initiatives to tackle diabetes with a macro model simulating the labour market and the full economy. In particular, the linkage is performed through a bottom-up process where decreases in the prevalence of people projected to have type 2 diabetes in response to interventions leads to changes in the aggregate labour supply which then permeates through the Australian economy to impact overall productivity.

How could a component-based model and a macro-level model work together?

73. The macro-level model could be used to introduce in the component-based model brakes/constraints on health spending growth from the economy by:

- Separately estimating the tax burden required to support the government share of health care expenditures and testing scenarios regarding the public's willingness to support such tax levels; and
- Separately estimating the impact of the growth of health care costs on the disposable incomes of families and, therefore, on their ability to consume other goods and services and testing scenarios regarding the public's willingness to support such health care costs.

74. The macro-level and component-based model types could also work together to model total – that is public and private – health spending. As an example, the US Centers for Medicare and Medicaid Services combines a component-based cohort or actuarial approach for Medicare and Medicaid spending with a macro-level model for private health spending (Centers for Medicare and Medicaid Services 2010).

Development of an international decision-support platform

75. Advances in computing technology and in detailed health and economic data enable the development of models that can more accurately disentangle the set of drivers of health expenditure growth; and can better help to test the potential future impact of policy interventions before they are implemented in the “real world”. Such models can help to direct efforts to where they may be the most effective. Emerging onto the scene are approaches that enable detailed “what if” questions about the introduction of policies related to prevention, treatment, organization and financing of care, technological innovation and health sector productivity.

76. On the horizon are systems of models, where a set of policy questions drives the development of a modelling platform. In those systems, a forecast from one model can provide a needed input parameter for another model, and all models in the overall architecture can be designed to work well together. Such systems enable a broad range of policy questions to be addressed and thus can become an on-going decision support tool capable of adapting to new questions as they arise.

77. There is an opportunity for modellers to develop and implement an international decision-support platform for health expenditure forecasting, benefiting from the lessons learned from model

development in different countries/organisations. Advantages of an internationally comparable forecasting platform include the opportunity to:

- Produce comparable forecasts through the standardisation of model specifications, assumptions and data;
- Estimate and compare the relative impacts of potential policy reforms; and
- Begin to examine global issues, including the pressures associated with cross-border movement of patients, personnel, services and capital.

78. An international platform would allow countries with weaker data the possibility to benefit from parameters from other countries where richer datasets are available. The platform could be used to estimate and compare the potential impact of new policies in different countries which would further validate the effectiveness of particular policy responses.

International workshop on improving health expenditure forecasting methods

79. The OECD organized an international workshop on improving health expenditure forecasting methods on the 30th of November, 2012. This workshop convened 21 delegations including leading experts from health and finance backgrounds in government, academia and international organizations to take stock of progress in health expenditure forecasting and to discuss future directions, in light of policy needs and recent advancements in techniques, detailed data and computing power.

80. The workshop included views of senior health and finance officials about the information they require for decision-making, followed by a review of the current state of the art, with presentations of selected innovative models from leading national and international modellers. The workshop concluded with highlights from the OECD's comparative review of health expenditure forecasting methods, followed by presentations from experts regarding their views of what are the most important shortcomings in current efforts and what should be the future direction of health expenditure forecasting efforts. The floor was open for workshop participants to exchange views on the benefits and drawbacks of new approaches.

81. Key outcomes of the workshop include that the key issue facing governments is to control health expenditure growth while not detracting from the quality of health care and the health status of the population. There is an issue with the data quality and granularity needed for model development and this is linked to limitations in model's ability to both distinguish drivers of health care expenditure and to delve deeper to a level necessary to uncover the cause of the causes of health expenditure growth. As public expenditure decisions about care financing shift the burden between public and private sectors, consideration should be given to ensuring models capture both private and public expenditures. The connection between health spending and distribution of health and service use, societal well-being and economic growth needs to be strengthened. There are fundamental issues about the health system, such as how to measure its productivity and the drivers of productivity that require both data and model development. There was a consensus that no single model can be expected to capture the granularity needed to address the policy questions that are of importance to decision making. Future progress should consider a modular approach to model development. Further, the coordination of modellers through the OECD is helpful to modellers and policy makers.

Models to evaluate risk factor prevention strategies

82. Macro-level compartmental models are common in the field of risk-factor reduction policy evaluation. Our review of recent literature describing policy models related to the control of alcohol use revealed a set of models of this type, all of which were directed toward evaluation of policies that may reduce binge drinking behaviour among college students and consider binge drinking as a

socially contagious behaviour. The most common methodological approach has been to construct compartmental models described by deterministic coupled differential equations as commonly used to model transmission of infectious disease (Anderson, 1992). These equations track the expected population density dynamics of the different compartments which characterize consumption levels (light or occasional, moderate and heavy drinkers) and describe how steady-state population densities may change in response to hypothetically effective policy interventions (Mubayi 2009 and 2011, Amzy 2009, Scribner 2009, DeJong 2009, Fitzpatrick 2012). Compartmental models ignore the heterogeneity that exists among individuals and ignore chance. It is difficult for compartmental models to account for several factors that influence an outcome, such as alcohol consumption, nor to consider multiple outcomes. Microsimulation approaches were developed to compensate for these limitations.

83. The risk-factor prevention policies we aim to evaluate through our decision-support computer simulation platform intend to influence the behaviour of individuals. Microsimulation models are able to take into consideration the underlying heterogeneity in populations and the underlying differences in individual's behaviours which influence the relative effectiveness of policies across different population groups (Gupta, 2007). Microsimulation models also overcome some of the challenges faced in other individual-level simulation approaches such as markov chains and semi-markov processes. In these techniques, the modeller must define all of the possible states and transitions that will take place, which can become extremely complex (Goldie, 2003 and Fone, 2003). In microsimulation, instead of defining a fixed set of possible states, the focus shifts to defining events that individuals may experience, creating a state space that is essentially limitless. Individuals' characteristics then influence the probability and the timing of events occurring. For example, an individual who is a sustained heavy drinker in the model would have a higher likelihood of developing an alcohol-related disease. All events in the model compete to be the next to occur in an individual's life and a stochastic process ensures that even those at high risk do not always experience a particular event. Micro-simulation models can, as a result, reproduce the characteristics and behaviours of a large sample of individuals representing the whole population of interest, and its underlying diversity. Individual life trajectories are simulated until death. When a representative population is projected, then future cross-sectional estimates can be presented.

84. Micro simulation models may allow individuals to interact with one another and such models are referred to as 'agent based'. There has been some interest in constructing agent-based models of alcohol consumption (Gorman 2006, Fitzpatrick 2012). In these cases, individuals change their drinking behaviour based on social interaction with other individuals in their neighbourhood. Results provide insight into the spatial assortment of alcohol outlets and how drinkers sort themselves by frequenting these establishments and forming social ties with fellow drinkers. While interesting and informative, such approaches are theoretically-based rather than empirically-based. They are computationally intensive, and therefore are restricted to few characteristics of individuals and a few outcomes.

85. In dynamic microsimulation models, certain characteristics and behaviours can evolve over the life course, such as alcohol-consumption, which the literature shows is subject to change over the life course. There are a number of recent case-based, dynamic micro simulation models that have been developed and used to support policy decisions (Gupta, 2007 and Astolfi et al., 2012). Dynamic micro simulation models like the U.S. FEM, the Swedish SISEM-LEV, and the Canadian POHEM allow the characteristics of individuals to evolve over time in a realistic manner due to factors endogenous within the models. All of these models have been used to evaluate the potential future cost-effectiveness of policies to improve health and reduce disease.

CHAPTER 3: SCOPE AND KEY FEATURES OF CDP 2.0

86. This chapter presents the overall architecture and key features of the CDP 2.0 platform. The conceptual plan was developed to address the policy needs and key questions that were discussed in the introduction. The plan was also developed in consideration of the reviews and consultations with experts regarding the advantages and disadvantages of modelling strategies to meet those needs and objectives that were presented in chapter two. The opportunity for such redevelopment was offered by the interest expressed by the European Commission through the award of a specific grant to the OECD by DG Sanco, and by the inclusion in the OECD Programme of Work and Budget for 2011-12 of an analysis of the impacts of policies to address alcohol-related harms, which required analytical tools similar to the ones previously employed in the assessment of policy options to counter the obesity epidemic.

A new architecture

87. The new Chronic Disease Policy model, or CDP 2.0, is designed to simulate a large population of individuals, one-by-one, from birth to death. This facilitates the representation of longitudinal processes which act at the individual level over the life course, such as persistent behaviours and their downstream health consequences. It also facilitates the representation of population heterogeneity, because the unit of simulation is a single individual, and each individual has distinct characteristics and a unique simulated lifetime.

88. The simulation of each individual is event-based, with each event contingent on the current and past characteristics of the individual. Those characteristics are themselves the consequence of previous events which occurred earlier in the life of the simulated individual. Each type of event in the model is specified using a statistical equation which has estimated numerical parameters. These event equations give the probability that a given event will happen next in the life of a simulated individual, and also provide the exact time when that event will occur.

89. In much the same way as a population census produces aggregate statistics for a real country; characteristics of all of the simulated individuals can be aggregated to produce tables which summarize the simulated population as a whole. The architecture of CDP 2.0 permits the construction of cross-sectional tables (by year), as well as longitudinal tables (e.g. by birth cohort).

90. CDP 2.0 is empirically-grounded in the data of a particular country. Viewed as aggregate annual cross-sections, the simulated population aligns with the age-sex population distribution of the given country in each year of the previous 15 years (the 'estimation period'). Put another way, the simulated population is statistically representative of the real population of the country during this period.

91. The simulated population also aligns with country-specific empirical survey data from the estimation period. This survey data can vary from year to year in coverage, design, and level of detail. A particular country-specific survey is 'implemented' in CDP 2.0 and applied to each individual in the simulated population, in the same year(s) the real survey was administered. The survey results from the simulated individuals are then aggregated to produce tables which are conceptually identical to the empirical tables from the real survey. Next, a statistical search procedure finds sets of values of the model's numerical parameters which, when simulated, produce tables which align statistically with the corresponding empirical tables from the survey. This search procedure involves performing many thousands of simulations. The results of the search procedure (the solutions) are retained for subsequent use.

92. As with any estimation procedure, the values of the numerical parameters are uncertain. This uncertainty is captured in the variability of the solutions identified by the search procedure. Each

of these solutions can be thought of as an equally-likely ‘alternate reality’ for the country, because each solution is consistent with the empirical data for the country. When CDP 2.0 is run subsequently, it simulates multiple ‘alternate realities’ in parallel, and reports averages across them. The dispersion of results around the average provides a direct measure of uncertainty in any model output.

93. CDP 2.0 is designed to perform conditional projections and evaluate policy interventions. CDP 2.0 can evaluate a policy intervention which can be expressed as a change in the behaviour or characteristics of the simulated individuals. Policy interventions are evaluated by simulating the population of a given country beyond the estimation period into a 50-year projection period. To evaluate a policy intervention, a matched pair of simulations are performed, one with the future intervention and one without, and the results compared. In fact, multiple pairs of simulations are performed, with each pair simulated in one of the possible ‘alternate realities’. This allows CDP 2.0 to estimate the degree of uncertainty in the projected effect of the intervention.

Main differences relative to the first version of the CDP model

94. The first version of the CDP model was designed to evaluate and compare specific policy interventions which reduce the health burden of chronic diseases on populations. This is a challenging problem, since a policy intervention can take years to work through an interacting web of cause and effect in a population of heterogeneous individuals.

95. CDP met this goal by combining a micro-simulation model with a more traditional compartment-based model¹. CDP 2.0 has the same goals as the first CDP, but builds on feedback received and lessons learned with the initial CDP. Key foundational improvements have been made in three areas: conceptual framework, empirical validation, and uncertainty. Each is discussed in turn below.

96. In the CDP 1.0 the computations of prevalence and incidence rates by age were performed at an aggregate level in the analysis performed before running the genuine micro-simulation. Aggregate prevalence rates resulting from those pre-analysis were then entered as an input in the micro-simulation module. Individual level equations had to conform to those inputs (calculated at aggregate level). The CDP 2.0 model differs profoundly in that prevalence rates are no longer considered as an input in the micro-simulation. Instead, prevalence is endogenously calculated as a result of individual-level events. Therefore, model dynamics are driven by events and equations at the individual level, not by the values of externally-imposed aggregates, and not by equations which operate at the aggregate level. Empirical parameters, however, do play a role in CDP 2.0 at the estimation phase rather than the modelling phase. Equation coefficients (which determine individual behaviour) are estimated in such a way as to be consistent with empirical aggregates, e.g. from the CCHS and the NPHS. But once estimated equation coefficients apply at the individual level.

97. Moreover, the conceptual framework of the first CDP contained two parallel components of the causal web: one modelling the interactions between risk factors and diseases before model time began (so called ‘static’ web) and another simulating the interactions occurring during the simulation (‘dynamic’). In contrast, CDP 2.0 represents all causal pathways in a single internally-consistent micro-simulation framework, which simulates all individuals from birth to death. This makes the interpretation of the results of simulations significantly easier.

98. CDP represented an idealized equilibrium population which was projected into the future. This made validation of CDP problematic, because results could not be easily compared to empirical data. CDP 2.0 instead has no starting population. The characteristics of the population during the historical estimation period (before the projection period) are completely determined by the same

¹ A “compartment-based” model characterizes a population of people by allocating each person to a stage or a compartment and then specifying equations to describe how people move or transition from one compartment to another.

behavioural equations and coefficients used to move the population forward in the projection period. Thus, CDP 2.0 has a high internal consistency. Models with a starting population have, structurally, issues of consistency between the imposed characteristics of the starting population and the dynamic equations of the model. This is dealt with in various ways (not entirely satisfactory), but the architecture of CDP 2.0 side-steps the issue altogether. Therefore, CDP 2.0 represents actual country-specific populations, simulates historically as well as projecting into the future, and incorporates both period and cohort effects. This makes it possible to validate CDP 2.0 by comparing historical simulated results to country-specific empirical data. It also makes CDP 2.0 directly relevant to specific individual countries.

99. CDP simulated using a single estimated value for each model parameter. However, the values of these parameters are uncertain. That uncertainty implies uncertainty in model results, and in any policy conclusions based on those results. CDP 2.0 always simulates using multiple sets of feasible parameter values. This enables CDP 2.0 to show bands of confidence around any projected model result. This provides policy makers with important additional information needed to quantify and manage risk.

Overall framework of CDP 2.0

100. CDP 2.0 is a dynamic microsimulation model. Dynamic microsimulation in the health field creates a virtual lab where policy analysts and researchers can experiment with the introduction of new policies to test their impact on a virtual population of thousands or millions of individuals that realistically represents actual societies. As do real people in real populations, actors in the simulation model live out full lives during which many different health-related events occur. They may gain or lose weight, start or quit smoking, become injured or not, develop diseases or not, experience different types of preventative and curative treatments, develop co-morbidities or not, enter long-term care or not and eventually die.

101. Developing CDP 2.0 requires modelling individual behaviour. If we had an idealised dataset to analyse using statistical or econometric techniques that contained all of the variables and outcomes necessary for policy evaluation in both the current time period and also in the future, then there would be no need for microsimulation whatsoever. Of, course we will never have such a database, even for the current period. Microsimulation sits at a higher level than traditional statistical or econometric methods. Microsimulation synthesizes results from relevant sets of statistical and econometric models, each developed from different data sources and containing different variables and outcomes. Through synthesizing results, microsimulation models enable policy analysis to take a very big leap forward in terms of evidence-based policy development.

Why is dynamic microsimulation the right modelling approach for CDP 2.0?

102. Firstly, microsimulation is helpful when the policy reforms we wish to consider are targeted to specific types of individuals or distributed differently to individuals based on their underlying characteristics. Microsimulation is also helpful when we need to know how potential policy reforms may have different impacts on the behaviours of different types of individuals. Classical economic models don't allow for any differences among people and can be quite misleading when it comes to testing impacts of policies. Cell-based models, however, as we discussed in chapter two, can help to disaggregate people into groups based on a very limited set of characteristics, such as sex, age and one or two other characteristics, such as time until death or occurrence of any chronic disease. A cell-based model where we care about a more nuanced set of characteristics such as individuals with a smoking status, BMI, multiple chronic conditions, access to different health care services, etc. is beyond the capacity of this approach. A cell-based model with only 15 variables of interest and where each variable is categorized into only five possible values, generates a table with more than 30 billion cells (5^{15}).

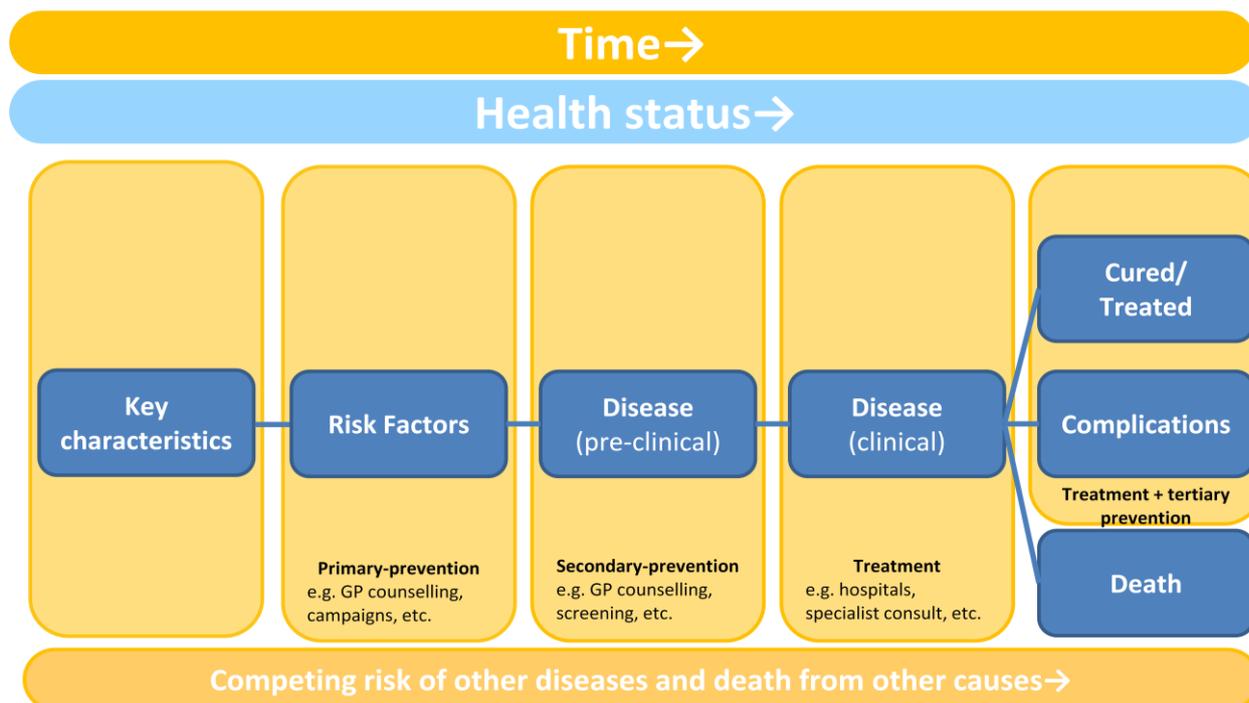
103. Secondly, individual behaviours are also modelled more easily at the level of individuals than for groups. Many policies we may be interested in developing will be targeted to people with different combinations of characteristics in a non-linear way. As a result it is very difficult to model the impact of these policies using traditional approaches. An example would be a policy decision to list for public insurance a new drug therapy for hypertensive patients which can only be prescribed to patients with particular disease states. Further, patients' likelihood of receiving the medication will depend on their age, sex, disease state and health status as well as their likelihood of seeking an appointment with their primary care physician. At the individual level, this is all very practical, as long as all of the necessary characteristics are included in the model.

104. Thirdly, and most importantly, dynamic microsimulation is the only modelling approach that is applicable if an individual's history matters. For example, an individual's history of risk-taking behaviour, such as smoking, alcohol use and nutrition matters for the development of certain diseases. An individual's history of health-care seeking matters for whether or not they will seek a new medical appointment. An individual's history of disease matters for whether they live or die. Microsimulation models are designed to remember an individual's history and take it into account to influence their future life course. Cell-based models, on the other hand, cannot take history into account by design. There is no memory of past cell membership.

105. Microsimulation models like CDP 2.0 operate at a different level from the statistical and econometric models that are necessary to build them. CDP 2.0 is able to synthesize results from sets of statistical and econometric models that are based on different data sets with different types of variables. As a result, CDP 2.0 is data intensive, requiring detailed data and analysis to ground the model in the best empirical evidence we have about risk factors, diseases, outcomes and costs. CDP 2.0 is also computing intensive, requiring thousands of simulations to estimate the best fitting model. While the first concern is significant, requiring cooperation and human-resources within the OECD; the second is becoming less important, due to advances in computing power and grid-computing. For example, we have been able to network powerful servers within the OECD secretariat to run simulations over night, when our computers are otherwise idle. We will discuss the data and analytical needs for CDP 2.0 in more detail in the chapters ahead.

106. The development of CDP 2.0 represents a novel approach to cross-country sharing of a common decision-support platform for the evaluation of health policies. The platform will enabling countries to test the implementation of policies previously developed and evaluated in other countries, in terms of their potential effectiveness overall and within specific communities of interest, such as socio-economic groups. Researchers will have the flexibility within the platform to borrow parameters from a similar country with stronger data to reduce the uncertainty of the estimates for their country. In enabling this type of international data sharing, the platform will enable better and more accurate estimates than would otherwise be possible for any one country developing a model alone. The innovative approach to developing platform for comparative analysis of policy impacts across and within countries we are proposing has the potential to be transformative in the field of social policy microsimulation modelling.

Figure 1. Overview of CDP 2.0 Framework



Key components of CDP 2.0

107. The key components of CDP 2.0 are summarised in figure 1. For each country, CDP 2.0 would represent its current population, as well as its future population, with all of the fundamental dimensions necessary for the evaluation of health and health care policies. Specific applications of the model may require additional development in the future. The goal of 2.0 is to provide the most appropriate and complete baseline model as is feasible and to employ a modular approach. The modular approach will enable future extensions without redevelopment of the whole model. Thus CDP 2.0 can grow and evolve as policy questions change and new data and evidence become available.

108. To answer the policy questions outlined in the introduction, CDP 2.0 should capture the key characteristics of people important for understanding health outcomes and their distribution. As a result, in addition to age and sex, information on educational attainment and labour-force participation might be important to study the impact of policy change on different key population groups. Risk factors for health, such as smoking, alcohol use and body mass will be essential, as will be health-care interventions to address risk factors, such as public health campaigns, GP counselling and therapies. The model should include leading diseases and injuries that account for a significant impact on population health, health care services and budgets. The model should also be able to describe interventions to reduce the health impact of diseases, such as early detection/screening and GP counselling to improve outcomes of those living with chronic conditions. The treatments prescribed should also be included, with both the key components of the treatment and information on where the treatment was provided. The model should go beyond capturing a typical treatment path for each disease, that is an average treatment package for an average cost, and, instead, enable representation of the range of treatments available, and to reflect the distribution of treatment pathways for patients with particular characteristics, such as variation due to age and presence of co-morbidities. The model should reflect the sequelae of disease, such as cure, re-currence, deterioration and death. As is true in actual populations, individuals should always face risk of developing both related and non-related diseases and injuries, as well as death from multiple causes and individuals should develop co-morbid conditions in a realistic manner with age.

109. The CDP 2.0 modelling framework would enable users to generate the following key outputs which will be essential to evaluating the impact of policy alternatives. These would include deaths, life expectancy, risk factor incidence and prevalence, disease incidence and prevalence, disability, disability-adjusted life expectancy (healthy years), primary prevention services, secondary prevention services, treatments; as well as the costs of services and treatments. As all of the results are estimated at the level of individuals, model results can be aggregated as desired, such as is possible from a large database. For example, tables can be generated by country, by single year of age, by income group, by region, and by any other variable included within the model. Composite outputs can also be estimated such as cost per healthy life year gained.

110. The baseline model represents all of these components as they have occurred in each country in recent years. The baseline model will project from the current situation into the future, under the assumption that there are no significant policy or environmental changes. Model users then have the flexibility to test the impact of the introduction of new policies and to compare results after policies have been introduced, to the no-policy change baseline results. This process will be discussed in more detail in the chapters to follow. The remainder of this chapter introduces basic concepts important to understanding and working with the CDP 2.0 platform.

Modelling software for CDP 2.0

111. The OECD made the strategic choice to build CDP 2.0 using Statistics Canada's model development platform Modgen. Modgen (Model generator) is a generic microsimulation programming language based on C++ that supports the creation, maintenance and documentation of dynamic microsimulation models. Several types of models can be accommodated, be they continuous or discrete time, with interacting or non-interacting populations.

112. Model developers do not need to have advanced programming skills as a prerequisite to use Modgen. This is possible because Modgen hides underlying mechanisms like event queuing, and creates a stand-alone model executable program with a complete visual interface and detailed model documentation. Model developers concentrate on model specific code: the declaration of parameters, simulated actors, and events.

113. Modgen has a number of useful features. These include:

- Discrete or continuous time simulation models supported;
- Interacting or non-interacting populations supported;
- Modular development;
- Multilingual models possible;
- Powerful tabulation facilities;
- Standard errors and coefficients of variation for tables;
- Export of parameters and tables to Excel;
- Unlimited number of dimensions for parameters and tables;
- Visualization of individual life courses;
- Common user interface for all models;
- Scenario management;

- Fully documented user interface;
- Generation of detailed encyclopaedic model documentation; and
- Multi-threading and grid-computing.

114. Modgen models are currently used to analyze, develop and cost government programs, such as public pension sustainability or post-secondary education; to estimate the life-time costs of diseases, such as heart disease or lung cancer and evaluate the potential impacts of public health interventions on those diseases; to generate detailed population projections; to perform human resources planning for large enterprises; and to examine the spread of infectious diseases among interacting populations. Modgen has also been used as an instructional tool to teach microsimulation itself to social scientists in both Canada and Europe.

115. A recent extension of Modgen developed for Canada's Cancer Risk Management Model (Canadian Partnership Against Cancer, 2011) is Modgen Web. Modgen Web enables models developed in Modgen to be hosted on a web server where model users may run simulations. This extension widely increases the dissemination potential of the models. Indeed, cancer policy analysts throughout Canada are now running simulations interactively over the Internet from a server hosted by the Canadian Partnership Against Cancer. Modgen model background information, software and documentation, and examples of applications in a variety of policy areas are freely and publically available (Statistics Canada, 2012).

116. Given the choice of Modgen as the software platform, an important requirement for the CDP 2.0 is that appropriate plans are made for a possible transition to a more generic C++ platform in the future, if further developments of the model were constrained by Modgen or if Statistics Canada took a decision to cease supporting Modgen and the latter became out-dated.

117. Features of object-oriented programming available with an advanced use of C++ are not available within Modgen. For example, all model processes using Modgen are delivered through the actors in the simulation, which may cause the code to be more complex than a pure C++ design, and the user interface is not customizable by the model developer.

118. The choice of Modgen as the main modelling platform for OECD health policy modelling work was confirmed, based on a strategic appraisal of alternative options, their potential strengths and limitations, although this choice does leave scope for using complementary modelling approaches and platforms, as required in the assessment of policies in specific areas.

Modgen concepts

119. Key concepts underlying Modgen will be incorporated as part of CDP 2.0. These concepts include actors, states, events and parameters. We will be using these concepts to describe further the design of CDP 2.0, so it is useful to review them in general here.

120. **Actors:** An actor is the entity whose life is simulated in a Modgen model. For CDP 2.0 our actors are persons representative of the underlying populations of countries. It is important to note, however, that an actor does not have to be a person in Modgen. In future development, for example, it may be useful to model health organisations as actors in a model. What is important about actors is that they are the minimum unit of analysis for the model. For CDP 2.0 we are interested in learning more about how our populations react to new health policies. Model actors are defined by their characteristics which are included as either states or events.

121. **States:** States contain descriptive information about each actor. States may be continuous, such as the actor's age, BMI and employment earnings; while others are categorical, such as the actor's sex, status as a smoker or non-smoker; and status as a diabetic or non-diabetic etc.

122. **Events:** Events transform the values of states for actors. In essence, simulation takes place through the execution of events. Examples of events in CDP 2.0 include when an actor is born, quits smoking, visits a primary care physician, experiences an AMI and dies. Each event consists of two functions: a time function to determine the timing of the next occurrence of the event; and an implementation function, which determines the consequences that result from an event occurring. For example, in CDP 2.0 an event could be the start of alcohol drinking. Actors who experience the start of alcohol drinking event would then be at higher risk of alcohol-related diseases and injuries. This higher risk is a consequence of experiencing a change in their state from non-drinker to drinker.

123. **Parameters:** Parameters are the rules governing each individual's likelihood of experiencing events. For example, whether an individual starts smoking and when. Because CDP 2.0 is a model driven by data and scientific evidence, the rules within CDP 2.0 are estimated from statistical analysis of data, such as the analysis of data using econometric or statistical techniques to estimate relative risks and hazards.

Why are the simulated lifetimes of individuals realistic?

124. CDP 2.0 is a stochastic or Monte Carlo microsimulation model. What this means is that it incorporates a certain randomness that is part of normal life. In life, not everyone who is a lifetime heavy smoker, for example, develops lung cancer. The same is the case in CDP 2.0. Applying the rules within the simulation, heavy smokers will certainly be at higher risk of developing a smoking related disease. Each year on the person's birthday, the simulation will apply the rules which, in this case, is a hazard representing the time until the person develops lung cancer. At the same time, a random number is generated between zero and 1. If the random number exceeds the hazard the individual will not develop lung cancer. The same process occurs for all of the other events that are included in the simulation (such as all other diseases and injuries). The events compete to be the first to occur in the individual's life. Once an event occurs, the individual's life has changed and new rules will apply and the whole process begins again to estimate the next event in their life.

125. Thus through the simulation, there is not one definitive answer in terms of the estimation of events for people, but a sample of potential answers. The best estimates converge toward true estimates for our populations as the number of simulated individuals increases. Thus, the error inherent in the Monte Carlo method gets smaller when the size of the simulated population becomes very large (approximating the size of the true population).

126. For CDP 2.0, the best confirmation that the simulated lifetimes are representative of the real underlying populations we wish to represent is through simulating an observed period. For example, starting the simulation ten years before the current date, so that we may compare results for the simulated population to the observed population (surveys, registries, administrative data, and clinical records). It is through these comparisons that we can detect and correct for error in the overall modelling framework.

127. However, there are many forms of error. Importantly, the rules we have input into the simulation come from analysis of currently available data. No dataset, however, contains all of the variables necessary to reduce the error in the estimated statistical equations to zero. There are always unmeasured and unknown influences on outcomes studied. Further, and importantly, the data we have to work with may come from only certain countries or even only certain regions or areas within a few countries. The representativeness of the data is then also a source of error for international applications. There will also be rules that we understand must exist, but where there are no data to estimate them. For example, we assume there will be a risk associated with patterns of alcohol drinking over a lifetime, but there are no longitudinal surveys in the world that follow people from birth until death. Lastly, there may be important rules that we are simply unaware of and, as a result, fail to include within the simulation. For example, a health risk that has not yet been quantified.

How do we measure and report error?

128. Given available data on casual processes related to human health are typically partial, often of low quality, come from different populations and studies with differing methodology, and are based on practices that evolve over time, we will be coping with error in the rules, or parameters, that we initially include in the simulation model. We can and should incorporate the uncertainty of input data in our models, and evaluate the effect of that uncertainty on model results.

129. For each rule (parameter) we identify a 'prior' distribution within which we expect reasonable values to fall. Typically these parameters are the results of statistical or econometric analysis of observed data. Sometimes we know a parameter exists, but have limited information about what the parameter values might be. In that case, we can choose a uniform distribution with lower and upper limits based on what can be gleaned from the literature, e.g. the minimum and maximum values reported in the literature, perhaps enlarged a bit to account for uncertainty in the underlying studies. If there is one single study with a point estimate, then we could pick ± 2 sigma from that point estimate. If there is no literature or data for the parameter, than it may have mathematical limits, e.g. it must lie within [0,1]. In that case, that interval becomes the prior distribution.

130. We then identify empirical aggregate data that can be used to constrain estimation (fit criteria). This may include multiple and discordant data, at differing levels of reliability and aggregation. For example, population prevalence from a large health measures survey, correlation of a risk factor with a condition from a clinical trial, etc. For each such empirical aggregate data points, we then specify an acceptance threshold that acknowledges the uncertainty of the value of that point data.

131. We may then search for values for the rules (parameters) within the model that lie within $\pm 10\%$ of each empirical aggregate data point. For data points based on a small population, we may relax the fit criterion to $\pm 20\%$. If we feel (for example), that the empirical data may be of limited applicability, e.g. it comes from a different country than our target country, then we may wish to widen the threshold for fit, to acknowledge that we expect the value for the target country to differ from the 'data' country.

132. Thus we search for the best values for parameters that help us to match important empirical data points. For example, the best smoking risks that produce simulated smoking-related disease prevalences that most closely agree observed data on the prevalence of smoking from a survey. Of course, our model has many more risk factors and diseases, thus we are searching for values that satisfy a range of conditions simultaneously.

133. There will be many possible solutions that closely agree with observed data. There is no basis for selecting one solution over another. All good fitting solutions represent the range of values for the parameter that are plausible, and thus reflect the variability of the parameter estimates.

134. We may think of all of the possible parameter values as part of a cube. Each point on the cube represents a vector of parameter values that satisfies our fit criteria. The cube is very, very big. As a result, we draw a representative sample from the cube. The method we use to draw this sample is called "Latin Hypercube sampling".

135. We run simulations, for example, trying out 500 samples of parameter sets and then we review the simulated model outputs and compare them with the observed data and discard the samples that are outside of the tolerances we have specified for being a good fit with the observed data. We retain only the samples that meet the good fit test.

136. From the good-fit samples, we then calculate statistics, for example mortality rates, life expectancy, number of treatments, average cost of treatments. For all of the outputs, we can construct a confidence interval representing the distribution of possible values of the statistic, determined from

the range of values produced from all of the retained samples. These confidence intervals represent the range of values for the output that are all equally likely, or put another way, the error around the point estimates.

137. The data cube of the best fitting samples becomes the universe of parameter values for all further simulations. Thus in the background of CDP 2.0, all of the good fit samples are run and the model produces values for model outputs that offer both the point estimates and the confidence interval around each of the point estimates. The CI represents the range of potential values generated by the samples. For "what-if" scenarios or interventions, we can then perform a base simulation and a variant simulation, each using all of the retained samples.

138. The benefit of this explicit methodology for assessing error is that model users can evaluate, for each policy intervention tested, whether or not the difference in model results would be worth the investment in the implementation of the policy; by not just seeing how the point estimates change following the intervention, but also comparing the confidence intervals.

Accessibility and user friendliness

139. While there is no doubt that CDP 2.0 embodies complex mathematical processes to realistically represent current and future populations, this "under the hood" machinery is not part of the model user experience. The goal of CDP 2.0 is to be accessible and useable for policy analysts and statisticians comfortable with data query tools. To reach this goal, we benefit from the features of Modgen, which enable a typical, Microsoft windows environment for setting up and running policy scenarios. It is very straightforward to view baseline model results and then to compare those results with new results generated by the user who is testing policy scenarios. Modgen enables visualising results using graphs and tables of results and we have programmed the most likely tables and graphs to be of interest. As a result, users can select the graphs and tables they would like to best visualise and compare results.

140. To enable testing of policy changes, CDP 2.0 makes the model rules (parameters) visible and presents them in a table format. Users may then modify parameter values based on data or assumptions about the impact of one or more policies. We will work through a few examples of testing policy scenarios in the chapters that follow.

141. Of course, CDP 2.0 is only as good as our planning today and tomorrow we will most likely have new policy questions to explore that we haven't envisaged. As a result, the aim of CDP 2.0 is to have both model source code as well as the software freely available to users. Those interested in learning the Modgen programming language can make changes to the model, enabling the baseline CDP 2.0 model we provided to become their own CDP 2.1. Alternatively, the OECD can work with countries to continue to develop CDP 2.0 into the future, so that it continues to meet evolving policy needs.

CHAPTER 4: DEMOGRAPHIC COMPONENTS

142. The backbone of CDP 2.0 is the demography of each country included in the model. In order to develop realistic and representative populations for country's today, the model needs to understand and incorporate past population dynamics. Thus far, the demographic core has been developed and tested for three countries (Canada, Finland and Australia).

143. The data to build the demographic core for CDP 2.0 has come from two principle sources. The first is the Human Mortality Database (Human Mortality Database, 2012). The human mortality database is a very impressive demographic resource for cross-country comparisons established by University of California Department of Demography in the United States and the Max Plank Institute for Demographic Research in Germany. It contains original calculations of death rates and life tables for national populations (countries or areas), as well as the input data used in constructing those tables. The input data consist of death counts from vital statistics, plus census counts, birth counts, and population estimates from various sources. This database is most appropriate for models involving OECD countries.

144. The second major source of data for the demographic component is population projections. While the United Nations provides such projections on an internationally comparative methodological basis, the microsimulation projections for CDP 2.0 require detailed data about the components of the projection which tend to remain unreported. As a result, the strongest data source of internationally comparable population projections is the US Census Bureau (United States Census Bureau, 2012). At present, it is the projections of the US Census Bureau that are incorporated within CDP 2.0. The U.S. Census Bureau's International Data Base (IDB) provides public access to detailed demographic projections for virtually all countries.

145. To build the demographic core, a country-independent script extracts the required HMD data for a specific country, and prepares it for input into CDP 2.0. CDP processes and transforms this HMD data into internal demographic parameters before starting the simulation of synthetic individuals.

146. CDP 2.0 is designed to represent current populations and to project them into the future according to established population projections from other sources. In so doing, any policy analysis with CDP 2.0 offers the possibility to compare results for either population cross sections, such as comparing results for the population in 2010 with those of the population in 2020; or for population cohorts, such as comparing outcomes for the cohort of boys born in 2010 with the cohort of boys born in 2020.

147. To create simulated populations that closely resemble the actual population there are several key inputs: historical and projected births by year; historical and projected mortality by year and by single year of age and historical and projected net migration. The output of the simulation is millions of synthetic lifetimes which reproduce the demographic past, present and future of a given country.

148. The demography is specific to each country included within CDP 2.0. The model simulates complete lifetimes of those born in the interval 1881-2051, and simulates complete and representative age-sex cross-sections of the population in the interval 1991-2051. Immigration is simulated explicitly during the interval 1991-2007, and implicitly in the interval 1881-1990.

149. The period from 1991 to 2010 represents an estimation period, during which we can compare the simulation results to empirical estimates from population census or population registries. To create the new demographic core of CDP 2.0 for Canada, agreement with historical data by year from 1991-2007 and by single year of age and sex was within 2% for all cells aged 80 or lower. For the majority of cells, agreement was within 1%. This is a high level of agreement, given some cells

have low population counts. The total population agreed within 0.1% for all years in the estimation period. Population by 5-year age groups (top group is 80+) agreed to within 0.5% except for the older age groups, where agreement was within 1.5%. Differences from the empirical data result from Monte Carlo variation as well as approximations and simplifications necessary for the demographic implementation.

150. Figure 2 shows a few hundred simulated lives from CDP 2.0 for Canada. In this illustration, each life has been sorted by birth year. By simulating births back to 1881, we enable the simulated population to have all of the characteristics of the underlying Canadian population beginning in 1991 that is containing the correct distribution of people of all ages. The dark green bar identifies what we refer to as the estimation period, which is 1991 to 2010. During the estimation period, we will be comparing simulated results for all dimensions of CDP 2.0 to estimates from observed sources, such as surveys, registries, clinical trials, administrative records and any other suitable source for validation of model results. As we move forward from 2010, simulation results begin to involve projections. These projections are able to estimate complete populations from 2010 through to 2051. After that, cross-sectional comparisons of results are not possible. However, it remains important to project a complete lifetime for all people born during the projection period to enable cohort-based analysis. Thus for anyone born in the simulation at any time up to 2051, they will live out a complete life in the simulation. In this sample of simulated lives, there are a number of persons born near 2051 who are still living after 2131.

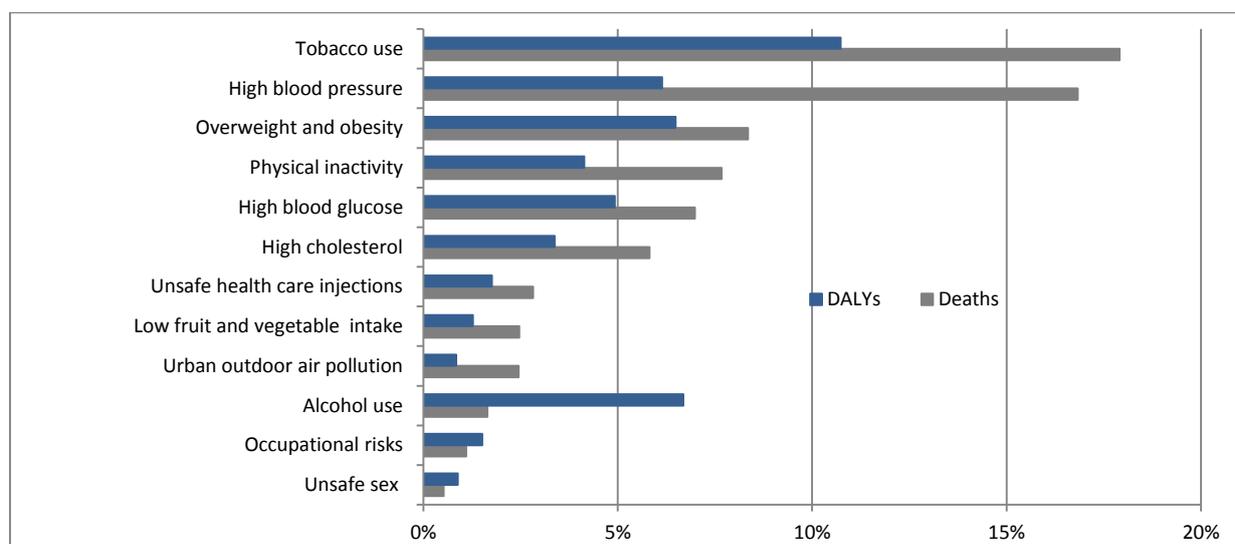
Figure 2. CDP 2.0 demographic core for Canada – Sample of 1000 simulated lives



CHAPTER 5: RISK FACTORS

151. Estimates by the WHO on the leading global health risks (WHO, 2008) identify twelve factors as responsible for the highest burden of deaths and years lived with disabilities (DALYs). The ranking of these risk factors is shown in figure 3, in terms of the share of mortality and disability adjusted life years attributable to each risk factor. The original CDP 1.0 model included a comprehensive set of these risk factors: low fruit and vegetable intake, physical inactivity, high fat intake, overweight and obesity, high blood pressure, high blood glucose and high cholesterol.

Figure 3. Population attributable fractions (%) and mortality (million deaths) for leading risk factors in high-income countries



Source: WHO, 2008.

152. The recommendation for including a risk factor within CDP 2.0 considers its importance, both in terms of mortality and morbidity, but also the strength of scientific evidence of a link between the risk factor and leading diseases responsible for the greatest health burden. A final consideration is parsimony. Each additional risk factor and disease included in the model remarkably increases the complexity of the model but does not necessarily enhance the strength of the evidence produced, particularly when there are only weak indications about how risk factors and diseases interact with one another.

153. Based on these prerequisites, tobacco consumption and harmful use of alcohol would be important additions to the set of risk factors already present in CDP 1.0. They both account for a nontrivial share of total mortality, with tobacco topping the ranking and alcohol within the first ten positions. In addition, alcohol is responsible for a large share of the burden of disease that is not fully reflected by mortality alone. WHO calculations for the European region (WHO, 2008) rank alcohol in the second position, just behind tobacco in terms of impact on disability-adjusted life years (figure 3). Also the link between these two risk factors and diseases with a high burden is well established.

154. A third risk factor that may be considered for CDP 2.0 is salt intake. Although not explicitly considered in the list of risk factors set up by WHO, salt intake is a major determinant of high blood pressure and, through this, of stroke and ischemic heart diseases (WHO, 2010).

How are risk factors incorporated into the model?

155. There are many excellent examples of dynamic microsimulation models that estimate and project the burden of risk factors within populations and there are several models that have examined the presentation of sets of risk factors that may impact upon health outcomes. Notably, the Future Elderly Model developed by the U.S. RAND Corporation and the UK model of the National Heart Forum (see annex 2), project the future prevalence of two risk factors, obesity and smoking, on a selection of major chronic diseases. The Statistics Canada Population Health Model (POHEM) model of first acute myocardial infarctions (AMI) from 2001 to 2021 evaluated the impact of cardiac risk factors on AMI through counterfactual analysis. In this model the Framingham risk equation was calibrated to Canadian AMI incidence, obtained from hospital discharge databases. Increasing obesity and decreasing smoking trends were estimated from longitudinal survey data (National Population Health Survey). Cholesterol, diabetes, and hypertension prevalence were estimated from cross-sectional population health survey data (Canadian Community Health Survey). In these models, policy scenarios test the impact of potential interventions to lower risk factor prevalence, including policies and practices to improve adherence to clinical care guidelines.

156. With very few exceptions, individuals' engagement in risky health behaviours varies over time. As a result, most risk factors can only be realistically represented within the simulation framework as dynamic or evolving states; that is they are time (or age) dependent. For example, there will be a point where the behaviour first occurs, an evolving pattern of behaviour which may or may not include periods of abstinence; and, in some cases a cessation of the behaviour. Further, these patterns will be conditional on other characteristics, such as gender, education and labour-force status.

157. Not only is the evolution of risk factors among simulated individuals over time realistic, it is also necessary so that distributions of risk factors by age agree with observed distributions from national population health surveys. In some cases, such as for Canada as we will be discussing in the next section, there is a national longitudinal survey that provides empirical evidence of the evolution of risk factor distributions by age and over an extended period of time. In many countries, however, such data is unavailable or is available only for non-representative samples, such as only certain age groups or sub-national geographies.

158. When national longitudinal data to examine the evolution of risk factors is absent, an initial set of transitions can be estimated from repeated national cross-sectional surveys. In this case pseudo cohorts may be formed. The distribution of risk factors in the population by age in each year that the cross-sectional survey was administered can be used to approximate the evolution of risk factor prevalence with age. For example, the change in smoking patterns between individuals aged 18-20 in a 1990 survey and individuals 5 years older in a 1995 survey (those aged 23-25). This method applies when the distributions change slowly over time, as the method ignores cohort effects. In this case, we know something about the states (that is the number of smokers for example in 1990 and 1995 by age and sex) and we are solving for the transition probabilities that enable the population to evolve.

159. With transition probabilities that vary by age and other key characteristics derived from either longitudinal data or pseudo cohorts; there is an initial set of parameter values to describe the conditional probability of moving from one state to the next over time. All of these parameter estimates will suffer, however, from error including statistical error as captured by the confidence interval of the estimate and other forms of error, such as misspecification of the model due to data or theoretical limitations. As a result, there are thresholds within which the best fitting transition probabilities lie.

160. As was mentioned in chapter 3, CDP 2.0 will employ a Bayesian estimation procedure to solve for the best fitting sets of risk factor transition parameters that will enable the simulated population to closely approximate the observed population during the estimation period. Using the best fitting parameter sets, the simulation model will proceed to estimate state transitions for all individuals in the simulation throughout their life course.

161. In other words, as individuals age they move realistically forward in their risky behaviour patterns in a manner that conforms with existing empirically observed trends and this movement is represented with both average values and error bands around those values.

162. Thus, it is possible to examine the future distribution of risky behaviours among population cross sections or for particular cohorts and to observe the changes in these behaviours that result from the implementation of new policy interventions (see chapter 5).

163. For CDP 2.0, early development work has focussed on the addition of alcohol use as a risk factor. As previously indicated, the subject of policies to address alcohol-related harms was chosen opportunistically for the development of a “proof-of-concept” model aimed at demonstrating how the new approach on which CDP 2.0 is to be based can be applied to a real set of health policy issues. The CDP 2.0 alcohol module is therefore being developed, initially set in the Canadian policy context and based on Canadian input data and to be completed in early 2013 for a set of three countries. Thus, in this chapter, a description of the work undertaken to include alcohol within CDP 2.0 is presented and acts as an illustration of the steps required to include each of the risk factors of interest.

Alcohol use component

164. The ultimate output of the alcohol consumption module is the number of drinks of alcohol in each day in the life of each simulated individual, from birth to death. This level of detail allows the construction of cross-sectional or longitudinal tables which are conceptually equivalent to empirical tables from statistical surveys, where definitions and classifications can change over time. Daily alcohol use also enables the construction of variables which are conceptually identical to explanatory variables used in studies from the literature. That in turn allows other components of the model to use the equations and parameters in those studies to simulate downstream effects, such as alcohol-related illnesses, injuries and mortality.

165. The alcohol component uses a series of causatively-linked events which take place in the life of each simulated individual. These events are driven by current characteristics of the individual and by estimated parameters which implement draws from statistical distributions. Every parameter in the alcohol component has a distinct value for men and for women. This reflects the observation that alcohol use, including patterns by year and age, vary significantly by sex.

166. Drinking event #1 is drinking initiation, which occurs when the person first consumes alcohol in his or her lifetime. By definition, this event can occur at most once in an individual’s life. For some individuals, this event never occurs, and the person is a lifetime abstainer. The proportion of lifetime abstainers follows an S-shaped curve which varies by birth cohort. The parameters of this curve are estimated for Canada from the analysis of the National Population Health Survey.

167. Drinking event #2 is a transition into or out of abstention. Abstention is defined as having consumed no alcohol in the previous 12 months. Thus, drinkers are at risk of transition to abstention at any time, whereas abstainers are at risk of transition to drinking only after 12 months of abstention. These transitions are implemented as estimated age-varying hazards.

168. Drinking event #3 is a change in long-term drinking frequency. It applies to current drinkers. Drinking frequency is a 7-category variable with levels such as ‘once a week’, ‘once a month’, etc. A series of conditional probability distributions is used to move from drinking frequency to the amount drunk on any given day. This pattern is then implemented mechanically using a repeating drinking schedule. For example, drinkers with drinking frequency ‘once a week’ will be assigned a given # of drinks on their drinking day of the week from an empirical distribution, and this pattern will be repeated weekly for the individual as time advances for the individual.

169. Drinking event #4 is a mechanical event which implements the repeating drinking schedule described above. It advances time for the individual from one drinking day to the next drinking day, and assigns the amount drunk on the drinking day.

170. For Canada, the parameters of the alcohol use component are estimated using data from the cross-sectional CCHS survey, and from the longitudinal NPHS survey. Estimation is performed using a Latin hypercube search procedure which finds sets of parameter values which, when simulated in the model, align with empirical tables compiled from the surveys. The alcohol use component includes tables which match conceptually to the CCHS and NPHS surveys, including the year in which a given survey was applied. To help the search procedure identify certain parameters, CCHS and NPHS surveys have been pooled across years to increase sample size.

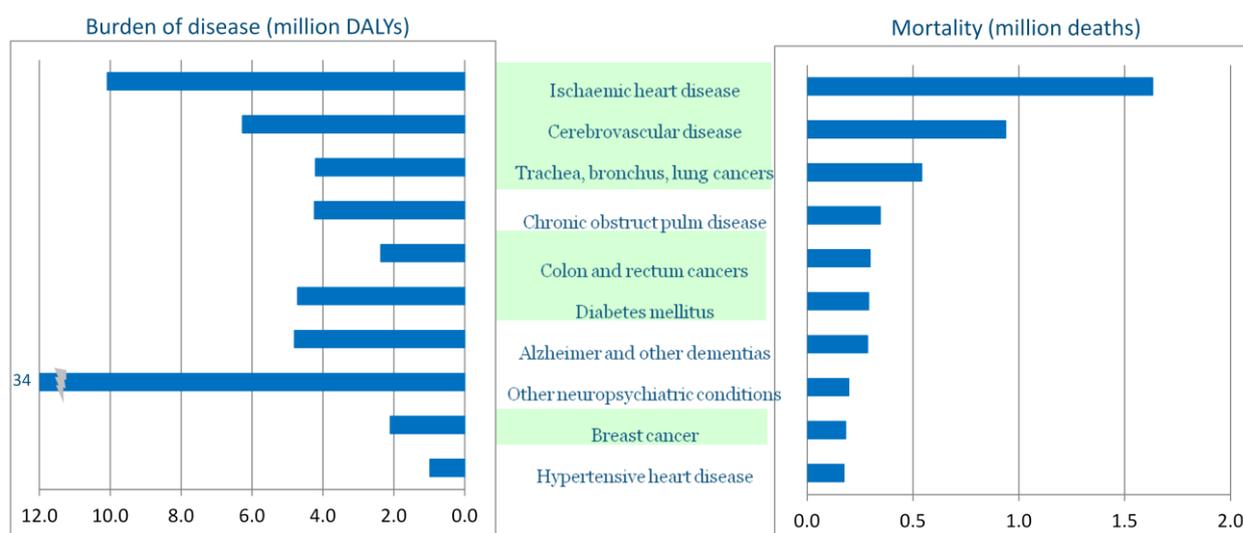
171. Interventions are simulated by applying statistical rules to modify the base pattern of alcohol use of each individual. These statistical rules summarize the expected effect of the intervention. For example, an intervention might decrease the amount drunk by 10%, uniformly across the population. For such an intervention, the number of drinks per drinking day for each individual would be probabilistically reduced so that expected annual drinks for the person is 10% lower than in the base pattern.

CHAPTER 6: DISEASES, INJURIES AND MORTALITY

172. As was the case for the identification of risk factors, a parsimonious choice of diseases for inclusion within CDP 2.0 is essential to the development of a useful and tractable model. In the existing literature, there are many examples of dynamic microsimulation models that examine individual diseases. Much less common are comprehensive models that enable the assessment of interventions to mitigate population health risks on a set of potential disease outcomes. Such models are powerful tools for the consideration of the potential benefits of policy interventions to reduce health risks, as most major health risks have downstream consequences across many different diseases, such as the well established relationship between smoking and obesity and sets of cancers and CVD outcomes. Again, leading examples include the U.S. RAND Future Elderly Model (FEM) and the U.K. National Heart Forum Model (NHF). Both models have identified sets of diseases responsible for a heavy health burden on the population and where there are established relationships to risk factors included in the model (smoking and obesity). (See annex 2).

173. CDP 1.0 also included a selection of diseases associated with a heavy health burden. These were ischemic heart diseases, cerebrovascular diseases and a set of cancers, namely: trachea/bronchus/lung cancer, colorectal cancer and breast cancer (women only). The CDP model also included diabetes; however it was modelled as risk factor rather than as a disease due to the elevated risk it presents to other diseases within the model (ischemic heart disease and cerebrovascular diseases). Figure 4 reports the top ten chronic diseases in terms of million deaths for the OECD area (with the red bar representing mortality in enhanced engagement and accession countries). The top three killers and, in total, six out of ten diseases are currently included in the CDP model (Figure 4 – green shaded items).

Figure 4. Estimated total deaths (million) by cause in OECD countries



Source: WHO

174. Nevertheless, the CDP model has a number of areas for further development. The recommendation of including other risk factors within CDP 2.0 has been based on the importance, both in terms of mortality and morbidity, of the factors as well as the strength of the link between the risk factors and diseases (See chapter 5). Given the selection of risk factors for CDP 2.0 as previously discussed, there are two important improvements for CDP 2.0.

175. As shown in figure 4, the CDP model currently considers cancers as a single disease; this means that all the epidemiological as well as the economic parameters are calculated at the aggregated level. CDP 2.0 will consider the three leading cancers individually (trachea, bronchus, lung; breast; and colorectal cancers). This step will greatly enhance the accuracy of the estimates, particularly the assessment of the impact of policies to improve the prevalence of specific risk factors and is essential to the examination of alternative healthcare pathways. The second potential improvement is to add chronic renal failure as consequence of diabetes (but a link with hypertension would be beneficial as well).

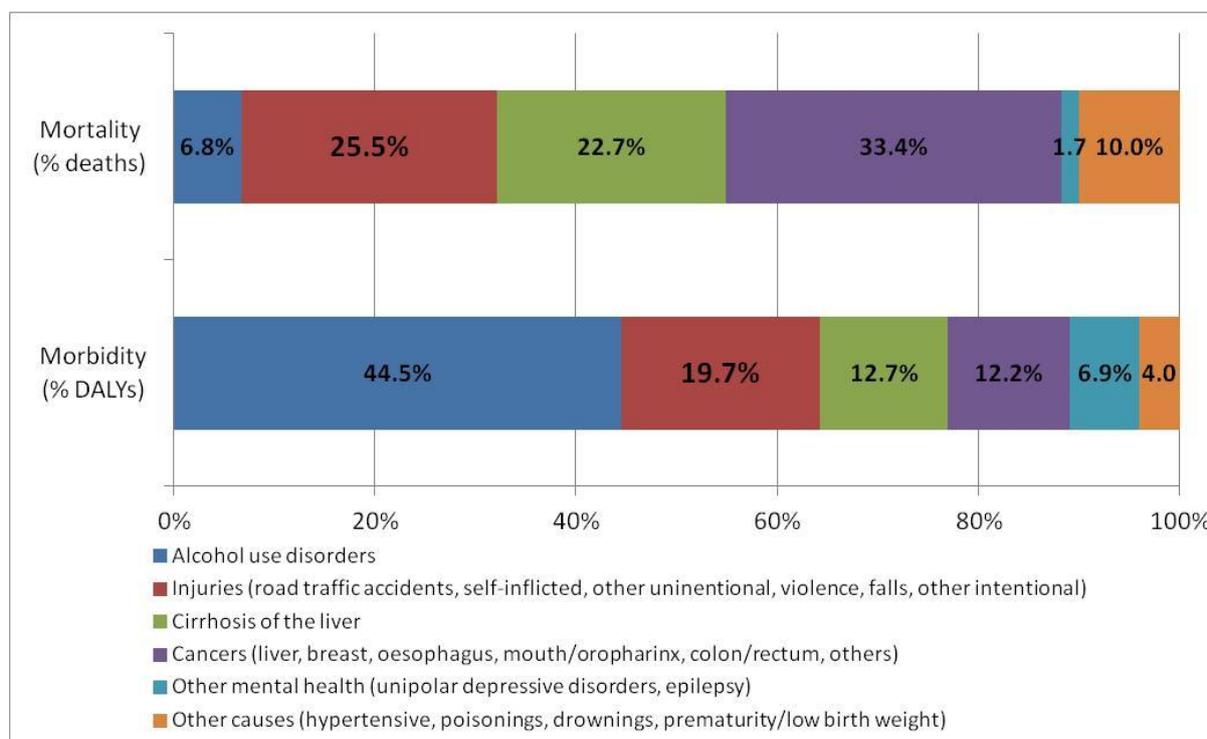
176. Diabetic nephropathy is one of the most common consequences of diabetes with a significant impact on the healthcare budget. The CDP model already includes the economic costs of diabetic nephropathy together with other common diabetic complications (e.g. retinopathy). However, an explicit inclusion of this disease would allow an evaluation of interventions in terms of quality of life.

177. Specific applications of CDP 2.0 however will point to the necessity to move beyond the leading diseases to consider diseases with close relationships to individual risk factors. This is evidenced in the first application of CDP 2.0 for the evaluation of policies to control harmful alcohol use.

Diseases essential to the evaluation of policies to control harmful alcohol use

178. Alcohol is related, directly as a cause or indirectly as a component, to more than 200 ICD-10 codes (Rothman et al., 2008), being a causal factor in about 60 types of diseases and injuries including, for instance, cancers, cardiovascular diseases and liver cirrhosis. Alcohol-use disorders (e.g. acute alcohol intoxication, alcohol dependence syndrome) account for a significant share of total morbidity due to alcohol, particularly for men (44.5%) (WHO, 2008).

Figure 5. Distribution of alcohol mortality and morbidity by category of disease or injury in 2004



Source: WHO, 2008

179. Compared to other risk factors, such as tobacco or hypertension, the net negative effects of alcohol on health start at younger ages, both for men and women. Globally, 3.8% of deaths are attributable to alcohol consumption in all age groups, and 5.3% in people younger than 60, particularly due to injuries. Likewise, most morbidity attributable to alcohol occurs in people aged 15-29 (33.6%), followed by those aged 30-44 (31.3%) (Rehm et al, 2009).

Table 2. Leading diseases associated with alcohol use

	% DALYs	% Mortality
Alcohol use disorders	34.2	3.9
Injuries	38.0	41.6
Cirrhosis of the liver	9.6	16.6
Liver cancer	3.2	8.2
Epilepsy	3.1	2.1
Ischaemic heart disease	2.6	3.8
Cerebrovascular disease	2.3	4.9
Oesophagus cancer	2.3	7.0
Mouth / oropharynx cancers	1.4	3.4
Breast cancer	0.8	1.7
Total	97.5	93.2

Source: WHO, 2008

180. The development of the alcohol use module of CDP 2.0 changes the prioritisation of the first set of diseases to be incorporated within the model. As is evident from table 2, alcohol use disorders (including harmful use, dependence and alcohol psychosis), injuries, and cirrhosis of the liver are important to the evaluation of alcohol use control policies. Further, the selection of cancers to be modelled differs from those with the highest overall burden and the neurological conditions of interest have narrowed.

181. As development of the CDP 2.0 modules for alcohol-related diseases and injuries remain under development, an evaluation of the feasibility of the inclusion of the complete set of diseases presented in table two is pending a determination of the availability of data and the strength of the epidemiological evidence.

How are diseases incorporated into the model?

182. Within the simulation model, the onset of disease or the occurrence of an injury represents an event that marks a transition from a state free of the disease to a state that includes the disease. The probability of an event should be conditional upon the individual's characteristics and presence of risk factors for the development of the particular condition.

183. Before discussing the CDP 2.0 further, it is useful to examine the incorporation of diseases within an established dynamic microsimulation model, the Statistics Canada POHEM. As previously discussed in this chapter, the POHEM model provides an example of a model that is inclusive of a set of established risk factors related to the occurrence of a first AMI event (Acute Myocardial Infarction or heart attack). Within POHEM, it is the Framingham risk function, obtained from literature, that relates risk factors to incidence (Wilson, 1998). The equation, as implemented within POHEM, is represented below.

184. The beta coefficients in the equation are those estimated by Wilson et al using a Cox proportional hazard model (a survival function) applied to longitudinal data of a sample of the population in the community of Framingham Massachusetts in the United States.

185. The alpha coefficient represents the baseline probability of developing an incident case of AMI in the Canadian population. The alpha varies by age, sex and province of Canada. The alpha values are calibrated to reproduce observed incidence rates from administrative records during the estimation period. Importantly, this calibration takes into account the distribution of risk factors in the population. In so doing, the calibration ensures that the alpha represents the baseline risk of AMI in the population in the absence of the risk factors of interest. This calibration is necessary in order to ensure that there is no artificial elevation of cases of AMI.

186. For every individual within the simulation, and for every year of their life, the baseline risk of an AMI (the alpha) and the risk factor coefficients (the betas) are determined based on each individual's age, sex, and province and risk factors (such as whether or not they smoke, whether or not they are diabetic, the level of their cholesterol, the level of their blood pressure etc.). The alpha and the betas represent model parameters that are stored in look-up tables. The probability of developing an AMI (F) is calculated for each individual and is then, through simple mathematical transformation, converted to a hazard and transformed to a waiting time. As discussed in chapter two, not all individuals at high risk of an AMI will develop an AMI. The waiting time is compared to a random number, and if the random number exceeds the waiting time, the AMI event will not occur that year.

187. As presented for POHEM, for each disease that is included within CDP 2.0 a risk function must be selected from the literature or estimated from empirical data. The selection of a risk function is a very important step in model development, because it governs the final selection of risk factors to be included within the model; as well as the quantification of those risk factors. For example, if a risk function requires five categories of smoker, it will not be sufficient to have included smoking as a simple yes/no value within the simulation. An upcoming step in the development of CDP 2.0 is the identification of the appropriate risk function for each of the diseases of interest, whether it is to be found in the literature or estimated from original analysis of data.

188. Of note, the estimation of baseline risk (the alpha), must be calibrated to estimate a baseline risk that is inclusive of all of the risk factors of interest and that enables the simulated estimates of risk factor prevalence to align with published estimates. The most appropriate iterative technique for this joint estimation problem is under study.

How do diseases progress in the simulation?

189. The topic of disease progression will emerge again in the next chapter which will explore the simulation of treatment pathways. For now, individuals in the simulation who develop an incident case of a disease become eligible for events related to the progression of their illness. They may be treated or go untreated, their disease may be cured, their disease may progress in severity or lead to the onset of additional diseases, and the disease may cause death. Each of these potential events must be governed by parameters that reflect the hazard of the event occurring conditional on the individual's characteristics and current state.

CHAPTER 7: HEALTH SYSTEM PATHWAYS

190. In the first phase of the Economics of Prevention project, our principal aim was to investigate the effectiveness, the cost-effectiveness and the distributional impact of primary prevention interventions, for which the functioning of health systems is less important. As a result, in CDP 1.0, after the development of a disease, the virtual individual/patient goes through a standard treatment procedure which is characterized by country-specific average effectiveness and average cost. Indeed, very few dynamic microsimulation models go beyond this point.

191. At present, the most sophisticated population health microsimulation models, in terms of shedding light on health care policies, have been those developed to evaluate cancer control options. Examples include the use of population-based microsimulation models to support evaluation of the comparative effectiveness of technologies used to diagnose and treat cancers, including comparing imaging methods, comparing pharmaceuticals, and comparing pharmaceuticals to surgical interventions and also using this evidence to support clinical care guidelines evaluation and to set public re-imburement levels for health services (Rutter, 2011; Miksad, 2011; Zucchelli, 2010). For example, US microsimulation models indicated that computed tomographic colonography (CTC) screening produced only slightly less life years gained than did colonoscopy screening at a substantially lower cost, and with higher potential population participation. These results were a significant factor in the decision of the US Medicare program to reimburse CTC screening (Rutter, 2011).

192. Statistics Canada's POHEM cancer modules include detailed diagnostic and treatment pathways for patients at various stages of disease progression. In POHEM, treatment pathways are cost from the bottom-up, including all aspects of care received. This enables both a projection of disease incidence, prevalence and severity and a projection of diagnostic tests and treatments consumed, the costs associated with each treatment type and the overall expenditure on diagnosis and treatment. This detail is essential to the development of cancer control policies in Canada (Evans et al., 2012). The model has been used to evaluate the impact on health and on public acute care and home care expenditures of an out-patient/early discharge strategy for breast cancer surgery patients (Will, 2001); to assess the potential health and public health-care expenditure impacts of adopting different approaches to colo-rectal cancer screening (Evans WK, 2000); and to evaluate the health benefits and additional treatment costs of introducing new, and more expensive, cancer drugs into Canadian treatment regimes (Goffin, 2011).

193. CDP 2.0 aims to build forward from the experience of cancer model development to include health system pathways for all of the key diseases included within the platform. Indeed, it is only through this development work that policy makers will be able to address the key questions raised in chapter 1. In essence, for CDP 2.0 to support evaluating the comparative effectiveness of both upstream (prevention) and downstream (treatment) policies and practices; the downstream dimensions of health care must be directly modelled.

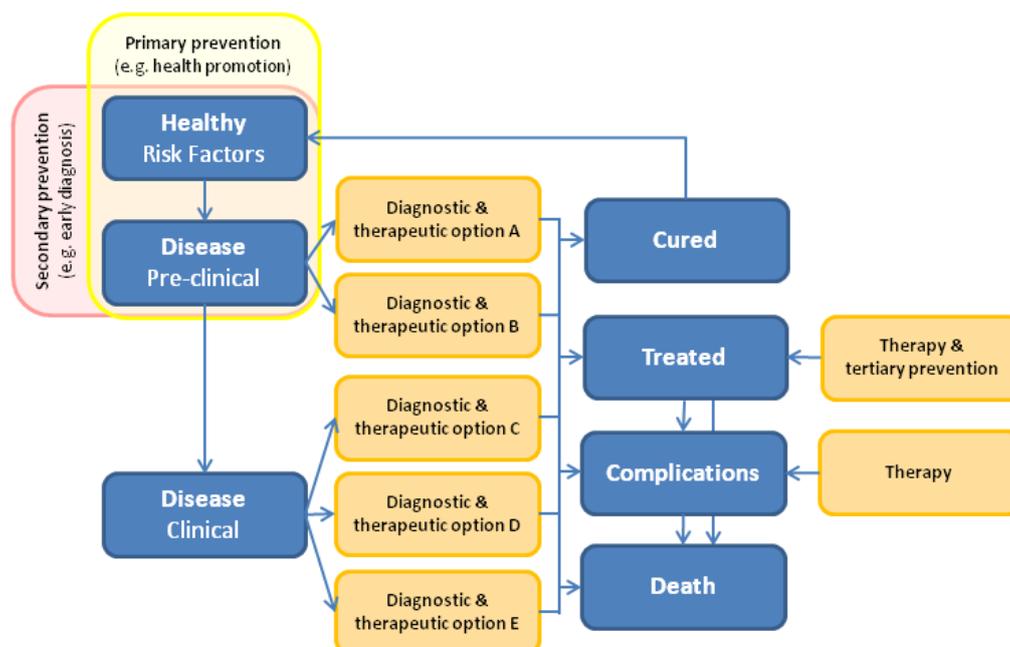
194. There are two important dimensions of modelling of health care pathways that will be explored in detail in this chapter. The first is the conceptual design of the pathways, including the elements that are essential and those that are desirable. The second is the development of the data necessary to estimate the pathways and considerations that data limitations bring to constraining the conceptual model to render it practicable.

Conceptual design of health-care pathways

195. The overall principle followed in designing the health system module is illustrated in figure 6. Interactions between an individual and the health system happen in different forms and at different levels according to the clinical state of the individual. Primary prevention as health promotion and

environmental changes reduces the share of the population with unhealthy behaviours, therefore decreasing the number of people that, at any given interval, develop a disease. Secondary prevention, as screening programmes, increases the number of cases diagnosed at an earlier stage while a number of diagnostic and therapeutic options emerge once the individual is diagnosed with a specific disease.

Figure 6. Framework diagram of the health system module (preventing, diagnosing and treating NCDs)



196. As for the epidemiologic input data, also for the health system component it is essential that the design and the starting data carefully portraits reality. This is a key issue both concerning the clinical pathways, their internal structure and their likelihood of being used, and in terms of the total health budget that a country devotes to tackling a disease. Our aim is to reproduce, for any disease included in the analysis, a limited number of healthcare pathways characterized by the following diagnostic and therapeutic options: inpatient care, outpatient care, office-based care, prescription medication, access to emergency room, institutionalised long-term care and home care.

197. The model should allow for a representation of the distribution of typical treatment pathways observed for different patient groups. Key groups would certainly include age and sex groups, but also socio-economic position (education). The complexity of the patient is a further consideration that will have a strong influence on the recommended treatment approach. Those with multiple morbidities face additional challenges from a risk of inappropriate treatment combinations and frailty that will change best care recommended practice and reduce positive health outcomes of care.

198. Strengths of this approach include enabling a wide set of comparisons to identify the most promising combinations of prevention, diagnosis and treatment approaches for different types of patients; going beyond the follow-up periods of typical clinical trials so that long-term outcomes can be compared; going beyond specially selected or ideal patient populations so that outcomes for typical patients can be assessed; going beyond narrow definitions of study outcomes to outcomes in real-world settings where patients are complex and remain at risk of developing a wide range of disease conditions; and allowing the testing of the potential impacts of policies and practices, through “what if” scenarios before incurring the costs of implementation.

199. Each arrow depicted in figure 6; however, represents an event that requires conditional transition probabilities to be estimated or to be determined from existing literature. The complexity of

the task grows with the addition of detail regarding treatment options and with the addition of multiple diseases within the model.

Exploratory analysis of patient pathways using survey data

200. In order to deepen our understanding of the complexity of patient pathways, a preliminary analysis of data from the United States Medical Expenditure Panel Survey (AHRQ, 2011) was undertaken to explore healthcare services and their related costs for patients with different chronic conditions. MEPS is an annual ongoing survey that collects data on healthcare utilization, health costs/expenditure, insurance coverage and source of payment for the US civilian non-institutionalized population. MEPS reports, for each individual/record, data on demography, educational level, employment status, access to healthcare and health status. Each panel and year is representative of the US national population, if the opportune weights are applied. MEPS is designed so that data of two, partially overlapping, panels may be combined to allow estimations for a calendar year. Any person in a panel is interviewed a total of 5 times over a period of about 30 months.

201. Datasets from 1996 to 2008 have been pooled and records for each survey component: inpatient visits, outpatient visits, office-based visits, emergency-room access and pharmaceutical expenditures have been combined. Nominal expenditures and charges in the data are adjusted for inflation using 2005 as a base year and specific events (e.g. inpatient) have been adjusted with indices pertaining to these events (e.g. hospital care price index). A descriptive analysis includes the socio-demographic characteristics of the population sample and reveals the main areas of expenditure and the use of healthcare resources in the United States (See Annex 3). The main findings from the descriptive analysis are as follows:

202. Individuals tend to have multiple conditions at once. Patients with hypertension, high cholesterol and diabetes have a chance to report any other non-surgical diseases that varies between 30% (for diabetes) to almost 60% (for hypertension). Patients with surgical conditions are less likely to report any other surgical condition as co morbidity (range between 1% and 16%) but are likely to report at least one non-surgical co morbidity (range between 13% and 65%). Patients with cancers have a lower probability to report co morbidities than patients with IHD or stroke. These results suggest that handling co morbidities properly is a key issue in the next phases of the project.

203. There are a sizeable number of observations with zero costs and data tend to be right skewed. For conditions for which hospitalization is less likely (i.e. hypertension and high cholesterol), the majority of expenditures are incurred to the left of the 5000 USD mark, while for conditions for which hospitalization is more likely (i.e. the others but diabetes), the majority of observations cluster in the area around the 10000-20000 USD mark. Diabetes, given its peculiar nature and development seems to present a mixed pattern with a large number of observations to the left of the 5000 USD mark (supposedly for those in the initial, i.e. medical, phase of the treatment), followed by a peak in the class of expenditure of 10000-20000 USD, probably, for those at a more advanced stage.

204. Analyses by share of total expenditure for health service and by class of expenditure show a clear pattern. First, emergency room access constantly accounts for a tiny fraction of total expenditure, about 3%, which seems to be plausible as this analysis mainly considers chronic diseases. It is probably not by chance that this expenditure component is somewhat larger (about 4-5%) for IHD and stroke which often develop as acute diseases and, then, become chronic. Second, medical prescription and inpatient hospitalization are the two main drivers of total costs. Prescriptions account for much of the total expenditure of cases with lower total expenditure but this share shrinks quite sharply as total health expenditure increases. The opposite, on the other hand, is true for inpatient hospitalization that accounts for more than 50% of the average expenditure when total expenditure is higher than 20000 USD per year. Third, expenditure due to office-based visits is higher for lower classes of expenditure and follows a decreasing trend as total expenditure increases. Finally, expenditure for outpatient visits is, in general, small but accounts for a higher share of the total expenditure in the case of cancers.

205. It is difficult to identify clear patterns of use of healthcare services for the set of considered diseases. Nonetheless, the picture coming out from the descriptive analysis suggests that the use of healthcare services varies quite widely across the different diseases. Patients with hypertension, high cholesterol or diabetes are more likely to seek care through office-based visits and, in the case of diabetes, as outpatients. They are also likely to request a high number of prescriptions. Patients developing IHD or stroke have a higher likelihood of being admitted to hospitals or seeking for emergency care but requires a lower number of prescriptions. Patients with cancers require a higher number of hospital admissions and visits both as office-based visits and outpatient visits.

206. Where care is particularly challenging and there is a theoretical basis for assuming that the coordination of care could be improved is among patients with multiple morbidities. Such individuals have a greater likelihood of seeing a number of different health care providers in a number of different health care settings. To begin to understand pathways for individuals whose care is more complex, it is likely that survey data will be insufficiently detailed.

Exploring the empirical estimation of patient pathways from health care data

207. There are promising developments in the field of health care quality and system performance measurement that shed new light on the health care pathways of individual patients and their health care cost implications. This section will focus on new work emerging independently within both the University of Toronto, Canada and the National Institute for Health and Welfare, Centre for Health and Social Economics in Finland. Both organisations have access to a wealth of individual level data covering a broad spectrum of the health care system and both have a long history of empirical analysis and research with their rich data stores. The underlying goal of both developments was to not only to improve measurement of patient pathways, but to also inform the system about potential areas where treatments could be improved to enhance efficiency and patient outcomes. Ultimately, analytical results provide an opportunity to identify problem areas and support policy development to provide better care at a lower cost. In both cases, clinical, health system and statistical expertise were essential to appropriately designing the research. In both cases, the research focuses on direct care and associated costs. Other costs incurred by the health system that are not attributed to care provision, such as research or administration, are excluded. Also excluded are indirect costs of illness, such as lost wages of individuals and their family caregivers.

208. The University of Toronto methodology begins by categorising patients with an index hospitalisation in a given year. An example would be patients hospitalised for cardiac arrhythmia, or patients hospitalised with two or more ambulatory care sensitive conditions. For each patient group, the individuals within the group are followed for a one or two-year period from their index hospitalisation to observe their use of physician services, medications, emergency room visits, acute hospital admissions, home care, long-term care and complex continuing care, as well as any deaths. This follow-up requires the linkage of data at the level of individual patients across data bases for the province of Ontario. The cost of the care paths followed is estimated for individual pathways based on data from administrative billing records and service-based fee schedules. The team has recently published a first analysis based on this methodology (Cohen et al, 2012). This project focuses on children with medically complex cases, such as multiple chronic conditions, neurological conditions or who require technology assistance. As very few children suffer from these conditions, very little was known about their care path. This is a strength of this approach, as it draws from complete data from the health care system, where all cases have been recorded.

209. The Finnish National Institute for Health and Welfare methodology was developed to measure health system performance using existing linkable data from registers with well-defined care episodes for the whole population (Petola et al, 2011). Numerous performance measures have been developed from this individual-level data with risk adjustment, to observe variation in performance at the level of the producers of health care.

210. The focus is on individuals and their entire treatment chain. As in the Canadian research, care episodes were first measured beginning with an acute hospitalisation and then including subsequent care provided by multiple organisations within a defined time period, typically one year. The first hospital admission is defined as beginning on the first index day and ending on the first discharge (or at death in hospital). For certain cases, a specified period of time of continuous in-patient care would constitute the index hospitalisation. The follow-up period ends one year after the index day and includes all health services used during the follow-up period or until death during the follow-up period.

211. Process indicators for in-patient hospitalisations estimated from this approach include the number of hospitalisations and the length of stay of each, in-hospital procedures and other treatments and the use of medicines in hospital. Finland lacks data to cost each individual element of a hospital stay. As a result, instead, hospital discharges are cost based on their diagnosis-related group (DRG). Where the DRG was too coarsely defined to reflect the hospitalisation, individual level cost-accounting data from a hospital was analysed. Out-patient visits, medication purchases, and data on social care services, including institutionalised and home-care are all included in the episode. Costing data are obtained from reimbursement databases.

212. The Finnish methodology includes outcome indicators for episodes of care that are measurable with existing data. Examples include re-hospitalisation and 7, 30, 90 day and one-year mortality following an AMI; share of patients staying in long-term care facilities; patients at home at 30, 120 and 365 days; total days spent at home; and 30, 120 and 365 day mortality following a hip fracture hospitalisation. Most outcomes are dichotomous (occur or not) and, as a result, probabilities are predicted using logistic regression estimation. Some models involve first examining the probability of being discharged alive followed then by, among those alive, the probability of purchasing a particular medicine or of an outpatient visit.

213. Special attention is given to the identification of co-morbid conditions, as the coding of secondary diagnosis for index hospitalisations is not considered reliable enough. As a result, for individuals within a cohort for an index hospitalisation, records are searched backward in time to identify their history of medications and any previous hospitalisations. In consultation with clinicians, specific ICD 9/10 codes were searched in previous hospital records and specific ATC codes for prescription medicines associated with chronic conditions were investigated.

214. With funding from the European Union, the Finnish methodology is now being replicated in a number of European countries with equivalent individual level data. The topic of country capacity to engage in this type of analysis is explored later in this chapter.

Modelling patient pathways

215. The Ministry of Health and Social Affairs of Sweden microsimulation model (SESIM-LEV) offers an excellent example of the development of health care utilisation pathways within a model developed to project health service usage and costs (Brouwers, 2012). For SESIM-LEV, an initial consumption of health care is estimated by age, sex and health status to be attributed to the simulated individuals at the beginning of the estimation period, which is 1999 in this case. The dynamics of health care use over time are also estimated. In addition to age, sex, health status and other background characteristics, key predictive power comes from the inclusion of individuals past patterns of health care consumption. In other words, health care consumption patterns are difficult to change once established and individuals' use of services in a previous year is one of the strongest determinants of their use of services in a current year. The key health care uses modelled in SESIM-LEV are primary care visits, out-patient visits, inpatient visits and medications.

216. The SESIM-LEV microsimulation approach enables exploration of the potential future health status of the population, the consumption of care, and the costs of that care and can examine how utilisation would change under different interventions to improve the health status of the

population. These questions are interesting and important and go beyond the capacities of CDP 1.0. However, if the objective of CDP 2.0 is to compare the effectiveness of different approaches to the treatment of key diseases, then the general approach of SISEM-LEV would need to be expanded to provide additional detail about the therapies used and the outcomes of the therapies. Thus, an extension to methods similar to those employed by Finland and Canada would be necessary to further describe the treatment pathway, as was discussed in the previous section.

217. In the remainder of this chapter, we will focus on a conceptual framework for modelling one disease for potential inclusion in CDP 2.0, this being chronic heart failure or CHF. CHF provides a very good example because it is a condition with multiple and complex treatment approaches in acute care, requirements for on-going monitoring by primary and specialist physicians, a high need for coordinated care and involves disabling conditions that may require assistance with daily living. Within CDP 2.0 a certain number of individuals will be diagnosed with chronic heart failure in any given year during the estimation period and during this time, the model will be calibrated to ensure that the number of new simulated cases aligns with the number of new cases observed in empirical data.

218. The theoretical framework for the treatment of a case of chronic heart failure should be consistent with guidance for best clinical care, while allowing for variation in actual treatments as measured with empirical analysis. The development of CDP 2.0 with clinical treatment detail should take place in consultation with clinical experts within the countries included in the model. It is only through clinical consultation that appropriate pathways are confirmed and that a parsimonious model can be developed, eliminating unnecessary detail in favour of detail of interest for the development of policy scenarios. For example, detail on precise medications prescribed may be essential, if policy scenarios regarding optimising best medical regimes for both cost and health care outcomes are a priority for assessment. Dialogue with a team of expert clinicians is an essential element of the development of Statistics Canada's POHEM (Evans, 2012).

219. In the United Kingdom, the NICE guidelines provide a very good overview of desirable clinical care pathways for patients newly diagnosed with chronic heart failure (NICE, 2012). Within this path, there is a strong role for primary health care practitioners. This includes:

- Lifestyle counselling regarding physical activity, smoking, and alcohol consumption and monitoring medications. Monitoring is recommended at two-weeks after any change to medications and every six months otherwise.

220. All CHF patients may receive a number of medications including diuretics, calcium channel blockers to control hypertension, anticoagulants, aspirin, inotropic agents (to alter muscular contractions) and amiodorone (antiarrhythmic medication). Some patients may also be prescribed ace inhibitors or beta blockers to relieve hypertension and stress on the heart.

221. Surgical interventions also occur for these patients. Some patients with arrhythmia may receive surgery to implant a cardio defibrillator to control arrhythmia. Coronary revascularisation is not normally recommended, but some patients may also receive this intervention. Surgical aortic valve replacement or new techniques such as transcatheter aortic valve replacement may be administered. Other new procedures such as percutaneous mitral valve annuloplasty or leaflet repair of the mitral valve may take place. Technologies to bridge patients awaiting heart transplantation may be administered, such as left ventricular assist devices, and some patients will receive a transplant or an artificial heart.

222. We will assume, for this example, that all of the treatments noted above are of interest for the CHF module. To begin to build the health system module for CHF patients, it would be necessary to estimate from empirical data the distribution of care during the year when their CHF was first diagnosed by type of patient. Table three provides the key patient characteristics necessary to differentiate key patient groups.

223. For each key patient group, the information within table four would be necessary to understand their treatment within the first year of diagnosis. Both tables use 2000 as a reference year, as it is a mid-point of the estimation period of CDP 2.0 (1991-2010).

Table 3. Classification of CHF patients in 2000

Sex	Age Group	Diseases of interest (other key diseases for inclusion in the model)	Co-morbidity count (other diseases not explicitly modelled)	Insurance coverage	Out-of-pocket share
Male	Under age 50	Early stage cardiovascular disease (no CHF) (yes/no)	0	0=none	0%
Female	Age 50 to 65	Cerebrovascular disease (yes/no)	1	1=private	LT25%
	Age 65 to 80	Peripheral arterial disease (yes/no)	2	2=public	GT 25 and L 50%
	Over age 80	AMI since 1991 (yes/no)	3		GT50 and LT75%
		Stroke since 1991 (yes/no)	4		GT75 and LT100%
			5+		100%

Table 4. Treatments of interest for new CHF patients in 2000

	% yes	Lower bound 95% CI	Upper bound 9% CI	Average number	Lower bound 95% CI	Upper bound 9% CI	Average length in days	Lower bound 95% CI	Upper bound 95% CI
Visits									
Primary care clinic	X	X	X	X	X	X			
Specialist care clinic	X	X	X	X	X	X			
Hospital outpatient clinic	X	X	X	X	X	X			
Emergency room	X	X	X	X	X	X			
Prescriptions									
Diuretics	X	X	X	X	X	X	X	X	X
calcium channel blockers	X	X	X	X	X	X	X	X	X
anticoagulants	X	X	X	X	X	X	X	X	X
inotropic agents	X	X	X	X	X	X	X	X	X
Amiodorone	X	X	X	X	X	X	X	X	X
Ace inhibitors	X	X	X	X	X	X	X	X	X
Beta blockers	X	X	X	X	X	X	X	X	X
In-patient hospitalisations									
Revascularisation	X	X	X	X	X	X	X	X	X
Implantable cardio defibrillator	X	X	X	X	X	X	X	X	X
Surgical aortic valve replacement	X	X	X	X	X	X	X	X	X
Transcatheter aortic valve replacement	X	X	X	X	X	X	X	X	X
Percutaneous mitral valve annuloplasty	X	X	X	X	X	X	X	X	X
Leaflet repair of the mitral valve	X	X	X	X	X	X	X	X	X
Electronic pacemaker	X	X	X	X	X	X	X	X	X
Heart transplant	X	X	X	X	X	X	X	X	X
Artificial heart	X	X	X	X	X	X	X	X	X
Home care services	X	X	X	X	X	X			
Institutionalised long-term care				X	X	X	X	X	X

224. The information within tables 3 and 4 provide a baseline set of information about the health care experiences for new CHF patients that can inform the simulation within the first year of the disease.

225. Given that we will be interested in a set of diseases for CDP 2.0 and not a single disease condition, a distinction is needed between the key set of diseases we are interested in including within the model, and all others. In this example, table 3 provides a simplifying assumption that the other key diseases included in the model are a set of cardiovascular diseases.

226. Considering the key diseases, the model should enable reporting of health services use, costs and health outcomes for complete populations of patients with each of the key diseases. However, many patients will have more than one key disease, such as an AMI patient who was previously diagnosed with CHF. Multiple morbidity involving key diseases must be given careful consideration in model design as there is a risk of over-counting therapies and over-representing costs. Models of individual diseases need to take the other focus diseases into account. To be avoided is the modelling of CHF disease progression while also modelling AMI progression including CHF patients; and erroneously doubling physician visits and prescribed therapies for the same individual. Each additional key disease increases the number of events requiring probabilities to be estimated.

227. The inclusion of variables for insurance coverage status and co-payment share in the estimation of model parameters will enable baseline estimates of health outcomes, treatments and treatment costs to be disaggregated by financing characteristics. These parameters can then be adjusted to test the impact of policy scenarios regarding changes to the financing of health care (see chapter 7).

Events in the health care pathway – disease states

228. All explicitly modelled diseases should be allowed to occur according to their own decision rules. Returning to the example of CHF, however, it is essential that CHF be explicitly included as a risk factor within the rules for any key disease events that are sequelae of CHF. According to the Mayo clinic, the sequelae of CHF includes kidney damage or failure; liver damage; acute myocardial infarction and stroke, as well as sudden death (Mayo Clinic, 2012). Thus, in this example, given AMI, stroke and death are all to be explicitly included in the model; we would need to estimate how the presence of CHF may elevate the hazard of developing these conditions. This will enable the simulation to place CHF patients at higher risk of these events; and better represent the health and economic benefits of strategies to either reduce CHF events or to better control disease progression.

229. Let's consider stroke as an example. Using a Cox proportional hazard model, we can estimate the hazard of stroke for a CHF patient conditional on key characteristics including sex, age, risky behaviours, time since diagnosis of CHF, count of co-morbidities, count of visits in the past year by type, prescription medicines by type (yes/no) and in-patient therapies by type (yes/no). The same equation specification could also be used to estimate the hazard of acute myocardial infarction and sudden death. In a multi-disease framework, all key diseases that may increase the hazard for stroke must be included within the stroke event hazard model.

230. This principle will apply to the risk equation for the development of CHF itself and, indeed, for all of the key diseases included in the model. The decision rule for the development of CHF, for example, should explicitly include the presence of any key diseases within the model that raise the risk of the development of CHF. The effort to connect the key diseases within the model will enable policy scenarios developed with the model to describe the full set of health consequences, service use and costs of policies that reduce or increase the risk of CHF, or any of the other focus diseases.

231. As discussed in the previous chapter, the alpha parameter in each estimated equation from the Cox proportional hazards model should be calibrated to equal the known distribution of incident cases of disease during the estimation period.

Events in the health care pathway – outcomes of care

232. While the statistical modelling of all possible transitions over time within patient's health care pathway is theoretically possible, it would not be practicable. For patients who do not go on to develop sequelae of their disease, there will still be changes over time in service use and therapies consumed. To enable CDP 2.0 to take this progression into consideration, tables 3 and 4 could be estimated for patients at 2, 3, 4, and 5 years following diagnosis of CHF and in the first and subsequent years following a sequelae of CHF. The change in distribution of patients could be used in the simulation to infer the transitions necessary to equal the control totals.

Outcomes of care

233. In consultation with clinicians, a set of potential indicators of outcomes of care for CHF patients could also be included in CDP 2.0. Their inclusion further enables policy analysis of the health and economic consequences of changes in treatment regimes, including changes to bring care delivered closer to best practice guidelines, and to, conversely, inform about consequences of recommended therapies leading to guideline revision. A practical example of a microsimulation model leading to a change in recommended care is provided by a Canadian study where the Population Health Model was used to evaluate the potential future impact of the administration of the drug tamoxifen to women at high risk of the development of breast cancer. While clinical trial results were promising and pointed to a survival benefit for high-risk women prescribed this medication; the publication of the long-term impacts of the drug using the POHEM model, indicated that such prescribing would not increase women's survival due to the long-term effect of drug complications which were beyond the follow-up period of the clinical trials (Wills, 2001; Brown, 2001).

234. For illustration, the outcomes of particular therapies could include:

- Death within a hospital admission controlling for procedures;
- Re-admission to hospital following a first hospitalisation controlling for procedures;
- Admission to hospital following the purchase of particular medicines or combinations of medicines where adverse drug reaction is noted on the record;
- Days spent at home controlling for particular therapies;
- Days spent in long-term care institution beds or the use of home-care services controlling for particular therapies; and
- Death following hospital discharge controlling for particular in-hospital procedures;

235. As is necessary, all such analysis should control for key patient characteristics and the presence of other morbidities which may complicate a patient's opportunity to have a better health outcome following treatment.

236. A way to conceptualise the inclusion of these care outcomes is to explicitly identify them as potential sequelae of diagnosis and ensure that all events in the sequelae fit together in a coherent framework; where it is reasonable that they compete with each other to be the next event to occur in the person's life.

237. Again parsimony is essential, as each assessment requires estimation of a statistical model. As discussed in previous chapters, a Cox proportional hazards regression model would provide the hazard of experiencing a particular outcome conditional on the patient's characteristics and health status (co-morbidities).

Persons without key diseases

238. This chapter has discussed, in detail, an approach to estimating essential parameters for the key diseases of interest to be included in the model. Remaining to be described is the health care use of individuals who are free of all of the CDP 2.0 focus diseases in any given year. Their distribution of health care use is described in tables 3 and 4 also. The evolution of health care use for these individuals will progress only with age until such time as a disease of interest develops or until death. It may be worthwhile narrowing the age bands for this population from those identified in table 3 in order to distinguish important phenomena, such as higher health care use among women of child-bearing age. The distribution of health care use by age groups in 2000 will be used as the basis for changing consumption of simulated persons as they age.

Costs of care

239. As was noted in the methodology for the Finnish project discussed earlier in this chapter, a variety of data sources will be needed to assign costs to the treatment pathways developed for inclusion in CDP 2.0. As costs are a relatively simple matter of price times quantity, sufficiently detailed quantity estimation for CDP 2.0 will enable the calculation of costs, given fee schedules are available. As was the case for Finland, the costing of hospital episodes can benefit from hospital DRG cost estimates.

240. A recent Canadian POHEM model of lung and colo-rectal cancer involved obtaining health care costs predominantly from Ontario sources and included the Ontario Health Insurance Plan (OHIP) Schedule of Benefits for physician fees, the Ontario Case Costing Initiative for hospital costs and Cancer Care Ontario's New Drug Funding Program (drug costs). The Juravinski Cancer Centre at Hamilton Health Sciences was the source of cost information for chemotherapy administration. Data from the province of Manitoba were used to estimate the cost of palliative therapy following the completion of active treatment. Total health-care expenditures were obtained from the Canadian Institute for Health Information. Census data (26) and the Social Policy Simulation Database and Model (27) were used for earnings, transfers and taxes.

241. A “bottom up” approach was used for the costing of health care. Costs for each component of cancer management, be it diagnosis, surgery, radiotherapy or chemotherapy were estimated in detail to arrive at a cost per person per type of treatment. Ideally, the costs of treatment, as estimated by the model, should line up with aggregate figures, such as those produced by the Canadian Institute for Health Information. However, these aggregated figures are only available for all cancers combined and, therefore, were not useful for model development or validation (Evans et al., 2012).

Improving the comparability of hospital costs across countries

242. New work within the OECD to identify the prices of hospital services will assist with the estimation of the costs of hospital episodes for CDP. 2.0. This innovation would enable greater comparability in prices and also reflect within prices costs beyond the direct provision of care, further improving the estimation of the underlying costs of different care paths (Lorenzoni and Pearson, 2011).

243. In international comparisons, the relative prices for a particular product or group of product are called Purchasing Power Parities (PPPs). PPPs are regularly measured for all components of GDP. Despite a long tradition of work in the area, the task remains challenging. Three main problems have to be addressed in the measurement of PPPs: to identify products that are comparable across countries; to ensure representativeness of products; and to estimate a price when there is a product, but no meaningful market price for comparison. Issues one and two arise in the comparison of all prices, issue three arises in the comparison of products that are produced and delivered outside markets. In many countries, health services count among these products.

244. When goods or services are supplied by a non-market producer such as the government, the prices charged to consumers are often significantly below the price that a market producer would charge. In some cases, the price may even be zero. It would make no sense to compare such prices charged to patients or consumers across countries as they reflect administrative decisions and not the value of products. It has therefore been customary in PPP compilations to compare costs of producing non-market goods and services.

245. There are two possibilities for comparing costs, one based on inputs and one based on outputs. The input-based method, traditionally applied in PPP comparisons of non-market products, consists of comparing the prices of inputs in the production process of non-market services. In the case of health services, an input-based method would, for example, compare the wage rate of a surgeon in different countries. In other words, the price comparison is approximated through a comparison of wages or values per unit of inputs. Apart from the fact that it is notoriously difficult to compare wages across countries (even for the same type of occupation, qualifications may be different, it is hard to control for experience and seniority payments etc.) the main drawback of this methodology is that it ignores any productivity differences between countries. In other words, if health services are provided more efficiently in one country compared to another, this would go unnoticed in a PPP comparison that is based on the price of inputs.

246. The second option for comparing costs is based on outputs. Here, PPPs are measured by comparing the costs per unit of output, in the case of medical services this is typically the cost per treatment. In the health domain, costs per unit of output are not generally readily observable but there is an alternative source of information that provides valuations of outputs: in many OECD countries, health services are managed through reimbursement schemes where health providers and health administrations or insurance companies either negotiate reimbursements per treatment or where the government administers reimbursements per treatment. Reimbursement values per treatment or per episode of illness can be used to emulate the role that prices play for other goods and services.

247. Negotiated or administered rates could be labelled as quasi-prices to signal that they are not necessarily the result of market transactions, that they are not prices that apply to transactions between producers and consumers of health services, and that they are not observed. The comparison of quasi-prices per unit of treatment is an output-based approach, and in principle is capable of reflecting productivity differences between countries. It is thus conceptually preferable to input-based approaches.

248. It is rare that hospital services can be directly measured and valued through free-standing costing studies and clinical trials with concurrent economic evaluation. A more promising avenue is to use secondary data sets available through health administrations and national insurance funds for purposes of reimbursement, health financing, and hospital budgeting.

249. Two main issues may limit the use of secondary datasets for across country price comparisons: differences in product classification and differences in how prices are set.

250. As to the former, measures of hospital production may differ across countries in terms of diagnosis coding systems (e.g. WHO International Classification of Diseases, ICD) and procedure coding systems (like the Canadian Classification of Intervention, CCI) used to report clinical information on hospitalizations, and classification systems (e.g. Australian Refined DRG, AR-DRG) used to measure hospital products.

251. As to the latter, quasi-prices comprise both negotiated prices and administered prices. The former are established through independent negotiations between purchasers/third party payers and providers, and are not necessarily directly tied to the cost of care. For instance, negotiated prices could include profit margins (or losses if some services are cross-subsidised by others).

252. Administered quasi-prices, on the other hand, are likely to be reflective of average costs per product. In the case of administered quasi-prices that typically reflect average costs of service provision, it is important that the scope of costs reflected in the administered price is similar across countries. As a general principle, the full set of costs should be reflected in the quasi-price. These comprise compensation of employees, depreciation of capital, intermediate inputs, and taxes on production. Both costs relating to health services directly as well as overhead costs should be reflected.

253. The study provided a description of the classification systems used to measure hospital services in selected OECD countries: Australia, Canada, England, France, Germany, Norway, and the United States. Three classifications were relevant: those on diagnoses; on procedures; and on products. In addition, methods used to measure the cost of hospital services were reviewed.

254. The study concluded that most OECD countries use a mix of payment arrangements to finance hospital acute care. These lead to various different incentives for the quantity, quality and productive efficiency of hospital services. Of particular interest are per case/diagnosis related group (DRG) payments, which directly relate to actual levels of activity. They are fees established prospectively for a single —product delivered by the hospital. In a survey of health systems characteristics carried out in 2009, 17 (out of 29 respondents) OECD countries reported the use of a payment per case/DRG. A new OECD survey of health system characteristics is forthcoming in spring 2013 which will further inform CDP 2.0.

255. Whether or not CDP 2.0 can rely on DRG-based prices a reliable way of comparing costs across countries depends on whether the same definitions are used to generate DRG payments across countries. The study concluded that comparisons are possible across countries notwithstanding the different approaches used in developing DRG prices. Secondly, the secondary data sets available through health administrations and national insurance funds for purposes of reimbursement, health financing, and hospital budgeting can indeed be used to estimate the cost of a representative basket of hospital products to compare price levels across countries. As a result, the study conclusions validate the proposed method of estimation of hospital-related costs for the CDP 2.0.

Validation of health care expenditure estimates from CDP 2.0

256. While the costing of health care pathways emerges from the bottom up, the fine-tuning and validation of these costing efforts require control totals from the top down. As a result, the development of CDP 2.0 will benefit from a recent initiative within the OECD to estimate health expenditure by major disease categories for countries that are able to produce these estimates. Such estimates will provide essential control totals for the validation of direct care costs estimated by CDP 2.0 in order to refine and improve the model's representation of care costs.

Cost-of-illness in the System of Health Accounts Framework

257. In order to increase the comparability of the estimates of spending on diseases across countries, the OECD is currently engaged in a project to derive expenditures by disease under the System of Health Accounts (SHA) framework. This section is an excerpt from a recent paper presented to the OECD Health Committee (OECD Health Committee, 2012). The final report from this study will be released in the fall of 2013.

258. The current project is a follow up to one completed in 2008, entitled *Estimating Expenditure by Disease, Age and Gender under the SHA Framework*. The first phase of the 2008 project developed a set of guidelines covering the main concepts, definitions and methodology to allocate health expenditures according to disease, age and gender. The second phase consisted of a pilot study to test the feasibility of implementing these draft guidelines in six countries (Australia, Germany, Hungary, Korea, Slovenia and Sweden) with varying degrees of experience in undertaking such studies.

259. At the core of the SHA framework, is a tri-axial relationship which tracks the consumption, provision, and financing of health care goods and services. Thus, SHA classifies all health care expenditures according to these three categories. Deriving expenditures by disease under the SHA framework results in consistent and comparable estimates which can be used to track spending on specific diseases from financing agents and by service provider, thus providing insight into how different countries treat different diseases and how patterns of practice change over time. This information can be used to understand differences in where resources are being allocated across countries and, when used in conjunction with outcomes data, can provide information on comparative funding levels, as well as information on effective and efficient allocation of resources. Estimating expenditures using similar, and consistent, methodologies is a key factor in increasing the validity of such comparisons.

260. Table five summarises the results for the total direct costs of NCDs derived by relevant diagnostic chapters, and other illnesses for those countries for which such data were available.^{2,3,4} Expenditure data have been converted using the OECD's GDP PPP rates and are reported in constant 2010 US dollars (USD). The table identifies costs for all ages and those aged over 65. The direct costs associated with NCDs range from USD3.1 billion in Slovenia to USD1.7 trillion in the United States. The results show that NCDs are responsible for the majority of all health expenditures, ranging from 70% in Canada to 84% in Hungary. The percentage of total health expenditures devoted to NCDs among those aged 65 ranged from 81% to 89%. Table five also shows that between 27% and 48% of all NCD spending goes towards those aged 65 and over. Even at this aggregate level, this gives an indication of the distribution of health care expenditure. For example, in Germany around 15% of the population is aged over 65 but this group accounts for 48% of all expenditures related to the treatment of NCDs.

Table 5. Direct Costs of NCDs (in constant USD 2010 million)

Country	All ages		Ages 65 plus		
	USD	% of all health expenditure on NCDs	USD	% of all health expenditures on NCDs	% of all NCD expenditure on those aged 65+
Canada (2000)	69,150	70.0	n.a	n.a	n.a
Czech republic (2009)	15,138	73.6	4,475	83.4	35.8
France (2002)	161,867	80.2	n.a	n.a	n.a
Germany (2008)	257,490	80.6	128,230	82.9	48.4
Hungary (2006)	14,789	83.9	4,248	89.3	27.0
Korea (2009)	73,552	81.4	28,859	89.1	35.9
Netherlands (2005)	42,794	74.7	17,774	81.6	38.0

² The following ICD chapters were included: II, Neoplasms; IV, Endocrine and related diseases; V, Mental disorders; VI, Diseases of the nervous system; VII, Diseases of the eye and adnexa; VIII, Diseases of the ear and mastoid process; IX, Diseases of the circulatory system; X, Diseases of the respiratory system; XI, Diseases of the digestive system; XIII, Musculoskeletal diseases; XIV, Diseases of the genitourinary system

³ Note that ICD chapters may not be exclusively split according to infectious and chronic diseases. For example, Chapter X, Disease of the Respiratory System, includes respiratory infections along with respiratory diseases, and only the latter are considered NCDs. This may bias the estimates upwards, and speaks to the need for more disaggregated data with respect to the disease categories.

⁴ The following countries participated in the pilot project: Czech Republic, Hungary, Korea, Netherlands, and Slovenia. Germany provided data for the original project but more recent data was downloaded from the German Health Reporting web site. Australia provided data for the pilot project, however according to Global Burden of Disease categories; hence the mental health expenditures were not directly comparable as the GBD categories use differ grouping of ICD categories. Sweden also participated in the pilot study but was only able to provide expenditures broken down by disease for the hospital sector.

Slovenia (2006)	3,194	76.4	1,311	86.2	36.4
United States (2005)	1,701,326	83.1	n.a	n.a	n.a

Source: n.a. = not available; Sources: Unpublished OECD data. Currencies converted using GDP PPP rates

261. Tables 6 and 7 present data on health care expenditures by disease type for all age groups and for those aged 65 and over, respectively. Circulatory diseases were the most costly disease category in all countries with the exceptions of France and the Netherlands where it was ranked second. For those aged 65 and over, circulatory diseases were, once again, the most costly disease group ranging from just under 18% of all health care expenditures in the Czech Republic to almost 33% in Hungary.⁵

262. In order to gain further insight into the differences in expenditures on specific diseases, it is necessary to look beyond data at the ICD chapter level. While those countries that produce expenditure by disease data on a regular basis (for example, Germany, Netherlands) produce results for some subsets of diseases within each chapter, the subsets are not similar for all countries. It has thus been recommended that countries produce expenditure data grouped by categories according to the International Short List of Hospital Morbidity Tabulation (ISHMT). The ISHMT provides a useful categorisation of ICD groupings that many countries can employ, as it provides a mapping between ICD-9 and ICD-10 codes and its categories. Thus, it provides a feasible approach for grouping diseases that can be used by all countries regardless of whether they record data according to either ICD-9 or ICD-10 codes. In addition, hospital discharge data grouped by ISHMT is available for all OECD countries and for other countries, providing further benefits of the applicability and usefulness of grouping expenditure data by ISHMT code.

⁵ Note that some of the differences between countries may be attributable to the lack of data in some countries on the allocation of expenditures for some health care providers. In order to increase comparability, it was necessary to re-allocate such expenditures across all disease groups which may affect some of the results. For example, Canadian expenditures on long-term care could not be allocated by disease. Redistributing these expenditures across all diseases would result in those diseases that employ much long-term care, such as many NCDs, to be underestimated.

Table 6. Expenditures for selected diseases, all ages (in US 2010 million USD)

	Canada		Czech Republic		France		Germany		Hungary		Korea		Netherlands		Slovenia		United States	
	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
Neoplasms	5,069.7	5.1	2,431.1	11.8	15,086.8	7.5	22,722.7	7.1	1,807.4	10.3	8,188.1	9.1	3,369.3	5.9	297.3	7.1	157,702.6	7.7
Endocrine and related diseases	4,492.9	4.6	781.0	3.8	8,403.7	4.2	17,231.2	5.4	1,329.3	7.5	3,670.5	4.1	1,603.4	2.8	100.2	2.4	96,070.0	4.7
Mental disorders	13,274.8	13.4	1,114.3	5.4	21,333.3	10.6	36,015.9	11.3	1,116.8	6.3	5,272.4	5.8	10,378.7	18.1	335.1	8.0	210,171.6	10.3
Diseases of the nervous system	2,988.5	3.0	827.6	4.0	7,377.0	3.7	15,726.6	4.9	600.0	3.4	2,706.4	3.0	1,427.2	2.5	188.4	4.5	98,434.8	4.8
Diseases of the eye and adnexa	2,250.2	2.3	431.4	2.1	11,556.4	5.7	8,598.6	2.7	463.3	2.6	3,538.6	3.9	2,368.4	4.1	194.6	4.7	35,915.4	1.8
Diseases of the ear and mastoid	1,157.9	1.2	133.4	0.6	1,672.4	0.8	3,217.7	1.0	209.0	1.2	893.9	1.0	897.8	1.6	35.7	0.9	0.0	0.0
Circulatory diseases	13,518.4	13.7	3,233.2	15.7	25,487.8	12.6	46,472.3	14.5	4,038.9	22.9	13,005.0	14.4	6,578.5	11.5	600.2	14.3	375,264.2	18.3
Respiratory diseases	8,480.5	8.6	1,203.2	5.8	15,540.0	7.7	16,577.6	5.2	1,273.1	7.2	10,979.7	12.2	2,936.5	5.1	278.6	6.7	144,400.6	7.1
Diseases of the digestive system	6,727.5	6.8	1,870.8	9.1	25,968.9	12.9	43,758.6	13.7	1,364.1	7.7	12,309.3	13.6	6,000.4	10.5	554.9	13.3	290,131.4	14.2
Musculoskeletal diseases	6,421.4	6.5	1,482.1	7.2	18,077.4	9.0	35,878.9	11.2	1,603.6	9.1	8,093.6	9.0	4,940.4	8.6	268.1	6.4	180,020.4	8.8
Genitourinary system	4,768.5	4.8	1,629.6	7.9	11,363.4	5.6	11,288.4	3.5	984.0	5.6	4,894.9	5.4	2,293.4	4.0	341.0	8.2	113,214.8	5.5
Other	29,579.0	30.0	5,442.8	26.4	40,004.6	19.8	62,121.0	19.4	2,835.9	16.1	16,755.3	18.6	14,490.1	25.3	989.1	23.6	345,704.2	16.9
Grand Total	98,729.3	100.0	20,580.7	100.0	201,871.7	100.0	319,609.5	100.0	17,625.3	100.0	90,307.7	100.0	57,284.0	100.0	4,183.2	100.0	2,047,029.8	100.0

Source: Sources: Public Health Agency of Canada (2010) unpublished data; Roehring et al 2009; Unpublished OECD data. Data are for the following years: Canada 2000; Czech Republic 2009; France 2002; Germany 2008; Hungary 2006; Korea 2009; Netherlands 2005; Slovenia 2006; United States 2005. Currencies converted using GDP PPP rates

Table 7. Expenditures for selected diseases, ages 65 plus (in US 2010 USD)

	Czech Republic		Germany		Hungary		Korea		Netherlands		Slovenia	
	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
Neoplasms	451.7	8.4	13,168.80	8.5	554.1	11.6	3,110.60	9.6	1,475.40	6.8	125.2	8.2
Endocrine and related diseases	140.5	2.6	9,557.70	6.2	363.3	7.6	1,535.00	4.7	698.9	3.2	38.2	2.5
Mental disorders	110.9	2.1	17,067.80	11	185.5	3.9	3,016.20	9.3	3,975.60	18.2	140.9	9.3
Diseases of the nervous system	90.2	1.7	7,742.70	5	140	2.9	1,460.50	4.5	489.6	2.2	67.4	4.4
Diseases of the eye and adnexa	106.7	2	3,300.70	2.1	175.4	3.7	1,455.20	4.5	882	4	91.6	6
Diseases of the ear and mastoid process	16.4	0.3	1,305.90	0.8	67.2	1.4	159.2	0.5	280.3	1.3	7.1	0.5
Diseases of the circulatory system	951.7	17.7	33,020.70	21.3	1,558.30	32.8	7,612.10	23.5	3,772.80	17.3	376.5	24.8
Diseases of the respiratory system	181	3.4	6,108.70	3.9	229.6	4.8	2,683.20	8.3	1,071.60	4.9	89	5.8
Diseases of the digestive system	235	4.4	14,005.90	9.1	280.1	5.9	2,382.10	7.4	1,162.30	5.3	133.6	8.8
Musculoskeletal diseases	227.6	4.2	18,097.20	11.7	437.9	9.2	3,722.70	11.5	1,599.50	7.3	102.8	6.8
Diseases of the genitourinary system	277.7	5.2	4,854.20	3.1	256	5.4	1,719.20	5.3	819.7	3.8	138.8	9.1
Other	557.2	10.4	26,482.10	17.1	508.7	10.7	3,547.60	10.9	3,663.00	16.8	209.7	13.8
Not allocated	2,022.00	37.7	0	0	0	0	3.7	0	1,895.60	8.7	0.1	0
Grand Total	5,368.60	100	154,712.30	100	4,756.30	100	32,407.20	100	21,786.30	100	1,520.90	100

Source: Sources: Unpublished OECD data; Data are for the following years: Czech Republic 2009; Germany 2008; Hungary 2006; Korea 2009; Netherlands 2005; Slovenia 2006. Currencies converted using GDP PPP rates

263. As illustrative examples of how such data can be employed, expenditures for circulatory diseases, which are a significant burden to health systems and an ageing population, have been derived using ISHMT groupings. The Czech Republic and Korea have provided expenditure data grouped by ISHMT as part of the current project. Data for Germany and the Netherlands are available for a subset of ISHMT codes.⁶ Tables eight and nine present results on the allocation of expenditures for circulatory diseases for all ages, and those aged over 65, respectively. Expenditures are allocated across the sub-groups differently in each of the four countries. For example, in Korea 39% of all expenditures related to circulatory diseases are directed towards the treatment of hypertension in comparison with only 14.2% in the Netherlands.

Table 8. Expenditures on Circulatory Diseases - by sub-groups (per-capita, 2010 USD)

	Germany		Korea		Netherland		Czech Republic	
	USD per capita	%						
Hypertension	140.7	24.5	104.3	39.1	59.6	14.2	12.9	8.6
Ischaemic heart diseases	96.4	16.8	36.3	13.6	116.6	27.8	42.1	28.0
Heart Failure	50.1	8.7	3.7	1.4	28.1	6.7	9.1	6.1
Stroke	126.2	22.0	94.8	35.6	96.8	23.1	26.1	17.4
Other circulatory system	160.8	28.0	27.4	10.3	117.6	28.1	60.3	40.0
All circulatory diseases	574.2	100.0	266.5	100.0	418.6	100.0	150.6	100.0

Currencies converted using GDP PPP rates

Table 9. Expenditures on Circulatory Diseases by sub-groups, ages 65 plus (per-capita, 2010 USD)

	Germany		Korea		Netherlands		Czech Republic	
	USD per capita	%						
Hypertension	90.7	22.3	54.1	34.7	32.7	12.6	6.4	6.8
Ischemic heart diseases	66.9	16.5	20.0	12.8	62.8	24.2	26.8	28.7
Heart Failure	45.0	11.1	3.1	2.0	22.8	8.8	6.9	7.4
Stroke	100.5	24.7	68.6	44.0	73.2	28.2	18.3	19.6
Other circulatory system	103.4	25.4	10.2	6.5	68.4	26.3	35.0	37.5
All circulatory diseases	406.5	100.0	156.0	100.0	259.9	100.0	93.5	100.0

Currencies converted using GDP PPP rates

264. Furthermore, with the aid of such disaggregated data, we are able to examine the allocation of expenditures across providers for single diseases. This information provides insights on the different approaches to disease management across countries (Table 10).^{7,8} For example, we can observe that in the overall treatment of circulatory diseases, Korea devotes a lower percentage of expenditures towards ambulatory care, and a higher percentage towards hospital care, in comparison with the other countries. This is particularly obvious in the management of strokes, heart failure and ischemic heart disease where Korea devotes less than 3% of expenditures towards ambulatory care. Also note that Korea devotes a much larger proportion of expenditures in the area of pharmaceuticals than the other countries in the treatment of

⁶ Although data were not grouped according to ISHMT chapter for Germany and the Netherlands, it was possible to group their data by some of the ISHMT codes for this analysis.

⁷ These results are preliminary nature and should only be viewed as exemplary of the type of information that this type of analysis can provide, rather than representing true differences in expenditure patterns.

⁸ Note that we have excluded from Czech Republic in Table 7 because the majority of their pharmaceutical expenditures data cannot be allocated to specific diseases.

these three diseases. In the treatment of strokes, Germany's proportion of expenditures in the area of ambulatory care is twice as great as that found in the Netherlands.

Table 10. Expenditures on Circulatory Diseases by sub-groups and Providers, (per-capita, 2010 USD)

	Germany		Korea		Netherlands	
	USD per capita	%	USD per capita	%	USD per capita	%
Hypertension						
hospital	8.3	5.90%	15.4	14.80%	2.7	4.60%
long-term care	0.2	0.10%	3.6	3.50%	0.7	1.20%
ambulatory	30.6	21.70%	11.7	11.20%	13.7	23.00%
pharmaceuticals	82.9	58.90%	60.1	57.60%	39.7	66.70%
Other providers	18.8	13.40%	13.4	12.90%	2.7	4.40%
All providers	140.7	100.00%	104.3	100.00%	59.6	100.00%
Ischemic heart disease						
hospital	55.4	57.50%	19.2	52.90%	62.4	53.50%
long-term care	1.5	1.60%	0.2	0.70%	2.2	1.90%
ambulatory	16.4	17.00%	0.4	1.20%	16.4	14.10%
pharmaceuticals	13	13.50%	13	35.80%	27.9	23.90%
Other providers	10	10.40%	3.4	9.40%	7.6	6.60%
All providers	96.4	100.00%	36.3	100.00%	116.6	100.00%
Heart failure						
hospital	23.6	47.10%	2.2	58.80%	14.8	52.70%
long-term care	7.1	14.20%	0.2	6.10%	4.8	17.20%
ambulatory	9.2	18.40%	0.1	2.80%	4	14.40%
pharmaceuticals	4	7.90%	0.9	25.50%	2.8	10.10%
Other providers	6.2	12.40%	0.3	6.80%	1.6	5.60%
All providers	50.1	100.00%	3.7	100.00%	28.1	100.00%
Stroke						
hospital	42	33.20%	62.4	65.80%	26.1	27.00%
long-term care	38.7	30.70%	11.4	12.00%	55	56.80%
ambulatory	25.8	20.40%	1.1	1.20%	9.4	9.70%
pharmaceuticals	4.4	3.50%	15	15.90%	3.4	3.50%
Other providers	15.3	12.10%	4.9	5.20%	2.9	3.00%
All providers	126.2	100.00%	94.8	100.00%	96.8	100.00%
All circulatory diseases						
hospital	207.1	36.10%	114	42.80%	175.7	42.00%
long-term care	50.6	8.80%	15.7	5.90%	66.6	15.90%
ambulatory	128.6	22.40%	18.8	7.00%	68.7	16.40%
pharmaceuticals	118.2	20.60%	93.8	35.20%	83.3	19.90%
Other providers	69.7	12.10%	24.2	9.10%	24.4	5.80%
All providers	574.2	100.00%	266.5	100.00%	418.6	100.00%

Source: Unpublished OECD data; German web site. Currencies converted using GDP PPP rates

265. By examining how resources are being allocated across provider types in the different countries, in conjunction with data on outcomes, we are able to ascertain whether certain approaches to disease management may be more effective in achieving better outcomes and whether certain approaches may also be more cost-effective than others. Such evidence, when combined with outcomes data, can inform

questions on comparative value for money obtained across countries and diseases, as well as over time, once longitudinal data becomes available.

266. As previously noted co-morbidities, particularly in older age groups are a significant concern. Many individuals suffer from multiple chronic diseases and the existence of some chronic conditions can impact the severity of other conditions. For example, mental health conditions often result in poorer health outcomes for those people with co-morbid conditions. It has been estimated that co-morbid mental health problems raise total health care costs by at least 45% for each person with a long-term mental health condition (Naylor *et al.*, 2012).

267. As part of its current expenditure-by-disease work, the OECD is also examining ways in which distributions can be applied to other countries in the area of allocating pharmaceutical expenditures across diseases. In the area of hospital expenditures, there is currently much data available for bed days used and average length of stay by ISHMT codes. Using data from countries that derive hospital expenditures by disease, we are checking to see whether these data can be exploited to derive estimates for expenditures by disease for those countries which currently do not have such expenditure estimates. Future work could develop more consistent methodologies to derive data on indirect costs associated with those diseases that are deemed relevant and important. A final project report on expenditure by disease, age and gender according to a revised set of guidelines is expected to be completed by the end of 2013.

Data availability assessment

268. As is clear from the preceding section, it will be difficult to obtain from the published literature the equations required for a detailed modelling of disease treatment and sequelae. Also, as differences in treatment patterns across countries included in CDP 2.0 are of specific interest, analysis of country-specific data will be required. The anticipated mechanism for the development of CDP 2.0 to enable cross-country comparisons of treatments and outcomes at baseline, and in response to policy interventions, is to develop a detailed analytical plan.

269. Understanding the progress of the health of populations and understanding the performance and quality of health care systems requires the ability to monitor the same individuals over time, as they experience health care events, receive treatments, experience improvements or deteriorations in their health and live or die. The capacity to construct accurate data to understand the pathways of patients through the health care system and to assess the health outcomes and costs that result is increasing rapidly. The health care sector is undergoing a significant transformation toward the adoption and use of information technologies. The computerisation of health care records and the development of capacity to exchange records to construct patient health care pathways is a promising new frontier for the advancement of measurement of the quality, efficiency and effectiveness of health care.

270. On 7-8 October 2010, *Health Ministers* met in Paris to discuss how to improve value in health care. In their final communiqué, they underlined the importance of better health information systems and *called for more and effective use of health data that has already been collected*. Ministers also noted that expanded use of health Information and Communication Technologies (ICTs), particularly electronic health records, can help to deliver better quality of care, reduce medical errors and streamline administration. They recognized the need to reconcile the legitimate concerns of citizens to protect their privacy with the use of health data to improve health sector performance and the quality of care.

271. As a result, the OECD conducted a study in 2011 and 2012 to report on the general environment in each country for the secondary use of personal health data as well as specific case studies. The questionnaire was sent to the members of the OECD Health Care Quality Indicators Expert Group in July 2011 and responses were received from 20 countries from September 2011 through to March 2012.

Countries participating in the survey include Australia, Belgium, Canada, Cyprus^{9,10}, Denmark, Finland, France, Germany, Israel¹¹, Japan, Republic of Korea, Malta, Norway, Poland, Portugal, Singapore, Sweden, Switzerland, the United Kingdom and the United States.¹² Members of the Health Care Quality Indicators Expert Group represent the 35 member countries of the Organisation for Economic Cooperation and Development as well as a number of non-member countries who are participating actively in the HCQI project.

272. As part of this questionnaire, contact persons were identified who were knowledgeable about the general environment for secondary use of personal health data involving data linkages and multi-country studies. Experts with knowledge of national level studies, as well as regional, state and health-care network specific studies were identified. Structured telephone interviews were conducted with 31 selected experts from September 2011 to March 2012.

273. A second mail-back questionnaire sought information about progress in the development of electronic health record systems and the specific elements of the design that relate to the ability to extract high quality data from these records to monitor and report on health care quality. The questionnaire was sent to the members of the OECD Health Care Quality Indicators Expert Group in February 2012 and responses were received from 25 countries from March to August of 2012. Countries participating in the survey include Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Indonesia, Israel, Japan, Republic of Korea, Mexico, the Netherlands, Poland, Portugal, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, the United Kingdom and the United States.

274. Eighteen countries have national data at the level of individuals for mortality (table 11). Such data can be organised in a database where each row of the database represents an individual. This type of data is a prerequisite for detailed analysis of risk factors or determinants of health and health care outcomes and is a prerequisite for data linkage. Seventeen countries have individual-level records in their hospital in-patient data, cancer registry data, population health survey data and population census or population registry data. Fifteen have individual-level data for primary care and thirteen have this data for prescription medicines, formal long-term care and mental health hospital in-patients. Seven have individual records for patient experiences.

Table 11. National data containing records for patients (persons)

Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
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⁹ Note by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the “Cyprus” issue.

10 Note by all the European Union Member States of the OECD and the European Commission: The Republic of Cyprus is recognized by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

¹¹ The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

¹² Italy participated in the telephone interview part of the study.

Australia	Yes									
Belgium	No	Yes	Yes	Yes	Yes	Yes	nr	No	No	Nr
Canada	Yes	na	Yes	na	Yes	Yes	na	Yes	Yes	Yes
Cyprus	Yes	na	Yes	na	Yes	na	na	Na	Yes	Yes
Denmark	Yes	Yes	Yes	Yes	Yes	na	No	Yes	No	Yes
Finland	Yes									
France	ns	Yes	Yes	Yes	Yes	ns	No	Ns	Yes	Yes
Germany	Yes	Yes	Yes	No	Yes	Yes	na	Na	Yes	Yes
Israel	Yes									
Japan	nr									
Republic of Korea	Yes									
Norway	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Poland	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Portugal	Yes	Yes	No	Yes	No	nr	nr	Yes	Yes	Nr
Malta	Yes	Yes	Yes	na	Yes	Yes	na	Yes	Yes	Yes
Singapore	Yes	Yes	Yes	na	Yes	Yes	na	Na	Yes	Yes
Sweden	Yes	na	Yes	Yes	Yes	na	Yes	Yes	Yes	Yes
Switzerland	Yes	na	na	na	Yes	Yes	na	Yes	Yes	Yes
United Kingdom	Yes									
United States	Yes	Dk	Yes	Yes						
Total Yes	17	15	17	13	18	13	7	13	17	17

Note: The data custodian should be a national authority and data should be included even when it does not cover 100% of the nation. 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

National infrastructure for data linkage and analysis

275. Record linkage involves linking two or more databases using information that identifies the same patient or the same person. An example would be linking patient records in a hospital database to any death records for the same persons in a mortality database in order to identify patients who died following treatment. A specific type of record linkage, often referred to as deterministic linkage or exact matching, involves using a unique identifier or set of identifiers to merge two or more sources of data. In health linkages, the identifier used is often a unique patient identifying number or UPI. When a unique patient identifying number is consistently applied and recorded with few errors, this type of record linkage yields the highest quality and most accurate results, at the lowest cost in terms of person-hours.

276. Seventeen countries reported a national number that uniquely identifies patients (table 12). In fourteen countries, the number is used for health care encounters and other governmental purposes, such as social security and taxation. The *United States* reports the Social Security Number as a unique identifying number that can distinguish patients in public health-care programmes such as Medicare and Medicaid. The SSN, however, is not used generally for health-care encounters in the United States and is therefore not a national identifying number for health care services. In three countries, *Canada*, *Portugal* and the *United Kingdom*, the identifying numbers are exclusive to the provision of health services and are not used for taxation and social security. In *Canada*, the provincial HIN will change when individuals move province and there is no linkage of old to new HIN numbers across provinces. As a result, record linkage studies that depend on the health insurance number might be affected by inter-provincial mobility. U.K. respondents to the telephone interview for this study were not sure if the NHS number issued to U.K. residents is a unique number that would be maintained when an individual moved within the U.K. or if it would change if an individual moved country within the U.K., producing a similar bias to that experienced in Canada.

Table 12. National number that uniquely identifies patients and the main uses of this number

	Name of the unique identifying number	Main uses of the identifying number
Belgium	INSZ NISS	INSZ NISS is a national person identifier (national number) used for various purposes, such as health care, social security, and tax.
Canada	Health Card Number	The provinces and territories assign a health card number that is a unique patient number for all publicly funded health-care encounters. There is also a unique Social Insurance Number assigned nationally for tax and social security purposes that is not used for health care.
Cyprus	Civil Identity Card Number	The Civil Identity Card Number is used by almost all government departments for administrative purposes, including the Ministry of Health, tax and social security.
Denmark	CPR NR (Central Person Register Number)	Used for 'everything' in relation to national and local governments including health care. Also banks and other business identifications etc.
Finland	Personal Identity Code	The personal identity code is used in practically all data collections in public services, such as health care, social welfare services, education, justice etc.
France	Numéro d'identification au répertoire (NIR)	Persons born in metropolitan France and overseas departments are registered on the national directory for the identification of natural persons (RNIPP) and are assigned a registration number (NIR). The NIR is used by medical authorities for the issuance of a 'carte vitale'. The NIR is also used for social security.
Italy	TS number	TS number contains both a health number and a tax file number and has nearly universal coverage of the population. It is managed through a publicly owned private company, SOGEI that could be considered as a trusted third party.
Israel	ID number	The ID number is used for tax, social security, education, health, licensing, banking and other identified activities.
Korea	Resident Registration Number	Resident Registration Number (RRN) is assigned to each individual upon his/her birth and contains various information including birth date, gender and location of birth. RRN is used in virtually all aspects of life, including economic activities, for personal identification in various documents and communications in Korea.
Malta	Identification Number ID No	ID No is a unique identification number used throughout the country for all purposes including electoral lists, taxation, social security, etc. It is based on the registration number at the Public Registry.
Norway	National Identification Number	The National Identification Number is used for tax, social security, health records, banking and other purposes.
Poland	PESEL	PESEL number is assigned to all citizens at birth; permanent residents; temporary residents with stays of 2 months or longer; applicants for an identity card; and other persons where regulations require it.
Portugal	Número de Utente do Serviço Nacional de Saúde	This number is used throughout the country for access to national health service care and benefits.
Singapore	National Registration Identity Care Number (NRIC)	NRIC is used for identification, government procedures, and some commercial transactions (e.g. the opening of a bank account)
Sweden	Personnummer (Personal Identity Number)	Personnummer is the main identifier used for all official purposes in Sweden (tax, social welfare, health care, living conditions, education and so on)
United Kingdom	NHS number Scotland also has the Community health index (CHI) number	Everyone registered with the National Health Service in England, Scotland and Wales is issued a unique NHS number. The NHS number is not used for tax/social security purposes. In Scotland, the CHI system was set up for administrative purposes to track patients registering with GPs.
United States	Social Security Number	The SSN is issued to U.S. citizens, permanent residents, and temporary (working) residents and its main purpose is for taxation.

Source: OCED HCQI Questionnaire, Secondary Use of Health Data, 2011/12 and, for Italy, follow-up telephone interview, October 2011.

277. Fifteen countries reported a unique identifying number for patients exists currently within their national hospitalization databases and that this number could potentially be used for data linkage (table 13). Fourteen countries reported the same conditions for their cancer registry, primary care data, and mortality data. Thirteen reported the same conditions for their prescription medicines data; and eleven for their formal long-term care data, mental hospital in-patient data, population health survey data and population census or registry data. Only one country, however, had a unique identifying number that could be used for data linkage of patient experiences data.

Table 13. National data contains a unique patient identifying number that could be used for record linkage

	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	No	Yes	No	Yes	No	No	No	No	No	No
Belgium	Yes	Yes	Yes	Yes	No	No	nr	No	Yes	nr
Canada	Yes	na	Yes	na	Yes	Yes	na	Yes	Yes	No
Cyprus	Yes	na	Yes	na	Yes	na	na	na	No	No
Denmark	Yes	Yes	Yes	Yes	Yes	na	No	Yes	No	Yes
Finland	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
France	ns	Yes	No	Yes	Yes	nr	No	nr	Yes	Yes
Germany	No	Yes	Yes	No	No	No	na	na	Yes	No
Israel	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Japan	Yes	Yes	na	Yes	Yes	Yes	nr	nr	Yes	Yes
Republic of Korea	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Malta	Yes	Yes	Yes	na	Yes	Yes	na	Yes	No	Yes
Norway	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Poland	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Portugal	Yes	Yes	No	Yes	No	nr	nr	Yes	No	Nr
Singapore	Yes	Yes	Yes	na	Yes	Yes	na	na	Yes	Yes
Sweden	Yes	na	Yes	Yes	Yes	na	No	Yes	Yes	Yes
Switzerland	Yes	na	na	na	No	Yes	na	Yes	No	No
United Kingdom	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
United States	No	No	No	No	No	No	No	No	No	No
Total Yes	15	14	14	13	14	11	1	11	11	11

Note: The data custodian should be a national authority and data should be included even when it does not cover 100% of the nation. 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

278. *France* reports the use of different unique patient identifying numbers and that this is a barrier to some data linkage projects. The identifying numbers used by hospitals may vary across hospitals and are different from the identifying numbers used for medical insurance. France has been working on establishing a national identifying number for medical records and this development was approved by law in 2007. Such a number would enable patients to be assured that when electronic medical records are exchanged among providers; health care providers are receiving the correct record for them. Medical insurance records, however, currently depend on a different unique identifier, the NIR which is the country's social security number. The NIR was considered to be too sensitive to be used for electronic medical records. Options being explored to overcome the difficulty of linking databases include the establishment of a third party who could hold the key that would enable health insurance records with an anonymised NIR to be linked with medical records with the new health identifying number. Another possibility would be to have the insurance system adopt the same identifying number as that used for medical records. Data protection, health insurance and other authorities are working together to determine the best solution.

279. There are new developments in three countries that have not been able to use a unique identifying number for record linkages, *Switzerland*, *Germany* and *Japan*. The current process in Switzerland involves the health care providers in the Swiss Cantons, who have access to patient names, dates of birth and sex, to create an encrypted identifier that cannot be reversed to reveal the identity of a person. The same algorithm

is applied throughout the country and through time and is provided to the Federal Statistical Office (FSO) who uses it to enable data linkages. The algorithm has limitations. In particular, it does not account for name change, which creates a systematic bias in the data, particularly for women, where changes in marital status may result in name changes. There is a unique Social Security Number (SSN) in Switzerland that could potentially be used for data linkage in the future in an encrypted form. Recently, the Swiss Federal Statistical Office (FSO) sought an opinion of the Swiss national Office of Data Protection to determine if the FSO had the legal authority to process data using the SSN. The determination was that this use is in compliance with the health insurance law and could be in compliance with the law authorizing the FSO, if the FSO amends the ordinance that accompanies its authorizing legislation that specifies the data that the FSO is collecting. The FSO is pursuing this change in its ordinance. In *Japan*, there is a current proposal to introduce a uniform identifying number for tax and social security purposes, including health care. In *Germany*, a health insurance number, incorporating a unique and unchangeable code for identifying insured persons, is already mandatory within the health insurance system. This number has also been used to support data exchange. In future, this health insurance number is likely to be used in all areas of care provision, once the electronic health card (eGK) has been introduced throughout the country.

280. Other variables in a database can also be used to link records through a process of exact matching or through probabilistic matching. For probabilistic matching, a set of possible matches among the data sources to be linked are identified. For example, identifying information such as names, dates of birth and postal codes, may be used to assess potential matches. Then statistics are calculated to assign weights describing the likelihood that the records match. A combined score represents the probability that the records refer to the same individuals. Often there is one threshold above which a pair is considered a match, and another threshold below which it is considered not to be a match. This technique is used when an exact match between records across databases is not possible, or when data capture errors have caused deterministic matches to fail.

281. More countries reported having a set of identifying variables within their databases that could be used for record linkage than reported having a unique patient identifying number (table 14). These variables included names, dates of birth, addresses or postal codes, sex, and dates of events. Not all of these identifying variables are available on all of the data, but all of the data have at least some of these identifiers. Seventeen countries reported having a set of identifying variables within their cancer registry and mortality databases. Sixteen reported these variables within their population census or registry and fifteen within their hospitalisation data. Fourteen reported these are part of their primary care data and their mental hospital in-patient data. Thirteen reported these within prescription medicines data and twelve within formal long-term care data and population health survey data. Only 3 reported such identifiers within patient experiences data.

Table 14. National data contains identifying variables such as name, sex, birth date, and address that could be used for record linkage

	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Belgium	Yes	Yes	Yes	Yes	Yes	Yes	nr	No	No	Nr
Canada	Yes	na	Yes	na	Yes	Yes	na	Yes	Yes	Yes
Cyprus	Yes	na	Yes	na	Yes	na	na	na	Yes	Yes
Denmark	Yes	Yes	Yes	Yes	Yes	na	No	Yes	No	Yes
Finland	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
France	nr	Yes	Yes	Yes	Yes	nr	No	nr	Yes	Yes
Germany	No	No	No	No	No	No	na	na	No	No
Israel	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Japan	nr	nr	Yes	nr	nr	nr	nr	nr	nr	Nr
Republic of Korea	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Malta	Yes	Yes	Yes	na	Yes	Yes	na	Yes	No	Yes
Norway	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Poland	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Portugal	Yes	Yes	No	Yes	No	nr	nr	Yes	No	Nr
Singapore	Yes	Yes	Yes	na	Yes	Yes	na	na	Yes	Yes
Sweden	Yes	na	Yes	Yes	Yes	na	No	Yes	Yes	Yes
Switzerland	Yes	na	na	na	Yes	Yes	na	Yes	No	Yes
United Kingdom	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
United States	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total Yes	15	14	17	13	17	12	3	14	12	16

Note: The data custodian should be a national authority and data should be included even when it does not cover 100% of the nation. Identifying variables can include name, address, postal code, date of birth. 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OCED HCQI Questionnaire, Secondary Use of Health Data, 2011/12

282. In Australia, data linkage and data integration are predominantly undertaken through probabilistic means involving a set of potential identifiers, such as name, birth date, sex, and sometimes address. While the two large national health insurance data bases (under the Medicare Benefits Schedule (MBS) and the Pharmaceutical Benefits Scheme (PBS)) have Medicare numbers, these numbers have not generally been used for linkage as the number is often not available on other databases and there are legal restrictions to its use. Specifically, there are legal restrictions concerning the linkage of MBS data to PBS data. Hospitalisation data in Australia at the national level are held by the Australian Institute of Health and Welfare. National hospitalisation data lack personal identifying information to permit data linkage, although State Government data sets may hold this information. Hence, any project requiring access to identifiable hospitalisation data in Australia requires seeking access to hospitalisation data from the relevant Australian State. In 2010, Australia introduced unique patient identifying numbers, however participation in e-health is not compulsory and the use of e-health numbers for data linkages has not been approved.

Sub-national infrastructure for data linkage projects

283. In some countries, data linkage is commonly undertaken at the level of regions, states or within specific networks of health-care organizations. Networks of health-care organizations, such as the U.S.A.

health-care organization network Kaiser Permanente, offer a broad range of health-care services and can conduct research where patient data is linked across the different health care facilities they operate.

284. Ten countries reported sub-national data linkage activity at the state or region level (table 15). *Canada* reported regular health-related data linkage activity across all the major types of health data in nine of the ten Canadian provinces and involving a unique patient identifying number, the provincial Health Information Number. Canada also reported that these provinces have a broader range of projects using data linkage because the provinces have access to more detailed and comprehensive data than is available nationally.

Table 15. Sub-national infrastructure for data linkage – regional or state-level record-linkage projects by type of data involved

	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Belgium	Yes	Nr	nr	No	No	No	nr	No	dk	nr
Canada	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cyprus	No	No	No	No	No	No	No	No	No	No
Denmark	na	na	na	na	na	na	na	na	na	Na
Finland	na	na	na	na	na	na	na	na	na	Na
France	ns	Ns	Yes	ns	ns	ns	ns	ns	ns	Ns
Germany	No	No	Yes	No	Yes	No	No	No	Yes	No
Israel	No	No	No	No	No	No	No	No	No	No
Japan	nr	nr	Yes	nr	No	nr	nr	nr	nr	Nr
Republic of Korea	na	na	na	na	na	na	na	na	na	Na
Malta	na	na	na	na	na	na	na	na	na	Na
Norway	na	Na	na	na	na	na	na	na	na	Na
Poland	No	No	No	No	No	No	No	No	No	No
Portugal	No	No	Yes	No	No	nr	nr	No	No	Nr
Singapore	na	na	na	na	na	na	na	na	na	Na
Sweden	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Switzerland	nr	nr	nr	nr	nr	nr	nr	nr	nr	Nr
United Kingdom	Yes	nr	nr	Yes	Nr	nr	nr	nr	nr	Nr
United States	dk	dk	Yes	dk	Dk	dk	dk	dk	dk	Dk
Total Yes	5	2	8	4	4	2	3	3	4	2

Note: 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

285. Similarly, *Australia* reported data linkage centres in almost all Australian States and Territories, where data linkage projects are being conducted with a broader array of health and social data than is possible at the national level. Also, a wider array of databases at the State level contain unique person identifying numbers that can be used to support data linkages and data integration. States have been better positioned to advance research based on data linkage due to less complex legislative and organisational restrictions than exist at the national level. The Population Health Research Network, with funding from the Australian government, is building the infrastructure for record linkage in all states and territories and also at the national level.

286. *Germany* reported data linkage project activity at the state level involving cancer registry, mortality, population health survey and other data. Examples include projects related to the development of a mortality index in Bremen State; sickness fund data linkages in Hessen; and linkages involving population health surveys in Augsburg and Essen. The states of Bremen and Hessen are undertaking health-related data linkage studies on a regular basis. These state-level linkages benefit from unique patient identifying numbers. Also, legal provisions allow data from a “morbidity-oriented risk adjustment scheme” of the statutory health insurance system, conducted at the state level, to be analysed at the federal level for health services research and to advance the health insurance system. *Portugal* and *Japan* reported sub-national infrastructure for data linkages within cancer registries.

287. *Sweden* also reported data linkage activity within some of the 21 county councils, such as the Skåne Region and the West Region and that these regions are able to undertake a broader range of data linkage activities than can be undertaken at a national level. For example, the West Region has a primary care register that may be linked.

288. The *United States* reports that each state (plus DC) has a wide variety of data users, data sources and products and may well be undertaking data linkage projects. Further, states have Social Security Numbers that might be used to facilitate linkages along with Medicaid identifiers. Whether or not the states are undertaking a broader range of data linkage activities than are taking place at the national level cannot be determined without an extensive survey. However, the medical and health services literature shows a wide variety of research studies by government, academia, health care quality organizations and industry in the United States.

289. The *United Kingdom* also reports sub-national data linkage activity in the region of Tayside Scotland. This local area does not, however, have a broader range of data linkage projects than are possible at the national level in Scotland. Data linkage activity was also reported for the Torbay Care Trust in England (see Case study 11).

290. Seven countries, *Belgium, Canada, Germany, Israel, Portugal, Singapore and the United States* reported networks of health-care organizations conducting data linkage projects with their own data (table 16). Belgium reported this activity within networks of hospitals. Germany reported this activity for several statutory health insurance funds such as Barmer-GEK, AOK and the Bremen Institute for Prevention Research and Social Medicine, BIPS. Israel reported this activity within four national health funds: Clalit, Leumit, Maccabi and Meuhedet. Portugal reported this activity within Integrated Delivery Services. The United States reported this activity among large health-care insurers including Kaiser-Permanente, Puget Sound, Harvard Health Plan and others. *Singapore* reported that public health-care providers undertake this type of work on an ad hoc basis.

Table 16. Sub-national infrastructure for data linkage – networks of health care organisations record linkage projects by type of data involved

	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	nr	nr	nr	nr	nr	nr	nr	nr	nr	Nr
Belgium	Yes	No	nr	No	No	No	nr	No	No	Nr
Cyprus	No	No	No	No	No	No	No	No	No	No
Canada	Yes	Yes	Yes	dk	Yes	Yes	dk	Yes	Yes	Yes
Denmark	Na	na	na	na	na	na	na	na	na	Na
France	No	No	No	No	No	No	No	No	No	No
Finland	Na	na	na	na	na	na	na	na	na	Na
Germany	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No
Israel	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No
Japan	Nr	nr	nr	nr	nr	nr	nr	nr	nr	Nr
Republic of Korea	Nr	nr	nr	nr	nr	nr	nr	nr	nr	Nr
Malta	Nr	nr	nr	nr	nr	nr	nr	nr	nr	Nr
Norway	No	No	No	No	No	No	No	No	No	No
Poland	No	No	No	No	No	No	No	No	No	No
Portugal	Yes	Yes	Yes	Yes	No	nr	nr	No	No	Nr
Singapore	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No
Sweden	No	No	No	No	No	No	No	No	No	No
Switzerland	No	No	No	No	No	No	No	No	No	No
United Kingdom	No	No	No	No	No	No	No	No	No	No
United States	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total Yes	7	6	5	4	4	5	2	3	2	2

Note: 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

Data linkages for public health research and health-care quality monitoring

291. Most countries with variables within their national databases that would permit data linkages have conducted data linkage projects. Overall, most countries reported record linkage projects involving mortality data, hospital in-patient data, cancer registry data, and prescription medicines data (table 17). Half of the countries also reported record linkage studies with all other major types of data, with the exception of patient experience surveys where data linkage has occurred in only one country.

Table 17. National data is used to undertake record linkage projects

	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	No	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Belgium	Yes	Yes	Yes	Yes	No	No	nr	No	Yes	Nr
Canada	Yes	na	Yes	na	Yes	Yes	na	Yes	Yes	Yes
Cyprus	No	na	Yes	na	Yes	na	na	na	No	No
Denmark	Yes	Yes	Yes	Yes	Yes	na	No	Yes	No	Yes
Finland	Yes	na	Yes	Yes	Yes	Yes	No	Yes	No	Yes
France	nr	Yes	No	Yes	Yes	nr	No	nr	Yes	No
Germany	No	No	No	No	No	No	na	na	No	No
Israel	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Japan	Yes	Yes	Na	Yes	nr	No	nr	nr	Yes	Yes
Republic of Korea	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
Malta	Yes	No	Yes	na	Yes	No	na	No	No	No
Norway	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Poland	No	No	No	No	No	No	No	No	No	No
Portugal	No	Yes	No	Yes	No	nr	nr	No	No	Nr
Singapore	Yes	Yes	No	na	Yes	Yes	na	na	Yes	No
Sweden	Yes	na	Yes	Yes	Yes	na	No	Yes	Yes	Yes
Switzerland	Yes	na	Na	na	Yes	Yes	na	Yes	No	Yes
United Kingdom	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
United States	Yes	Yes	Yes	Yes	Yes	Yes	Yes	dk	Yes	Yes
Total Yes	14	12	13	13	15	10	1	8	10	11

Note: The data custodian should be a national authority and data should be included even when it does not cover 100% of the nation. 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

Table 18. National data is used to undertake record linkage projects on a regular basis

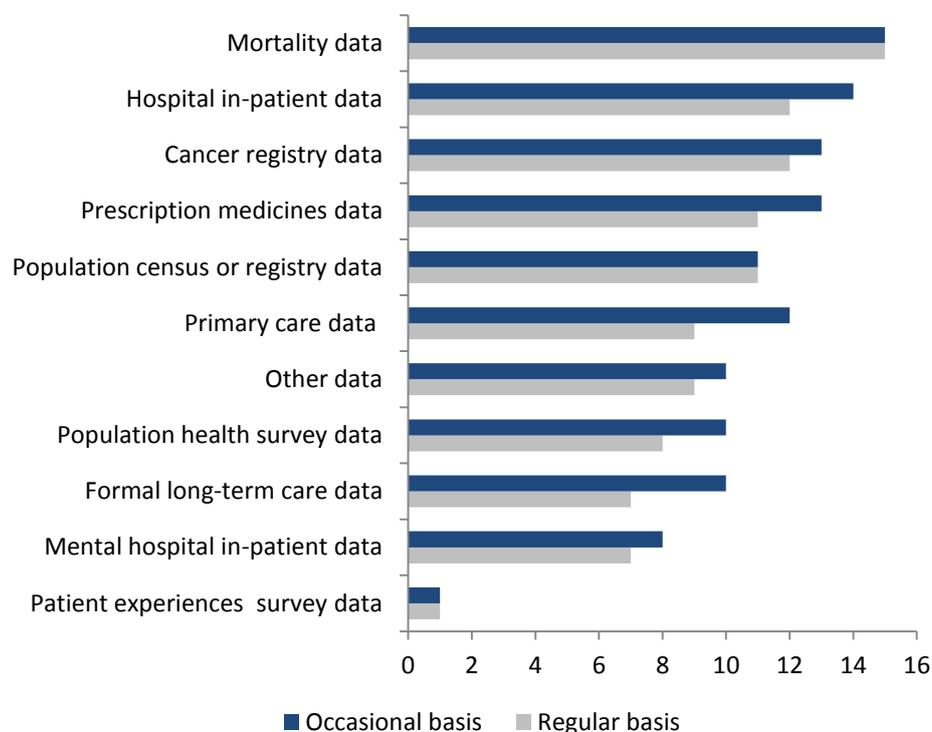
	Hospital in-patient data	Primary care data	Cancer registry data	Prescription medicines data	Mortality data	Formal long-term care data	Patient experiences survey data	Mental hospital in-patient data	Population health survey data	Population census or registry data
Australia	No	Yes	Yes	Yes	Yes	No	No	No	No	Yes
Belgium	Yes	No	Yes	Yes	No	Yes	nr	No	No	Nr
Canada	Yes	na	ns	na	Yes	nr	na	nr	Yes	Yes
Cyprus	No	na	Yes	na	Yes	na	na	na	No	No
Denmark	Yes	Yes	Yes	Yes	Yes	na	No	Yes	No	Yes
Finland	Yes	na	Yes	Yes	Yes	Yes	No	Yes	No	Yes
France	ns	Yes	No	Yes	Yes	ns	No	ns	Yes	Yes
Germany	No	No	No	No	No	No	na	na	No	No
Israel	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Japan	No	No	na	No	nr	nr	nr	nr	nr	Nr
Republic of Korea	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
Malta	Yes	No	Yes	na	Yes	No	na	No	No	No
Norway	No	No	Yes	No	Yes	No	No	No	Yes	Yes
Poland	No	No	No	No	No	No	No	No	No	No
Portugal	No	Yes	nr	Yes	nr	nr	nr	No	nr	Nr
Singapore	Yes	Yes	No	na	Yes	Yes	na	na	Yes	No
Sweden	Yes	na	Yes	Yes	Yes	na	No	Yes	Yes	Yes
Switzerland	Yes	na	na	na	Yes	Yes	na	Yes	No	Yes
United Kingdom	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
United States	Yes	Yes	Yes	Yes	Yes	Yes	Yes	dk	Yes	Yes
Total Yes	12	9	12	11	15	7	1	7	8	11

Note: A regular basis indicates that there is usually a project underway. 1=yes, 0=no, nr – no response, na – not applicable, dk – don't know

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

292. Fewer countries reported undertaking data linkage studies on a regular basis, such that a project was usually underway (table 18). Only mortality data was used regularly to support data linkage project in most countries (15 countries). Twelve countries regularly undertook data linkage studies with hospital in-patient data and cancer registry data and eleven countries with prescription medicines data and population census or registry data. Less common were regular data linkage studies with primary care data (9 countries); population health survey data (8 countries); formal long-term care data (7 countries); and mental hospital in-patient data (7 countries). Only one country reported regular data linkage activity with patient experience data.

Figure 7. Number of countries reporting national data used to conduct record-linkage projects on an occasional and on a regular basis



Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

293. Seven countries have a regular occurrence of data linkage projects involving many national databases (Denmark, Finland, Israel, Republic of Korea, Sweden, the United Kingdom and the United States). In all but one of these countries, a unique patient identifying number is available to facilitate the linkages (table 19). The United States relies more on sets of patient identifying information to establish links. Australia, France, Singapore and Switzerland also undertake projects involving the linkage of several databases on a regular basis. France and Singapore have greater ability to conduct these linkages using a unique patient identifying number, while other identifiers are more often used in Australia and Switzerland. Belgium, Canada, Malta and Norway conduct regular data linkage projects with some databases and use a unique identifying number to undertake the work. Cyprus (5 databases) and Portugal (4 databases) have national databases with patient identifying numbers and/or other patient identifiers, but engage in data linkage on a regular basis with only two of the available databases. Germany, Japan and Poland all have databases with variables that could be used to undertake data linkage projects, but none do so regularly with any of these databases.

294. Countries are divided, with just over one-half engaged regularly in national data linkage studies to monitor health care quality involving their hospital-inpatient, cancer registry and mortality data and less than half of countries with their prescription medicines data. Regular linkage studies to monitor the quality of primary health care, mental hospital in-patient care and formal long-term care remain relatively rare, with only 4-5 countries reporting undertaking such work.

295. *Finland* reports that hospital in-patient data is linked to formal long-term care data on a regular basis to get complete information on institutionalised care; cancer registry data is combined with mortality

data to complete the data with all cancer cases; and data on deaths is combined with the Medical Birth Register and the Register on Congenital Malformations to get more exact information on perinatal and infant deaths. To monitor health care quality, examples include combining registers to get information on the consequences of the use of medicines during pregnancy on the health of newborns; to benchmark hospital health-care quality performance for major diseases and medical conditions, such as stroke and very premature births; and to monitor life-expectancy among patients with severe mental health disorders who have been hospitalized. This last project was a multi-country study with other Scandinavian countries.

Table 19. Distribution of the regular occurrence of health-related record linkage projects by availability of databases with patient identifiers

	Most national data with a unique patient identifying number (UPI)	Most national data with other patient identifiers	Some national data with a unique patient identifying number (UPI)	Few national databases with patient identifiers
Data linkage projects on a regular basis...				
With 7+ national databases	Denmark, Finland, Israel, Republic of Korea, Sweden, United Kingdom	United States		
With 5-6 national databases	France, Singapore	Australia	Switzerland	
With 3-4 national databases	Belgium, Canada, Malta, Norway			
With 2 national databases			Cyprus, Portugal	
None	Japan		Poland	Germany

Source: OECD HCQI Questionnaire, Secondary Use of Health Data, 2011/12

296. *Israel* reports regularly conducting projects involving linkages of mortality data to cancer registrations, long-term care data, mental hospital inpatient data and to data from the census of population. A number of indicators are regularly estimated in order to monitor health care quality. These include thirty-day mortality rates after admission to hospital and after procedures within hospital; rates of rehospitalisation; and deaths after discharge from mental health hospitals. Also regularly undertaken are survival analysis and analysis of leading causes of death using linked databases.

297. The *Republic of Korea* reports an extensive programme of regular health-care quality monitoring using data linkages. Indicators from the linkage of hospital in-patient data to mortality data include thirty-day case fatality for acute myocardial infarction and thirty-day post-operative mortality for major types of surgery. Linkages of mental hospital in-patient data to hospital in-patient data enable monitoring hospital re-admissions for mental-health patients; and further linkage to prescription medicines data enable monitoring health outcomes of prescribing to mental-health patients. Outcomes of prescribing patterns in primary care are monitored through linkage of prescription medicines and primary care databases. Korea also links the cancer registry data to mortality data to assess the relative survival of cancer patients and links long-term care data to survey data on the activities of daily living to estimate the percentage of patients with reduced activities of daily living.

298. *Sweden* also reports a comprehensive programme of data linkages that facilitate health care quality monitoring including regular linkages of all registers to mortality data; linkages of patient registry data to the prescribed drug register; and the cancer register to the patient register. *Denmark* reports a similar data linkage capacity including linkages to more than 50 national clinical quality databases.

299. The *United Kingdom* has the most comprehensive suite of national data among the countries that participated in this study; however, the coverage of these databases is often limited to one or two of the member countries. In Scotland, hospital in-patient data, cancer data, mental hospital in-patient data and mortality data are maintained as a permanently linked database. Prescription data has only recently become available at record level with a UPI in Scotland and will now be regularly linked. Population health survey data is used regularly in research linkages in Scotland. Scotland reports using linkage to monitor outcomes of health care including HEAT targets, such as monitoring readmissions and deaths among coronary heart disease patients. In England, hospital data is linked to mortality data on a monthly basis. England monitors hospital standardized mortality ratios that will be replaced, in future, with a summary hospital-level mortality indicator (SHMI). Cancer incidence data in England is routinely linked to mortality, hospital treatment (surgery and radiotherapy) and, for a proportion of the population, to primary care data. Birth notifications are linked to birth registrations (e.g. to determine prematurity) and to death registrations in England and the cancer registry is linked to mortality data. England produces a thirty-day post-operative mortality rates for patients following colorectal cancer surgery. In England and Wales, the ONS Longitudinal Study (LS) has linked a 1% sample of the population census in 1971, 1981, 1991 and 2001 across censuses and to births, deaths and cancer registrations. The study can be used to understand the distribution of health outcomes by census population characteristics as well as changes in characteristics and health outcomes over time. Wales has linked births to hospital delivery records; and the cancer registry to mortality data. The linkage of hospital in-patient data to other databases is under development.

300. The *United States* reports the regular creation of files linking hospital records, the cancer registry and the population census to mortality data; and population health survey records to mortality data and to health care records for Medicare and Medicaid enrollees. National health care quality monitoring from data linkages includes cancer survival rates, thirty-day mortality following in-patient hospitalizations, and infant mortality.

301. *Australia* reports that mortality data are linked to cancer registry and diabetes registry data on a regular basis. Data from the population census is also regularly linked to mortality data in order to assess under-reporting of Indigenous status on mortality records. Data from the Australian and New Zealand Dialysis and Transplant Registry are linked with mortality data to produce estimates for end-stage kidney disease in support of monitoring quality of care. None of Australia's regularly published Health Performance Indicators, however, currently involve the linkage of databases. There are pilot projects underway that may lead to linkage-based indicators in future. *France* reports regularly undertaking data linkage of primary care data to data on in-patient hospitalisation and to health survey data. France is developing health care quality indicators and does not yet regularly link databases for this purpose.

302. *Switzerland* reports the linkage of hospital in-patient data, mental hospital in-patient data, formal long-term care data, mortality data and the population census. *Singapore* reports linking data on hospitalisations to both primary care data and to mortality data on a regular basis for policy analysis. Singapore also uses data linkages to develop regular health care quality monitoring indicators including annual rates of 30-day mortality inside and outside of hospital following hospitalisations for Acute Myocardial Infarction and Stroke.

303. In *Belgium*, hospital data is regularly linked to hospital expenditure data; and cancer registry data is linked to mortality data, to health insurance nomenclature, to hospital in-patient data and to cancer screening. Databases on cystic fibrosis and neuromuscular disease patients are linked to the population register to capture year of birth, district, sex and deaths. Belgium reports data linkages to produce process and outcome indicators for breast, testicular, and rectum cancers with on-going work on oesophagus and stomach cancers. Linkage has also been used to assess GP performance. Belgium also maintains a linked sample of health insurance records to monitor health care consumption and expenditures.

304. *Canada* also has a number of national databases that are regularly linked using a unique health care identifying number administered by each province. Hospital in-patient data are often linked to other types of health care including emergency room visits; and population health surveys are routinely linked to in-patient hospitalization data and to mortality data. At the provincial level, data linkage activity to inform about population health and health-care quality is extensive.

305. *Norway* regularly undertakes linkages of data from the cancer registry to mortality data and data on prescription medicines to data on hospital in-patients. Data linkages are also used to regularly monitor health care quality. Indicators include annual rates of five-year relative survival after four types of cancer and annual rates of diabetes-related lower extremity amputations. *Malta* regularly links data from the cancer registry to mortality data. Also regularly linked are data on hospitalisations to data within the cancer registry, the congenital abnormalities register and to mortality data. Cancer survival rates are regularly reported to monitor quality of care.

306. *Portugal* reports regularly undertaking projects linking primary care and prescription medicines data. In *Cyprus*, from 2004 on-ward mortality data have been regularly linked to the Cancer Registry in order to obtain the follow up data necessary for cancer survival estimation. Survival calculations, however, have not yet been produced.

307. Overall the outlook is positive in terms of the development of detailed and linkable national or regional data to study the pathways of patients and outcomes of patients. Countries with the strongest national capability include Belgium, Denmark, Finland, Israel, Republic of Korea, Singapore, Sweden, the United Kingdom and the United States. At a provincial/state level, Canada and Australia also have strong capabilities. While not reported in this OECD study, the scientific literature results point to strong national capability in other countries, such as Estonia, as well as strong state/regional capabilities in other countries, such as Italy.

308. This is not to underestimate the challenge inherent in the development of a common study protocol for the estimation of model parameters across countries. Differences in variables, in data coding and in data quality and the organisation of the data present significant challenges to overcome. There are at least two European research projects that will provide valuable insights to future development of CDP 2.0. These are EuroHOPE and EuroREACH.

309. EuroHOPE, the European Health Care Outcomes, Performance and Efficiency project, is a new initiative funded by the European Union and coordinated by the National Institute for Health and Welfare in *Finland* to evaluate the performance of European health care systems in terms of outcomes, quality, use of resources and costs through data linkages (EuroHOPE, 2012). Participating countries all have the necessary health information infrastructure and legal framework to undertake the data linkages and include *Norway*, *Sweden*, *Scotland*, regions in *Italy* and the *Netherlands*. For EuroHOPE, each participating country will link health care administrative databases for in-patient hospitalisations, pharmaceutical data, and cancer registry and mortality data in order to begin to generate indicators of the quality of hospital-based treatments across the whole cycle of care that would be comparable across the participating countries. The five focus areas for the development of these health care quality indicators are acute myocardial infarction, stroke, hip fracture, breast cancer and low birth-weight infants.

310. EuroHOPE aims to develop indicators that could be recommended to the EU for routine reporting, develop methods for international comparative health services research based on data linkages of person-level data; and inform about the policy-relevant drivers of health care quality, including treatment practices, use of medicines and new medical technologies, waiting times, financing, and the organisation of care. EUROHOPE is following the analytical model established by National Institute for Health and

Welfare in Finland. The Finnish project is expanding beyond hospital care to examine primary care, elder care and social services.

311. EuroREACH, is also an EU funded project where representatives from participating countries in Europe and outside of Europe with experience in conducting national data linkage studies are working together to develop a web site. The web site would support researchers within and outside of government in the launch of multi-country health services research based on data linkages. It will draw on best-practice country examples in establishing comprehensive systems of performance measurement in European countries, and in granting research access to patient-level data for the study of health services. It will also report on the person-level databases within countries that could support analysis and research and the steps required to produce population-based linked data sets and use them for multi-national health research projects (EuroREACH, 2011). In order to demonstrate the benefits and challenges of multi-country studies, the EuroREACH project included a demonstration study of diabetes care pathways and outcomes estimated from linked primary care, hospital, pharmaceutical, and mortality databases in three countries (Israel, Finland and Estonia).

312. A common study protocol was developed to identify new diabetic patients in 2003. The patients were identified as those receiving diabetic medications for the first time. The cohort of patients was then followed via data linkage until 2011 for medicines, tests, complications and deaths. The cost of treating the patients in terms of bed days, doctor visits and purchased medicines was also compared. The data were not pooled, instead a parallel study was done by researchers in each country. Data on primary care and laboratory tests was not available for Finland. Costing data was not permitted for Israel. The methodology and results will be submitted for publication to a journal as well as providing information on the Navigator website.

CHAPTER 8: BROADER HEALTH AND ECONOMIC OUTCOMES

313. To evaluate the effectiveness and the comparative effectiveness of different approaches to the prevention and treatment of key diseases, the CDP 2.0 should estimate and project the health and economic consequences of the risk factors and diseases modelled under a baseline assumption of the continuation of current programs and practices. Key outcomes would include:

- Prevalence of risk factors: smoking, alcohol use, physical activity, nutrition, obesity, hypertension, dyslipidaemia and diabetes;
- Incidence and prevalence of diseases;
- Utilisation of clinical prevention, diagnosis, and treatment encounters and practices including use of recent advancements in imaging techniques; pharmacological therapies; devices and surgical procedures used to treat key diseases;
- Health care costs overall and for specific diseases, treatments or health care providers
- Life expectancy and numbers of deaths
- Prevalence of disabilities and disability adjusted life expectancy

314. Further extensions of CDP 2.0 could be considered to explore additional outcomes that have a direct connection to individuals and that provide further evidence of the broader impact of health policies. Such outcomes could include:

- Education
- Participation in the labour force
- Employment earnings

315. These outcomes can be analysed by sex, age country, populations with particular risk factors or with particular diseases, incident cases or advanced cases, or by any other variable included within the simulation. This is because the output of the simulation model is equivalent to a large microdata file for the population with all of the variables included, presented for the current years and for years into the future. The population is representative of the country cross-sectionally and is also longitudinal for individuals; permitting analysis of cohorts. Thus the analysis of the results of the model can be similar to analysis of detailed cross-sectional and longitudinal microdata.

316. The first four health outcomes were reviewed in the preceding chapters. This chapter will focus on numbers of deaths and life expectancy; prevalence of disability and disability-adjusted life expectancy; and further extensions to education, participation in the labour force, and employment earnings.

Deaths and life expectancy

317. Official estimates of deaths, as well as projected numbers of deaths, are developed by Statistical Offices as well as for world countries by organisations including the United Nations and the U.S. Census Bureau. Such organisations provide estimates of the probability of death by sex and single year of age historically and projected for future years. Such data provides a baseline risk death for all individuals within the simulation and is essential to model calibration.

318. As was discussed in the preceding chapter, the degree to which the hazard of death rises for individuals with different characteristics, such as the presence of risk factors, diseases and the experience of different health care pathways must be estimated or, if available, drawn from the published literature.

319. The pilot development of CDP 2.0 to examine the impacts of harmful alcohol use is an example of the approach to the estimation of deaths that will be further developed. For this module, only alcohol consumption elevates or diminishes the risk of mortality from the baseline mortality of the complete population. Alcohol-related mortality effects are implemented using relative risks from the literature. Every individual is subject to a base hazard of death which varies by year, age and sex. This base hazard is adjusted up or down by a relative risk which is a function of the person's current and past drinking behaviour. The form of this function and the manner in which it is applied (e.g. time lags in effect) reproduces the design of the underlying study from which the relative risks were obtained.

320. As each individual within the simulation lives out a complete life, each has a calculated time until death or life expectancy. These durations may be averaged for particular groups in order to compare life expectancies.

Prevalence of disability and disability-adjusted life years lived

321. The measurement of disability-adjusted life years has been adopted by the World Health Organisation as a measure of the burden or health impact of disease. As was raised in chapter 6, all of the key diseases of interest for CDP 2.0 have significant disability-adjusted life years and some have a high impact on DALYs while having a low impact on mortality. Thus the estimation of DALYs in CDP2.0 will provide an important metric to the evaluation of the comparative effectiveness of health policies.

322. There are two possibilities to approach the inclusion of DALYs within CDP 2.0, assignment and estimation. In the assignment method, as simulated individuals develop diseases within the model, they are assigned a DALY value based on the estimates provided by the WHO or the more recent burden of disease study lead by the University of Washington in the United States.

323. The estimation method is more complex, but would yield greater value in terms of policy scenarios. In the estimation method, the distribution of disability within the population is assigned to simulated individuals based on levels determined from population health surveys. Many countries have adopted the WHO standard for the International Classification of Functional Impairment or ICF. Within the ICF framework, disability is determined through the administration of questions regarding the status of individuals in terms of functional impairment and ability to engage in activities of daily living (ADL).

324. A 2007 OECD study was able to report the prevalence of severe disability as measured through ADL questions within the population health surveys of twelve OECD countries (LaFortune, 2007). Further, this report was able to present prevalences of severe disability by chronic condition and other characteristics such as age, sex and level of education.

325. Thus there is an empirical basis for the assignment of levels of disability to individuals as they age within the simulation. Further, progression throughout life to more severe levels of disability may

proceed according to age/sex specific rates for individuals and be increased, as appropriate, for those who develop key chronic health conditions.

326. In so doing, it would be possible to evaluate the change in disability adjusted life years experienced by individuals in response to policies that either postpone disease or that direct patients to more effective treatments.

Education

327. In the published literature, as educational attainment rises, so does health status and life expectancy. However the causality of the relationship is bi-directional, as the presence of disease and disability may detract from educational progression. Educational attainment is not only widely collected on health surveys, it has also been internationally standardised by the OECD. Thus it is possible to compare educational levels among OECD countries. Understanding the progression of educational attainment benefits from longitudinal data; where covariates such as sex, age, disability status, presence of disease conditions and risk factors can be included in the analysis. In so doing, the hazard of progression in education level may be estimated conditional on health and risky-behaviours with a theoretical connection to educational progression, such as alcohol use.

328. Further, as educational levels are associated with engagement in risky behaviours, the estimation of equations to obtain key hazards for the progression of risky behaviours, such as smoking transitions, alcohol consumption transitions or obesity transitions should include educational attainment as a covariate. In so doing, the educational attainment of individuals will become an important factor influencing the engagement in risky behaviours and the consequent development of health problems.

Participation in the labour force and employment earnings

329. There are many more models of life course transitions for the purposes of the evaluation of tax and pension policies than there are for the evaluation of health. As a result, there are many examples of the inclusion of labour-force participation and earnings within microsimulation models that can be adopted for CDP 2.0. Most countries have censuses or full population registries that provide indication of labour-force participation rates by age and sex and the distribution of earnings by age and sex for workers with different labour-force attachments, such as full-year/full-time workers; part-year full-time workers; full year/part-time workers etc.

330. The greatest challenge for the incorporation of labour-force characteristics within CDP 2.0 is the estimation of the relationship between the development of disease and labour-force engagement. This is because it is not common for labour-force surveys to provide detail about health status and chronic conditions and it is not common for health surveys to provide detail about labour-force participation and earnings. The bridge between disease and labour-force impacts may be provided by the estimation of ADL, as discussed above. Labour force surveys should include questions regarding why individuals have left the labour force or have a less than full-time attachment to the labour force and the common categories should include disability as a reason. This is true, for example, of the Eurostat Labour Force Survey. National labour force surveys may have even greater utility for CDP 2.0, as some may measure ADL directly. Further research is needed to evaluate the sources of input data among the countries to be included within CDP 2.0.

331. As was the case for educational attainment, labour-force participation is both impacted by the presence of health problems and may also influence the development of health problems. Again, longitudinal data of labour-force progression that includes measures of health status, disability or diseases could provide insight into the degree to which health influences the hazard of progression over the life course.

CHAPTER 9: EVALUATION OF POLICY ALTERNATIVES

332. Cost-effectiveness analysis is concerned with how to make the best use of limited resources in the health sector. The large and growing literature on the topic is dominated by comparisons of interventions aimed at a particular disease, risk factor or health problem. In practice, however, decision-making at the country level requires a broader set of information, involving comparisons of different types of interventions across the entire health sector - whether they are aimed at treating diabetes, reducing the risk of stroke, providing kidney transplants, or other. Cost-effectiveness analysis is seldom used to address whether existing health resources are allocated efficiently, despite evidence that in many settings current resources do not in fact achieve as much as they could (Tengs et al., 1995). In addition, most studies are context-specific. The efficiency of additional investment in interventions aimed at a given disease depends in part on the level and quality of the existing health infrastructure (including human resources). This varies substantially across settings, as does the mix of interventions available in each setting, which contributes to determining the effectiveness and cost-effectiveness of individual programmes.

333. In response to these concerns, a generalized approach to cost-effectiveness analysis was developed by WHO in order to allow policy makers to evaluate the efficiency of a mix of health interventions and to generalize results across settings. Generalized cost-effectiveness analysis (GCEA) and its implementation via the CHOICE framework (in the broader context of which the first version of the CDP model was developed) allows for an assessment of the efficiency of the current mix of interventions by analysing all interventions and combinations incrementally, with respect to a “null set” counterfactual (Murray et al., 2000; WHO, 2003; www.who.int/choice).

334. The GCEA framework has been applied to a wide range of diseases (including cancers and mental disorders) as well as risk factors (e.g. obesity, unsafe sex, hypertension and smoking). In particular, the work on obesity and NCDs described in [DELSA/HEA/EP\(2012\)3](#), which OECD and WHO jointly carried out, was based on a modified GCEA approach, adapted to the specific needs and context of OECD countries. In this modified approach, the counterfactual scenario is defined as current practice in the relevant setting, accounting for policies already in place. In addition, the modified approach includes analyses of the distributional impact of policies.

335. The CDP 2.0 modelling platform provides participating countries with a virtual population laboratory within which an array of policy questions may be tested in order to compare the effectiveness and cost-effectiveness of various combinations of policy approaches. Revisiting the key questions facing countries with a rising burden of chronic disease that were described in chapter 1, this chapter provides additional detail on how the CDP 2.0 may be used to answer these key questions.

What may be future trends in health care utilisation of populations experiencing single and multiple chronic diseases?

336. The baseline CDP 2.0 model will provide projections of the future use of health care therapies including laboratory tests, prescription medications and in-hospital procedures and can group these costs under categories of care provision (outpatient services, in-patient services, long-term care institutions and home care services). These future utilisation figures are also accompanied by their associated costs measured in current units of local currency, as well as converted to a comparable international standard

using purchasing power parities. Projected costs may also be presented as a percentage of projected GDP or potential GDP, provided GDP projections are available for the country from another source.

337. Unlike most health expenditure forecasting models identified as a result of the OECD comparative analysis, CDP 2.0 provides both a direct projection of future population health and offers results disaggregated by any patient or health system characteristic included in the model. For example, tabulations of health care use and costs by type of care for patients aged 40 who are male and who have a mild activity limitation and who visit their primary care physician once per year can be tabulated.

To address the needs of an aging population, should we invest more in up-stream primary prevention, secondary prevention, down-stream treatments, including new drugs and health technologies, or long-term care provision?

338. CDP 2.0 is designed to address this question, as it provides a coherent, valid and complete picture of individuals' lives including their encounters with the health system and resulting health outcomes. As an illustration, a government could be considering policies to introduce bans on tobacco advertising, to incentivise physicians to counsel patients and provide quit smoking therapies, and to introduce a new lung-cancer screening system via CT scans.

339. To evaluate the advertising bans initiative, evidence is needed from studies of the impact of the policy on smoking behaviour. This evidence may come from any country and, indeed, a consensus of evidence from a systematic review would be a strong indicator of the impact of the intervention. Within CDP 2.0, the intervention is implemented by adjusting hazard of quitting smoking to a new level consistent with the evidence. The model is re-run and results in terms of health outcomes, treatment uses and costs can be compared with a baseline scenario where there is no program initiated.

340. To evaluate the incentive for physicians to counsel patients and to administer therapies to smokers to encourage quitting, as with the advertising ban example, evidence is needed about the impact of the incentive on physician behaviour and the acceptance and adherence rates for patients. Assuming the quit smoking therapy has already been included within CDP 2.0, the hazard of receiving the therapy would be adjusted upward to the new level consistent with the evidence. If there is a new therapy to be evaluated, then evidence about its cost, and its influence on smoking behaviour must first be included within the model.

341. As in the first example, baseline projections, without the incentive, can be compared with new results following implementation. Health outcomes and costs of care before and after implementation can be compared. If the incentive program is based on the patient's prescribed the therapy, then the cost of the incentive program may be compared with the health outcomes and savings from health care costs deferred or avoided due to lower smoking rates.

342. The new lung-cancer screening program may be evaluated by adding this new therapy to CDP 2.0. Input to CDP will be information about the characteristics of patients targeted, for example all smokers or only smokers over age 50, the proportion of physicians likely to prescribe the therapy, the sensitivity and specificity of the screening test (i.e. to explicitly include false positive and false negative results); and the health risks of the test, if any have been identified. Of note, the health care pathways, treatments and costs estimated will include both the benefits of earlier diagnosis of lung cancer and also health care usage consequences resulting from false negative results that postpone diagnosis or false positive results that provoke unnecessary treatments. The model should also include any secondary health impacts of the therapy (such as elevation of risk of other diseases).

343. Each of these evaluations provides powerful information for decision making about the implementation of the policy. Provided that results of all three initiatives appear promising, it is a simple step to experiment with the initiation of combinations of the three policies in order to determine if there is merit in implementation of a combination. While the examples above relate to the implementation of policies where there is evidence of effectiveness, the CDP 2.0 environment can also be used to test hypothesis about the potential effectiveness of policies, where hard evidence is not yet available.

Example of the CDP 2.0 pilot – evaluation of alcohol control policies

344. The pilot of CDP 2.0 focuses on the evaluation of alcohol control policies. A detailed review of the literature was undertaken to uncover and evaluate the strength of the evidence related to a broad suite of potential policy alternatives. Viable alternatives range from policies to control the pricing and availability of alcohol to clinical therapies administered to patients with harmful drinking behaviours. The range of policies investigated, the evidence of their effectiveness and the estimation of the costs of the interventions are described in Annex 4. This review is an essential component of model building.

To what degree does the organisation and financing of care influence future disease burden and health care costs?

345. As previously discussed, the baseline CDP 2.0 model estimates the current organisation of care and the costs of the treatments administered within that organisation. Baseline projections of physician-provided and hospital-provided therapies and services are based on current case provision and projected services are based on an assumption of no policy change; that is, future demands for care for patients with similar characteristics will be satisfied tomorrow as they are satisfied today. As discussed in the OECD comparative review of health expenditure forecasting methods (Astolfi et al, 2012), the provision of health care services is an important driver of health spending and has a strong influence on the recommended care provided by the system. Thus the treatment pathways estimated for CDP 2.0 have been influenced by the existing funding, capital and human resources available within health systems.

346. Baseline projections of service provision and costs from CDP 2.0 may reveal difficulties ahead for the public financing of healthcare. Policy-makers may consider future costs, as a share of projected GDP, to be unsustainable and, therefore, use CDP 2.0 to evaluate the potential impacts on health outcomes, services provided and costs of various alternatives to the status quo. For illustration, we could consider the evaluation of a policy to promote therapies with the lowest cost that do not also reduce health status; reductions in the public provision of some services and a policy to increase private co-payment for services.

347. The CDP 2.0 model parameters governing the proportion of patients following different treatment pathways can be adjusted and results in terms of health-outcomes and costs compared. Thus the first round of analysis could reveal potential reforms to the provision of care that would result in lower costs without compromising health outcomes. The question for policy makers from this type of analysis, is to determine if such a change in health care provider behaviour can be developed and what would be the costs of such an initiative.

348. The second policy alternative is to reduce the public provision of some services, for example, removing some medications from public reimbursement. Such a scenario requires further analysis. In a situation where a generic medication has a similar effectiveness to a de-listed medication, it may be reasonable to assume that all health care providers will recommend the generic drug. As a result, the cost of the drug can be reduced in the counterfactual scenario and the savings compared with the baseline cost estimates. However, if there is no medication available with similar effectiveness to the de-listed medications, individuals without private insurance and with lower earnings may forgo the therapy.

Evidence or assumptions will be needed about the proportion of patients that will continue to use the delisted therapy and those who will not do so. The health and economic consequences of the change in therapy use can then be compared with baseline estimates to determine if such a policy is appropriate.

349. The third policy alternative, which is to increase the co-payment for services, is similar. Individuals without private insurance and with lower earnings may forgo the use of services. Such rationing may well result in higher future health expenditures due to later diagnosis and treatment of health problems. CDP 2.0 is ideally positioned to evaluate the long-term impacts of such policies. However, what is necessary is evidence or assumptions about the impact of the price increase on health-seeking behaviour.

350. As has been undertaken in the evaluation of policies to control harmful alcohol use (see annex 4), evidence to inform these scenarios may be gleaned from reviews of the published literature. Models of individual and firm behaviour, such as the RAND Compare model summarised in annex 2, employ a utility maximisation framework to estimate how families and firms make choices about the offering and the uptake of health insurance pre- and post- insurance reform. Thus, the approach provides some insight into the likely impact on public expenditures of the implementation of health reform. Further work to develop a model of behaviour change in response to a shifting of costs between public and private sectors may be a possible extension of the CDP 2.0 environment in the future.

How do different prevention, treatment, and health care financing options affect different socio-economic groups?

351. As discussed in the previous chapter, CDP 2.0 is an ideal model for the evaluation of the distributional impacts of policy alternatives. Provided that educational attainment, labour-market participation and employment earnings have been included within the framework as described in the previous chapter, then all tabulations of health impacts, health care usage and costs can be disaggregated by level of educational attainment, labour-force attachment and earnings level and the differential impact on different groups may be evaluated. However, as noted above, differential changes in behaviour by socio-economic characteristics in response to policies related to shifting payments to the private sector will be necessary for a reasonable assessment of the policy.

How does the effectiveness of the same policies vary across countries? How effective in my country will be innovative policies implemented in another country? If my country adopted health-care financing policies in use in another country, how would health outcomes and public health care costs change?

352. CDP 2.0 is developed to enable the comparison of health, health care usage and cost impacts of policy alternatives across countries. As the modules within CDP 2.0 are designed to be similar across countries, the same parameters are available for adjustment to execute and compare policy scenarios. However, where additional information is needed to inform the policy scenario, careful analysis of country data or consultation with country experts may be required to make informed decisions about differences in input parameters.

CONCLUSIONS

353. CDP 2.0 has the potential to become the first computer simulation to dynamically model the complex relationships deriving from interactions between socio-economic factors, epidemiological trends, treatment pathways and the organisation and financing of health care. The model would be designed to consider all major NCDs and to compare the effectiveness of policy interventions at all stages of the process of care, from prevention through to treatment and to long-term care. Further, this simulation model will provide a platform for developing and testing policies in different countries and comparing differences in program effectiveness in different contexts. The simulation technology will be extensible to future policy needs and will be freely shared with participating countries, so that they may adopt and enhance the model to make local policy decisions.

354. While many steps have been taken toward CDP 2.0 as described in this report, there are several key issues in the continued development of CDP 2.0 to be resolved include engagement of decision-makers in model development and model use; validation of model results; planning for future developments so that investments in CDP 2.0 meet both short-term and long-term objectives of the OECD; and securing funding.

Engagement of policy makers

355. CDP 2.0 is a policy decision-support tool and will be designed to be accessible to and widely used by policy-makers and researchers in countries throughout the world. Through the Health Committee of the OECD and through the WHO, senior officials of health ministries in countries will be engaged in model development from conceptual planning through to access, use and dissemination of results. Further, through the OECD Expert Group on the Economics of Prevention; technical experts and representatives of health ministries have an opportunity to work together to ensure that the model is methodologically and technically sound, while preserving its policy relevance.

356. Technology exchange and capacity building at the local level are also essential to model development. As work proceeds on the development of health care pathways, analysis of detailed and sensitive health care administrative data will be essential. Partnership, where OECD countries analyse data following a common study protocol will be a prerequisite to model development. CDP 2.0 will be designed to support country-specific policy analysis, as well as analysis by world regions. The model will be freely disseminated and the source code provided to researchers wishing to develop extensions to the model. A new feature of the software platform, ModgenWeb, could be considered as part of the dissemination strategy for CDP 2.0. ModgenWeb enables CDP 2.0 to be disseminated to users over the Internet. Users would not only be able to access documentation, publications and browse model scenarios, they would be able to implement new simulation scenarios in real-time and view graphs and tables of results.

357. Countries wishing to customize the model to meet local policy questions will be able to do so, as the source code of CDP 2.0 will be shared. The OECD and WHO will support countries in using the model through the regular provision of hands-on training workshops and regular webinars for all modellers.

358. The OECD and WHO already have a robust capacity for disseminating information to policy communities. This experience will contribute to a strong knowledge translation plan. The OECD and WHO will consult with countries on the policy needs of highest importance and will develop publications,

using the CDP 2.0 model, to address those policy needs. Based on on-going discussions with countries, it is likely that they will place a high priority on publications informing about effective policies to address rising health expenditures; as well as publications targeting effective management of a selection of NCDs, such as diabetes and cancer. As was already done for the CDP model, the OECD and WHO will engage the public-health, health-services and health economics research communities by publishing research findings in leading academic journals and presenting findings at international conferences. Researchers interested in using the model, will be able to access it over the Internet and to participate in training workshops, webinars and benefit from the other communications mechanisms in place for countries.

CDP 2.0 model validation

359. Validation is essential to our platform's credibility. This project will follow best-practices in model evaluation (Kopec, 2011 and Weinstein, 2001). The plausibility (face validity) of model outputs and the internal consistency of outputs will be evaluated by teams of clinical and policy experts in each country through the networks of the OECD and WHO. Model validation will include uncertainty analysis using the novel approach to whole of model measurement of parameter uncertainty described in chapter 3. In this approach, sensitivity analysis is essentially a systematic component of the model, and parameters that are both subject to greater uncertainty and exerting a strong influence on model results will be identified. Prospective data will be used for external validation. By starting our simulation at t-10 years, we will be able to validate estimates of key output parameters from our simulation platform against empirical measurements from surveys, censuses, registers and administrative databases that were not used to develop the platform. This is the strongest form of external simulation model validation (Kopec, 2011).

360. A strength of this platform, over the development of a single model for one country, is the ability to compare results among different models developed with the same underlying structure and processes. Between model comparisons are easily facilitated to evaluate the impact of differences in parameter values and parameter reliability across countries. It will also be beneficial to compare results for countries with any similar alcohol policy models within their country. In this case, differences in model structure, assumptions, and computer implementation will need to be evaluated in a systematic manner.

361. A further key validation step will be an assessment of the degree to which the countries participating in the platform go on to use it for local policy development. The degree to which the model is used and feedback on its usability will be monitored and evaluated through the networks of the OECD and WHO. Essential to both the development of CDP 2.0 and the dissemination and use of CDP 2.0 is the validation of model. The execution and public reporting of validation results ensures that the model is credible and ready for use to evaluate policy options. The validation of CDP 2.0 will be guided by the principles and steps specific to the validation of population-based disease simulation models (Kopec et al., 2010). These validation principles and steps are outlined in table 20.

Table 20. Recommendations for gathering evidence of model credibility

Evidence from examining model development process

Conceptual model

Underlying theories	The conceptual model should be based on an accepted theory of the phenomena under study. The lack of an adequate theoretical basis is a serious limitation that may compromise the model's credibility.
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Definitions of variables	Definitions of the variables in the model should be justified. Evidence that the definitions are acceptable should be provided (e.g., a reference to published and/or generally accepted clinical criteria or results from validation studies).
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Model content and structure	Evidence should be provided that the model is sufficiently complete and that the relationships between the variables in the model are correctly specified. If some variables or interactions are omitted, explanations should be given why this is acceptable and does not invalidate the results.
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Parameters

Parameters obtained from experts	The process of parameter elicitation should be described (number of experts, their areas or expertise, questions asked, how the responses were converted to a parameter). Plausibility of the parameter value(s) should be assessed by independent experts. Comparisons should be made with other sources (if available) and the differences explained.
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Parameters obtained from the literature	Quality of the source should be ascertained. If available, a published meta-analysis should be used, but a single high-quality study may be an alternative. If information from several sources is combined, the methodology should be explained. Comparisons should be made with alternative sources and discrepancies explained. If alternative sources are not available, plausibility of the parameter values should be assessed by independent experts.
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Parameters obtained from data analysis	Validity evidence regarding the data and methods of analysis should be equivalent to that required for a publication in a scientific peer-review journal. The results should be compared with estimates from other sources and (if not available) expert opinion. Evidence to support generalizability of the parameters to the population modeled should be provided.
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Parameters obtained through calibration	Calibration methodology should be reported in detail (target data, search algorithm, goodness-of-fit metrics, acceptance criteria, and stopping rule). Plausibility of the parameters derived through calibration should be evaluated by independent experts and their values compared with external data (if available).
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Computer implementation

Selection of model type A justification for the selected model type should be provided (stochastic vs. deterministic, micro vs. macro-level simulation; discrete vs. continuous time models, interacting agents vs. non-interactive models, etc). Whether or not the type of model is appropriate should be determined by independent experts.

Simulation software Information should be provided on the simulation software and programming language. The choice of software/language should be justified.

Computer program Independent experts should evaluate the key programming decisions and approaches used. The results of debugging tests should be documented and the equations underlying the model should be made open to scrutiny by external experts.

Evidence from examining model performance

Output plausibility Plausibility (face validity) should be evaluated by subject-matter experts for a wide range of input conditions and output variables, over varying time horizons.

Internal consistency Internal consistency should be assessed by considering functional and logical relationships between different output variables. Internal consistency should be tested under a wide range of conditions, including extreme values of the input parameters.

Parameter sensitivity analysis Model validation should include uncertainty and sensitivity analyses of key parameters. Screening methods should be used to select the most influential parameters for more extensive analysis. If feasible, probabilistic uncertainty/sensitivity analysis is recommended. If parameters are estimated through calibration, the model should be recalibrated as part of uncertainty/sensitivity analysis. In probabilistic models, the Monte Carlo error should be estimated.

Between-model comparisons Comparing the results of different models provides important evidence of validity. Between-model comparisons should take into account the extent to which models are developed independently. If feasible, the impact of different elements of model structure, assumptions, and computer implementation on the results should be evaluated in a systematic fashion.

Comparisons with external data Ideally, prospective data should be used for external validation. If prospective validation is not feasible, ex-post forecasting and backcasting based on historical data should be used to support predictive validity. Data used for validation should be different from data used in model development and calibration. Cross-validation and bootstrap methods can be considered as an alternative. Criteria for model acceptability should be specified in advance.

Quality of decisions Quality of decisions based on the model should be evaluated and compared with those based on alternative approaches to decision making, using both subjective and objective criteria.

Model usefulness Uptake of a given model by policy makers should be monitored to assess model usefulness.

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Planning for future developments

362. The CDP 2.0 developments described in the previous chapters will provide estimation of the future use of health care resources and expenditures that derive from the health of the population. This is a health care demand driven approach to understanding health system impacts. Under different policy scenarios, it would be possible to estimate the health care treatments provided and the organisations providing the treatments. Thus information on future demand can feed estimates of the necessary supply of care to meet the demand. Further independent projections of the supply of health care services could be tested for their impacts on health and care utilisation within CDP 2.0 by constraining or rationing available services and treatments.

363. Development work on a modelling framework for the supply of health services would complement CDP 2.0. This could be done, initially, by identifying the relevant macro dimensions that can be used to describe the distinctive features and constraints of a health system in terms of financing and organizational arrangements. Previous OECD studies describing health system characteristics (Paris *et al.*, 2010 and Paris *et al.*, forthcoming) and the OECD health database (2012) may provide a starting point for this work. Subsequently, relevant literature will be reviewed to identify how policy interventions modify provision and delivery of healthcare and, ultimately, population health. Significant previous work in this area includes, for instance, the RAND COMPARE model (see annex 2) and literature on how financing arrangements modify the behaviour of hospitals (Duckett SJ, 1995) and physicians (Armour *et al.*, 2001). The two different components (i.e. ‘supply’ and ‘demand’) should be complementary, so that outputs of one can be inputs to the other and vice versa, depending on the health policy scenarios under evaluation.

364. A further desirable extension of the CDP model would include the estimation of the economic impact of preventing chronic diseases on the wider economy. The epidemiology of chronic diseases may affect the population cohort aged 40 to 70 and in so doing have a big impact on the labour market and, consequently, on the wider economy.

365. Micro-simulation models, such as the CDP, are well situated to estimating the number of years individuals might spent with risk factors as they can account for the population heterogeneity as well as model individual histories. However, microsimulation models are not conceived to explicitly include the broader economic environment in which the virtual individuals live. This aspect is better modelled by macro-economic models as, for instance, computable general equilibrium models which are able to specify the economy in terms of several entities, including households, producers and governments.

366. An option worth exploring is to link the CDP model to a macro-economic model generating a system able to link effects of prevention policies on individuals with the entire economy. A notable example in that direction is the NATSEM-CHE-CoPS Micro-Macro Chronic Disease Prevention Model (see annex 2) which combines a microsimulation approach to model the effects of population health initiatives to tackle diabetes with a macro model simulating the labour market. In particular, the linkage is performed through a bottom-up process according to which the decreasing prevalence of people projected to have type 2 diabetes in response to interventions leads to a change in the aggregate labour supply which then permeates through the Australian economy.

Funding

367. Funding from the European Commission and contributions from interested countries have enabled the CDP model development that has taken place thus far. Further progress toward CDP 2.0 will require the engagement of countries as partners in the selection of policies to test and in the extraction and analysis of country-specific data to parameterise country models. Development of sophisticated disease simulation model does not fit well with the development cycle of most projects undertaken by the OECD, which typically have a two-year duration from initiation to publication of results. Whether there will be sufficient interest in the development of a decision-support platform will depend both on the strength of the interest in model development among countries; agreement to appropriate time frames; and the ability of the OECD to partition model development to enable short-term outcomes while making incremental progress toward longer-term objectives for model functionality.

368. Once developed, maintenance of the model is a lesser but still important issue. Essential to the continued relevance of CDP 2.0 will be selecting projects that enable new policies to be evaluated and, in so doing, the underlying model parameters to be refreshed.

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ANNEX 1: BACKGROUND TO MICROSIMULATION IN HEALTH AT THE OECD

Introduction

369. The demand for a quantitative assessment of the impacts of health policies, emerging from many OECD governments, was addressed for the first time using a computer-based simulation approach in the context of the economics of prevention programme. The primary goal of this activity, which started in 2007, was to provide governments with evidence, not otherwise available from experimental and observational studies, of the effectiveness and cost effectiveness of public health interventions aimed at tackling behavioural risk factors for chronic diseases. In the years 2007-08, the main focus of the OECD economics of prevention work was on obesity, therefore modelling started around policies to improve aspects of diet and to increase physical activity. After an initial phase, during which the CDP micro-simulation model was developed and populated with relevant input data, a series of applications were carried out to simulate the epidemiology of risk factors and chronic diseases, and the impacts of alternative prevention policies, on a range of countries covering roughly two thirds of the world population. In 2010, worldwide modelling experts met in Paris to discuss the state of the art of modelling in health, health care and health policy; to assess progress made with the development of the CDP model; and to outline possible strategies for further future developments in the use of computer-based modelling in the context of OECD work on health. The conclusion reached at the 2010 workshop was that a long-term health policy modelling strategy could be built upon the foundations laid with the development of the CDP model. A new development phase therefore started in 2011, which is intended to lead to new model, or set of models, encompassing a broader range of risk factors and chronic diseases, as well as a detailed representation of typical health care pathways for those conditions.

370. The remainder of this paper outlines the main steps in the development of the existing CDP model, the key goals of further developments foreseen in OECD health policy modelling work and progress made so far in the pursuit of such goals.

Early development of the CDP model

371. Following a mandate received from the Health Committee and a grant received from the European Commission (DG Sanco), the OECD started a project on the economics of chronic disease prevention in 2007, which involved an assessment of the efficiency and distributional impact of interventions to prevent chronic diseases linked to unhealthy diets and sedentary lifestyles¹³. The latter was jointly undertaken with the Health Systems Financing group at the World Health Organisation (WHO), and was designed to broadly follow WHO's CHOICE (CHOosing Interventions that are Cost-Effective) framework, and to rely on a computer-based microsimulation approach for the assessment of policy options. In this work, the OECD had a primary role in designing the study, collecting data and conducting analyses, while the WHO led the development of the CDP micro-simulation model, upon which the analysis was based. The CDP model was designed to include two components: an epidemiological model aimed at assessing the efficacy of policy interventions on a target population, in terms of improved health and longevity, and an economic model aimed at assessing the effects of policy interventions on public expenditure.

¹³ Detailed information on the CDP model and its use in the context of the initial OECD economics of prevention project can be found in Sassi *et al.*, 2009, and Cecchini *et al.*, 2010.

The epidemiological model

372. The epidemiological model, initially named *PMLifestyle*, was designed to analyse how lifestyle risk factors may influence the probability that individuals develop chronic diseases. Written in ModGen¹⁴, CDP is a dynamic stochastic microsimulation model¹⁵ able to simulate population and epidemiological dynamics over a specified period of time for each country or region analysed. Simulation outputs include births, deaths and the incidence and prevalence of risk factors and chronic diseases.

373. The PMLifestyle/CDP design relies on the epidemiological concept of a “causal web” of risk factors. According to this concept, patterns of health and disease can be linked with a network (or “web”) of interacting risk factors. Some of those risk factors, identified as *proximal* risk factors, represent an immediate vulnerability for a particular condition or event, while others, labelled as *distal* risk factors, represent background characteristics that may put individuals at risk for an event or condition at some point in their lifetime. In a complex causal web, additional layer(s) of (*intermediate*) risk factors may exist between those labelled, respectively, as distal and proximal.

Diseases

374. The CDP model explicitly accounts for three groups of chronic diseases (see figure 8 below):

1. Stroke;
2. ischemic heart disease; and,
3. cancer (an aggregate category consisting of lung, colorectal and breast cancer).

The probability of developing those diseases is influenced, directly or indirectly, by the risk factors.

375. The model accounts for mortality from all causes of death and assumes that mortality rates associated with diseases that are not explicitly modelled remain stable at the rates recorded in the relevant populations. Incidence and prevalence of disease in the population of a specific country are matched to observed (marginal) distributions of risk factors via a calibration procedure, which ensures that the observed distributions are mutually compatible and consistent.

Risk factors

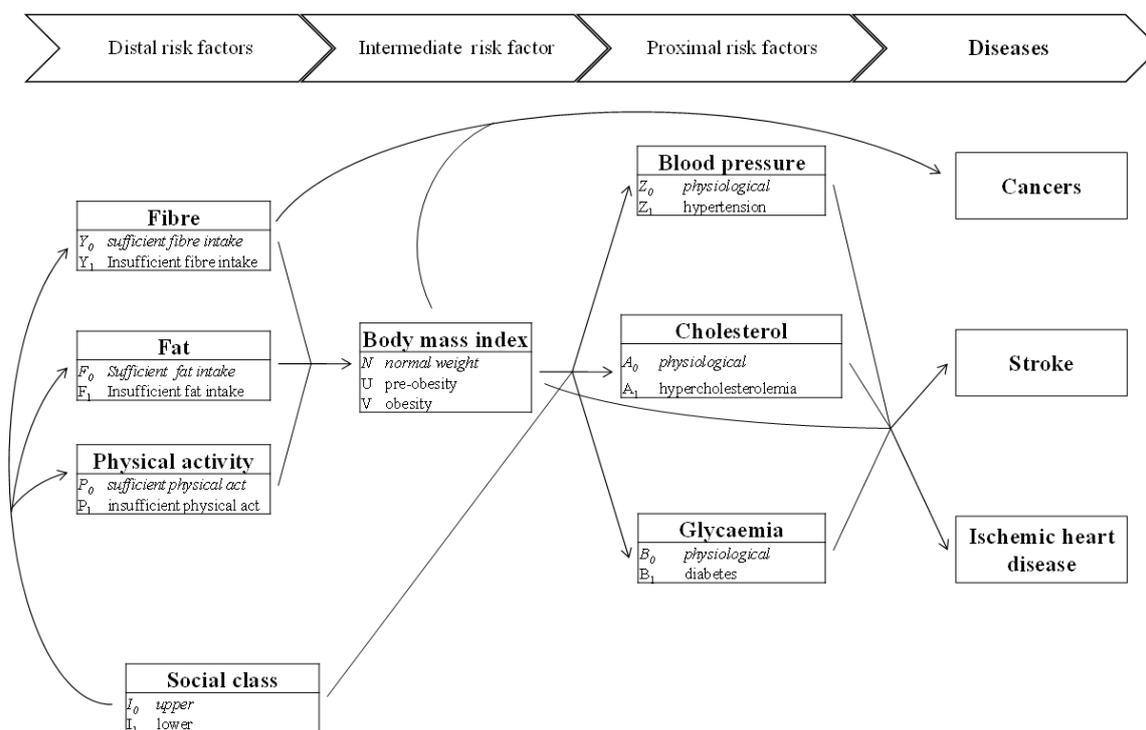
376. Based on the causal web approach, risk factors with a potential to affect the development of chronic diseases are grouped into the above three categories (proximal, intermediate and distal). In the original CDP model each group included the following (see also figure 8 below):

- proximal risk factors: high blood pressure, high blood glucose (i.e. "diabetes") and high cholesterol;
- intermediate risk factors: body mass; and,
- distal risk factors: physical inactivity, levels of fat and fibre in the diet.

¹⁴ Modgen is a C++ pre-compiler created by Statistics Canada for the development of microsimulation models (www.statcan.gc.ca/spsd/Modgen.htm).

¹⁵ The term "microsimulation" refers to the fact that the model separately represents the lifetimes of many different individuals; while the term "stochastic" indicates that the model employs random variation.

Figure 8. Overall casual web in the CDP model



Interventions

377. Interventions for which evidence of effectiveness at the individual-level was available in the literature were included in the studies. On the other hand, interventions for which evidence was limited or not available were not considered, even if they were part of the public debate about chronic disease prevention.

378. Interventions whose efficacy was assessed in the various applications of the CDP model may be grouped into the following three categories:

- a) health education and health promotion, including:
 - i. mass media campaigns;
 - ii. school-based interventions;
 - iii. worksite programmes;
- b) regulation and fiscal measures, including:
 - iv. fiscal measures altering the prices of healthy and unhealthy foods;
 - v. government regulation or industry self-regulation of food advertising to children;
 - vi. mandatory food labelling; and,
- c) Primary-care based interventions, including:
 - vii. counselling of individuals at risk in primary care;
 - viii. physician and dietician counselling of individuals at risk.

In addition to the above interventions, a number of packages combining different sets of interventions were assessed in CDP-based analyses.

379. The assessment of the effectiveness of the interventions at country or regional level was based on the following three criteria:

1. efficacy in changing behaviours and risk factors;
2. coverage (i.e. share of the population covered by the intervention); and,
3. time to steady state.

380. In practice, while the effectiveness of interventions at the individual-level is an exogenous parameter retrieved from the literature, the impact of each intervention at country or regional level is estimated in CDP simulations. The resulting effectiveness of the intervention for the whole population varies depending on the specific characteristics of each population analysed. For instance, country-specific information was used to establish potential population coverage (e.g. the proportion of the population working for large employers in worksite interventions) and to adapt intervention effects to the distribution of risk factors observed in the specific population (e.g. rates of television viewing by children in connection with interventions to regulate food advertising to children).

Exogenous information/input data

381. The CDP model requires a series of epidemiological input data by gender, class of age (0 to 100) and socio-economic status. A first group of parameters allows the software to model population changes over time. This includes global mortality, fertility and the demographic structure of the population. A second group of parameters relates to the three levels of risk factors (i.e. distal, intermediate and proximal). This group includes the following epidemiological parameters: prevalence, incidence of new cases, remission rates, and relative risks (RRs) for higher level risk factors. A third and last group of parameters is used to model diseases. This includes prevalence, incidence rates, remission rates, relative rates (RRas) of disease for different risk factors, and case-fatality hazards (risk of dying of a disease for individuals who have that chronic disease).

Cost model

382. For each intervention analysed in the epidemiological model, a corresponding cost model is developed, to evaluate the net effect of each intervention on public expenditure. The cost model estimates the difference between the expenditures emerging and those averted as a consequence of the adoption of specific interventions. Intervention costs are evaluated using the standard WHO-CHOICE “ingredients” approach, and result from the sum of the following three components:

1. costs at the target level (e.g. health professionals’ working time, equipment, etc.);
2. program costs (e.g. planning and enforcing at the central level); and,
3. training costs (i.e. education of personnel involved in the intervention).

Savings were estimated on the basis of possible reductions of medical expenditures and increases in productivity (e.g. fewer days of work lost due to associated disabilities).

383. OECD/WHO adopted a modified version of the generalised CEA approach used in previous CHOICE analyses. The main difference between the two approaches is that while the counterfactual scenario adopted in CHOICE is defined in terms of what would happen to the health of a population if all interventions currently provided were stopped or had never existed, in OECD/WHO analyses the

counterfactual is a situation in which no prevention is systematically delivered but chronic diseases are treated as they emerge with conventional medical means available in the relevant countries.

384. A further difference relative to the traditional CHOICE approach is that the OECD/WHO model was specifically designed to assess the distributional impacts of interventions on costs and health outcomes, in addition to their overall health impacts and cost-effectiveness.

Main assumptions

385. The following assumptions were consistently used in CDP model applications:

- a. a time perspective of 100 years was set in order to capture the full effects of all interventions, including those targeting young children;
- b. the effects of interventions cease once adults are no longer exposed to the interventions;
- c. for children, instead, a 50% reduction in the effects of interventions starting from the first year after the end of the intervention;
- d. in line with most current practice in cost-effectiveness analysis, both future costs and effects are discounted at a rate of 3% per year;
- e. the impact on disability and premature death for the diseases considered was expressed in disability-adjusted life years (DALYs), but age weighting is not used;
- f. the effects of interventions on health expenditure estimated by CDP include only changes in expenditure for the diseases and the risk factors explicitly included in the model, that is: hypertension, hypercholesterolemia, diabetes, cancer, ischemic heart diseases and stroke.

Applications of the CDP model

386. The CDP model was used to simulate the epidemiology and the impact of interventions to improve diet and increase physical activity in a wide range of countries and WHO regions. In its first application in 2009, the CDP model was used to assess a range of prevention policies in the EUR A WHO Region¹⁶. A second application included a selection of individual OECD countries (Canada, Italy, Japan, Mexico, and UK, the latter limited to England), while a third application covered a number of emerging economies (Brazil, South Africa, China, India, and the Russian Federation). Finally, analyses were undertaken on the WHO AMR-B and SEAR-D regions. Although the architecture of the model was kept unchanged throughout the various applications, analyses were contextualised by adapting the interventions assessed and combinations thereof, as discussed below.

First application: WHO EUR-A Region

387. The first analysis carried out using the CDP model focused on the WHO EUR-A region and aimed at assessing the efficiency of policy options in the above three groups, aimed at tackling unhealthy lifestyles and related chronic diseases.

Main findings

388. Co-operation among stakeholders, leading to the implementation of an appropriate mix of interventions, was found to be a strategy that might meaningfully reduce the size of the obesity problem

¹⁶ The EUR A region includes: Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom.

and associated chronic diseases. Evidence generated as part of CDP analyses on the WHO EUR-A region suggested that no single stakeholder would be in the position of trigger fundamental changes in the individual and collective behaviours that produced the obesity epidemic. At the same time, no single intervention, however effective and broadly based it may be, could reduce significantly the scale of the obesity problem.

389. The preventive interventions evaluated were generally found to have favourable cost-effectiveness ratios, relative to a scenario in which no systematic prevention is undertaken and chronic diseases are treated once they emerge. This finding added to evidence from previous studies, indicating that interventions in at least four areas may be cost effective: counselling of individuals at risk in a primary care setting; community-based counselling; school-based interventions; and interventions on the physical environment.

390. The analysis also emphasised that interventions targeting younger age groups are unlikely to have significant health effects at the population level for many years. The cost-effectiveness profiles of such interventions may be favourable in the long-term, but remain unfavourable for several decades at the start of the interventions. Preventive interventions do not always generate reductions in health expenditure, when the costs of treating a set of diseases that are directly affected by diet, physical activity and obesity are considered. This is mainly because interventions tend to postpone the onset of diseases, rather than prevent diseases altogether, and to extend life with diseases. Individuals tend to live longer with chronic diseases, when they benefit from prevention, and survive long enough to experience other diseases which they would not have experienced otherwise. This translated into improved health outcomes and longevity, overall, but with limited changes in health expenditure.

391. The distributional impact of preventive interventions is generally favourable; with reductions both in overall inequalities in age at death, and in inequalities in life expectancy and disability adjusted life expectancy between socio-economic groups.

Second application: individual OECD countries

392. A second set of CDP-based analyses focused on five individual OECD countries – Canada, England, Italy, Japan and Mexico. This group included countries with some of the highest rates of obesity in the OECD area, such as Mexico and England, as well as the country with the lowest rate, Japan, with Italy and Canada faring, respectively, in the lower and upper sections of the ranking. The results of these analyses formed part of the OECD report “Obesity and the Economics of Prevention: Fit not Fat”, published in view of the 2010 OECD Health Ministerial.

Main findings

393. The second study confirmed most of the finding previously obtained. Specifically, interventions were found to have favourable cost-effectiveness ratios; the use of multiple-intervention strategies was shown to significantly enhance overall impacts, relative to those of individual interventions. Multiple interventions considered for OECD countries included: mass media campaigns, food labelling, self-regulation of food advertising, school-based interventions and physician counselling in primary care. Interventions delivered outside the health care sector were shown to have the most favourable cost-effectiveness profiles.

394. Further findings included the following. Counselling of individuals at risk in primary care has the largest health impact, but is also the most expensive intervention of those assessed in the analysis. Interventions, especially those aimed at children, may take a long time to make an impact and reach favourable cost-effectiveness ratios. Impacts on health expenditure are relatively small (in the order of 1%

of original expenditures for the relevant diseases), intervention costs exceed health care cost savings for most interventions. The distributional impacts of interventions are mostly determined by differences in morbidity and mortality among socio-economic groups. Fiscal measures are the only intervention producing consistently larger health gains in the less well-off. The distributional impacts of other interventions vary across countries.

Third application: Emerging economies

395. A paper published in the Lancet, examined a range of measures to combat obesity in OECD key partner countries (Brazil, China, India, Russian Federation and South Africa, England and Mexico were included for comparative purposes). In this application, the structure of the model was slightly modified by turning off the socioeconomic dimension of the causal web of risk factors, because of the lack of relevant information in the countries concerned. The prevention strategies evaluated were also adapted to the countries included in the analysis, and additional parameters were introduced to account for a more limited health care coverage in some of those countries.

Main findings

396. As in previous studies, also in this case it was found that a strategy combining several interventions would generate substantially larger health gains than would individual interventions, often with a favourable cost-effectiveness profile. Price interventions and regulation can produce the largest health gains in the shortest timeframe. Interventions in primary care can be very effective in countries with less capacity constraints.

397. Regulation of food advertising to children can be more effective and efficient than can school-based health promotion.

398. Private-sector initiatives might contribute to tackling some risk factors while alleviating the burden on public-sector budgets, but more evidence of their effectiveness is needed.

Fourth application: Latin America and South-East Asia

399. The OECD participated in the United Nations High-Level Meeting on Non-Communicable Diseases, held in New York in September 2011. The UN event brought the current epidemic of chronic diseases to the attention of world leaders. The OECD made important contributions to the preparatory work leading up to the New York event and to the background documents for the High-Level Meeting.

400. In addition to the findings of previous model applications, used to identify possible best-buy strategies in the area of dietary improvement, new analyses were undertaken to gain further insights on the potential role for programmes to increase physical activity in the context of chronic disease prevention. The model used on this occasion was slightly modified compared to its original version in order to provide a more comprehensive coverage of the effects of physical activity on health and longevity.

401. Simulations were carried out on two WHO regions in Latin America (Amr-B) and South-East Asia (SearD). The set of interventions assessed was also expanded to include the promotion of physical activity at the community level and support to active transport. These were considered alongside interventions assessed in previous analyses, such as counselling in primary care, promotion of physical activity on the workplace, and promotion of physical activity in schools.

Main findings

402. Physical activity was found to reduce the risk of NCDs and to improve health outcomes and longevity. Promoting physical activity through the media (in combination with a healthy diet) was estimated to be a cost-effective, low-cost and highly feasible option. Other strategies were found to provide good health returns, but only at a higher cost. The findings of OECD analyses on the impacts of policies to improve diet and increase physical activity were used to support evidence statements in WHO's "Best buys" background paper to the UN High-Level meeting. The relevant sections of the summary table presented in that paper are replicated in Table 21 below.

Table 21. Interventions to tackle noncommunicable disease risk factors: identifying 'best buys'

Risk factor	Interventions / actions	Avoidable burden	Cost-effectiveness (US\$ per DALY prevented)	Implementation cost (US\$ per capita)	Feasibility (health system constraints)
(DALYs, in millions; % global burden)	(* core set of 'best buys')	(DALYs averted, millions)	[Very = < GDP per person; Quite = < 3* GDP per person Less = >3* GDP per person]	[Very low = < US\$0.50 Quite low = < US\$ 1 Higher = > US\$ 1]	
Unhealthy diet (15-30m DALYs; 1-2% global burden)c	Reduce salt intake * Replace trans fat with polyunsaturated fat * Promote public awareness about diet *	Effect of salt reduction: 5 m DALYs averted Other interventions: Not yet assessed globally	Very cost-effective	Very low cost	Highly feasible
	Restrict marketing of food and beverages to children Replace saturated fat with unsaturated fat Manage food taxes and subsidies		Very cost-effective? (more studies needed)	Very low cost	Highly feasible
	Offer counselling in primary care Feasible (primary care) Provide health education in worksites		Quite cost-effective	Higher cost	Feasible (primary care)
	Promote healthy eating in schools		Less cost-effective		Highly feasible
Physical inactivity (> 30m DALYs; 2.1% global burden)	Promote physical activity (mass media) *	Not yet assessed globally	Very cost-effective	Very low cost	Highly feasible
	Promote physical activity (communities)		Not assessed globally	Not assessed globally	Intersectoral action
	Support active transport strategies Offer counselling in primary care		Quite cost-effective	Higher cost	Feasible (primary care)
	Promote physical activity in worksites Promote physical activity in schools		Less cost-effective		Highly feasible

Source: WHO 2008

ANNEX 2: DESCRIPTIONS OF MODELS INCLUDED IN THE 2011 AND 2012 OECD WORKSHOPS

403. The OECD Workshop in November 2010, involved selected modellers with expertise in the world's most sophisticated computer-models for the evaluation of health policies. The subsequent comparative review of health expenditure forecasting methods, conducted in 2011/12 provided further insight into innovative decision-support models for the evaluation of health policies (Astolfi et al, 2012). The most innovative models from that review were featured as part of background analysis for a second workshop held in November 2012 involving policy-makers in both health and finance communities as well as a selection of modelling experts. Lessons learned from examination of the different modelling approaches have influenced the development of CDP 2.0. This annex presents a summary of innovative models from these exercises.

Population Health Model (POHEM)

Organisation: Statistics Canada

404. The Population Health Model (POHEM) projects the potential future health and health-care utilisation of particular chronic diseases (lung, breast and colorectal cancer; osteo-arthritis; and cardiovascular disease and diabetes) (Statistics Canada, 2011). POHEM is not developed to generate projections of total health expenditures, but rather provides a platform for the evaluation, through scenarios, of the health and health care system impacts of new prevention or treatment policies targeted to specific risk factors or to particular diseases. For example, the new POHEM Cancer Risk Management Model, projects total public health expenditure and other economic impacts (labour-force participation and taxes and transfer payments) of lung, colo-rectal and cervical cancers at baseline and in response to policy scenarios (Canadian Partnership Against Cancer, 2011).

405. Statistics Canada leads POHEM development and works in partnership with the Canadian Partnership against Cancer, the Public Health Agency of Canada, and other health organisations and experts.

Policy questions the model has supported

406. POHEM supports testing a wide-range of user-defined policy scenarios related to prevention and treatment policies. Example policy questions include:

- What would be the impact on public acute care and home care expenditures of an out-patient/early discharge strategy for breast cancer surgery patients? (Will, BP et al. , 2001)
- What may be the potential health and public health-care expenditure impacts of adopting faecal-occult blood testing as a screening technique for colorectal cancer? (Maroun J et al. , 2003)
- What would be the additional treatment costs if indications were expanded for the use of a more expensive treatment (drug X) compared to current treatment practice? (Canadian Partnership Against Cancer, 2011)

Class of forecasting model

Microsimulation (dynamic)

Forecasting method

407. POHEM focuses on individuals and builds a virtual population that represents Canada (Wolfson MC, 1994). Individuals experience health-related events, such as developing risk factors and disease, experiencing treatments, gaining or losing health and eventually dying. Risk factors are explicitly modelled, including changes in smoking behaviour, body mass, hypertension and others.

408. Recent cancer models include detailed diagnostic and treatment pathways for patients at various stages of disease progression; the costing of treatment pathways from the bottom up including all aspects of care received. This enables projection of total public expenditure on cancer diagnosis and treatment. The models also include the estimation of other economic impacts, such as the individual's capacity to continue working during treatment and impacts of cancer on individual's earnings, income and consumption taxes.

409. POHEM is a dynamic microsimulation model in continuous time based on a monte-carlo process. Hazards compete to determine the time of the next event in a person's life. The occurrence of an event effects a change in the state of the individual's life. Events compete to be the next to occur. The monte-carlo process involves the generation of a random number that influences the occurrence of events and allows outcomes to vary from one individual to another. The dynamic framework ages the individual through their lifecycle and allows for time spent with multiple health conditions.

410. POHEM integrates data distributions and equations from a wide range of sources including nationally representative health surveys, particularly the Canadian Community Health Survey and the National Population Health Survey; cancer registries; hospitalization databases; vital statistics; censuses of population; health-care costing databases; as well as parameters in the published literature.

Health expenditure drivers

- Population dynamics
- Distribution of health risk factors (e.g. smoking, obesity, hypertension, cholesterol)
- Disease prevalence and severity
- Utilisation of diagnostic tests and health-care therapies
- Cost of diagnostic tests and health care therapies

Projected variables and measurement units

411. Projects the future incidence and prevalence of chronic diseases (breast, lung and colorectal cancers, diabetes, acute myocardial infarction and osteo-arthritis); risk factors associated with these diseases; the prevalence of use of diagnostic tests and treatments (primary care and specialist visits, out-patient care, in-patient hospitalisations and palliative care); and the estimated public expenditure on these diagnostic tests and treatments.

412. Public expenditures on diagnostic tests and treatments are projected in total and by sub-components such as sex, age group, region, and organisation of care. Recent cancer models project expenditures in constant 2008 dollars. POHEM also supports projection of cost-effectiveness and cost-

utility measures such as cost per life year gained and cost per quality-adjusted life year gained. POHEM incorporates official population projections of Statistics Canada. The time horizon of the projections is usually twenty to twenty-five years with recent projections from 2011 to 2030.

413. Tests “what-if” scenarios, such as the impact of potential breakthrough technologies as well as changes in lifestyles and in the health care system—by exploring changes in the parameters of the model.

Assumptions, sensitivity analysis and criteria to assess the forecasting method

414. POHEM explicitly models the potential future health status and healthy life expectancy of the population at baseline and in response to policy scenarios. This differs from other models where future health status is incorporated as a model assumption. POHEM also enables the testing of scenarios of the potential future impact of a wide variety of technological developments, such as new medications, medical tests and other therapies. This contrasts with other models that do not explicitly include technological change.

415. POHEM does not consider several drivers of health expenditure observed in other models. Administration and infrastructure costs that may be needed to meet projected health care demand are not included. Impacts of new technologies can be tested as model scenarios, however, the baseline model does not explicitly include technological change as a driver of future health care demand and costs are projected in constant prices. Similarly, the model does not consider the impact of national income or health-care budgets on demand for health-care services. The cancer model does consider the impact of developing disease on labour-force participation. It excludes, however, impacts of changes in demand for care and labour-force participation on the overall economy.

416. Elements of model validation include the development of a conceptual model based on underlying evidence and theories; development of definitions of variables consistent with the scientific literature; and assessment of the appropriateness of parameters through comparison across different sources of parameters and consultation with experts. Once developed, POHEM models undergo calibration, internal and external model validation; uncertainty and sensitivity analyses; and face-validity evaluation. Further, POHEM models generally begin in the recent past to provide a number of years during which forecasted results can be compared with observed values.

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Future Elderly Model (FEM)

Organisation: RAND

USA *FEM (Medicare RAND)*

417. The Future Elderly Model (FEM) projects the potential future Medicare, Medicaid, and total medical and drug expenditures of the population aged 51 and older in the United States, given current demographic, health status and disability trends (RAND, 2011). FEM simulates and evaluates how future trends may change in response to potential changes in the health care environment including health status trends, medical innovations, reduction in chronic diseases and reduction in the number of elderly who are obese or who have other risk factors (Goldman, D.P, B. Shang, J. Bhattacharya et al., 2005).

418. The Future Elderly Model was developed jointly by the RAND Corporation and the University of Southern California, with collaborators from Harvard University and Stanford University. FEM development has been sponsored by the Centers for Medicare and Medicaid Services (CMS), the National Institutes of Health (NIH), Pfizer, the McArthur Foundation and the US Department of Labor (RAND, 2011).

Policy questions the model has supported

419. FEM supports testing a wide range of user-defined scenarios. Example policy questions include:

420. What may be the future health status and health care expenditures related to an aging population? How would these forecasts change if the health status of the elderly were to improve? (Chernew, M.E., D.P. Goldman, F. Pan and B. Shang, 2005)

421. What will be the potential impact on health and health care expenditures for the future elderly if different medical technologies or innovations are introduced? (Shekelle, P.G., E. Ortiz, S.J. Newberry et al., 2005)

422. What will be the potential health and health care expenditure impact for the future elderly given current obesity trends? (Lakdawalla, D.N., D.P. Goldman, and B. Shang, 2005)

423. Issues analysed with FEM include obesity, disability, technological advances, cancer, the burden of chronic diseases, global pharmaceutical policy and health in the United States and Europe, age versus life expectancy as a predictor of health-care spending, and the fiscal implications of healthier aging.

Class of forecasting model

Microsimulation (dynamic)

Forecasting method

424. The initial population for the model is drawn from the Medicare Current Beneficiary Survey. The model has three main components: a model for health status transitions, a rejuvenation model that predicts health characteristics of new Medicare enrollees introduced into the simulation each year, and a model for health care costs.

425. The model of health status transitions includes transitions into mortality, cancers, cardiovascular disease, stroke, neurological disorders, diabetes, hypertension, ADL, and facility residence (entry to a nursing home) using piecewise Gompertz proportional hazard models.

426. The rejuvenation model ensures that the simulation remains representative of the population aged 51+ into the future. FEM incorporates population projections of the U.S. Census Bureau. Health status of future cohorts are estimated by obtaining age-specific prevalence rates for each chronic disease of interest and disability status from the National Health Interview Survey. Age-incidence trajectories are completed by combining information on age-specific prevalences with disease-specific death rates from US Vital Statistics. Age-specific prevalence rates and disease-specific trajectories are then used to predict the health status of the incoming Medicare sample.

427. The models of health care costs estimate Medicare, Medicaid and total medical and drug expenditures based on the demographic and health characteristics of the population using OLS regression equations. Independent variables include activities of daily living, chronic diseases, and interactions of ADL categories and disease conditions. Ever having smoked, residing in the Northeast, mortality, obesity, and physical health status (measured by number of ADLs and admission to nursing home) have considerable effects on expenditures. Further, individuals who die during the year have substantially higher medical expenses than survivors. Results of the health care cost models are used to forecast future health expenditures based on the characteristics and health status of the projected future elderly population from the other two FEM model components.

Projected variables, measurement units and time horizon

428. Projects the future prevalence of risk factors such as obesity and smoking; major chronic diseases (cancer, heart disease, hypertension, stroke, arthritis, lung disease, Alzheimer's disease, and diabetes); disability; facility residence; and public Medicare and Medicaid expenditures and total drug and medical expenditures that may be associated with the future burden by disease type and overall.

429. Projects total expenditures for the population aged 51+ for Part A, Part B, total Medicare, total Medicaid and the total from all sources. Per capita expenditures are also calculated for each of these four payment categories. All projected expenditures are in real terms that correspond to 1998 dollars. Projections are presented for a thirty year period from 2000 to 2030.

430. Tests "what-if" scenarios, such as the impact of potential breakthrough technologies as well as changes in lifestyle and in the health care system—by exploring changes in the parameters of the model.

Health expenditure drivers

- Population dynamics
- Distribution of risk factors
- Prevalence of chronic diseases
- Annual costs of disease treatment

Assumptions, sensitivity analysis and criteria to assess the forecasting method

431. The model enables projections of the number and type of health care treatments that may result from different policy scenarios, however, further costs that may result, such as the need to purchase additional equipment, to train new health-care providers or to build new health-care facilities are not part of the model. Administrative costs are not included. There is an assumption of constant prices. Extensive sensitivity analysis were conducted based on back-testing the model, that is running the model using the

2000 cohort and comparing model projections to observed data from the Health and Retirement Survey through to 2010.

432. In the baseline projection, FEM makes no assumption of what future technological changes may be. Thus the baseline projections consider future health and health care cost trends using current technology. In FEM, it is through the introduction of scenarios that the impact of new technologies on costs and health in the future can be evaluated. In contrast, other models include implicit or explicit assumptions of a growth in the adoption of new medical technologies. In these models, it is usually impossible to deduce what these technologies may be.

433. A feedback loop between policy scenarios and potential changes in the behaviour of people is not modelled.

434. The model also excludes impacts of changes in labour-force participation of those experiencing disease and treatments on the total demand and supply of labour or any broad impacts on the productivity of the whole economy (such as changes to GDP, consumption and investment).

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Archimedes

Organisation: Achimedes Inc.

435. The Archimedes model is a person-by-person, object-by object, large-scale simulation model of physiology, disease, and health care systems written at a high level of detail using object-oriented programming and run on a distributed computing network (Schlessinger & Eddy, 2002; Eddy & Schlessinger, 2003; Eddy & Schlessinger, 2003; Eddy et al. 2005). The core of the model is a set of ordinary and differential equations that represent the physiological pathways pertinent to diseases and their complications. Currently, the model includes coronary artery disease (CAD), stroke, diabetes and its complications, congestive heart failure, obesity, smoking, asthma, and the metabolic syndrome in a single integrated model. The model also includes aspects of diseases and health care systems needed to analyze downstream clinical events, utilization, and costs including signs and symptoms; patient encounters with the health care system (e.g., emergency room visits, office visits, and admissions); protocols and guidelines; tests and treatments; patient adherence to treatment recommendations; and clinical events that affect logistics, utilization, and financial costs.

436. Costs related to the conditions that are in the model are calculated by tracking all the pertinent cost-generating events using micro-costing methods. The model uses person-specific data from real populations (e.g., the National Health and Nutrition Education Survey [NHANES]) to create simulated populations that match the real populations, person by person. Each individual can be matched to variables such as demographics, risk factors, biological variables, current and past medical histories, and current treatments. The model's accuracy is checked by using it to simulate clinical trials that have been conducted in the real world and comparing the predicted results with the real results. This has been done successfully for several hundred treatments and outcomes in 48 randomized controlled trials thus far.

NATSEM-CHE-CoPS Micro-Macro Chronic Disease Prevention Model

National Centre for Social and Economic Modelling, University of Canberra

437. The Micro-Macro Chronic Disease Prevention Model forecasts the health, health-care costs and macroeconomic impacts associated with population health initiatives. The first version of this model was developed to study the impact of type 2 diabetes on the Australian population including health, health expenditures and broader economic impacts, such as changes in employment and productivity. The model was used to test the potential future impact of various policy interventions to reduce the future burden of diabetes for the purpose of improved decision-making regarding population health investment, work-force participation and productivity.

438. It represents the first generation of model building where both health expenditures and broader macroeconomic impacts are forecast together in an integrated framework. As a result, it enables estimates of both short term costs of a policy intervention, as well as potential broader and longer-term returns on this expenditure. For example, a diabetes prevention program may produce higher future health expenditures but also produce growth in employment and GDP.

439. The joint models were developed by the National Centre for Social and Economic Modelling (NATSEM) at the University of Canberra and the Centre for Health Economics (CHE) and the Centre of Policy Studies (CoPS) at Monash University.

Policy questions the model has supported

440. What are the relative benefits of investing in primary prevention compared to secondary prevention in terms of health outcomes and health expenditures?

441. What is the optimal balance of investment across strategies aimed at the whole population versus those targeting high risk groups?

442. What could be the health, health expenditure and macro economic impacts of the introduction of a program to reduce the incidence and progression of type 2 diabetes?

Classes of forecasting methods

443. The framework incorporates together two forecasting classes: component-based and computable general equilibrium.

Technical description

444. The Micro-Macro Chronic Disease Prevention Model links a projection model of disease prevalence to a computable general equilibrium model (CGE) of the Australian economy through a labour supply model.¹

445. The *diabetes model* is a cell-based simulation model with 3,456 cells representing eight diabetes risk factors: sex, age, income, waist circumference, blood pressure, abnormal cholesterol, physical activity and smoking history. Data from the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) are used to initialize the model. The prevalence of diabetes and pre-diabetes are determined for each cell depending on the risk factors within that cell. The population base is updated every three years to reflect population ageing according to estimates from the Australian Bureau of Statistics. Assumptions of changes in the prevalence of modifiable risk factors are based on historical trends. Alternative prevention programs are tested by moving records from cells with higher prevalence of certain risk factors to cells with lower risk

factor prevalence. The probability of diabetes for a particular cell, multiplied by its population, yields the number of persons expected to develop diabetes. The model then estimates the overall prevalence of diabetes, disability-adjusted life years, and total direct health expenditure enabling estimates of cost effectiveness, cost-utility and cost-benefit.

446. The *labour supply model* is a logistic regression model examining a discrete choice, working or not working. This choice is a function of predicted health status, objective measures of health, and individual characteristics. Predicted health status is a linear combination of past health status and individual characteristics estimated via an Ordinary Least Squares (OLS) model.

447. The *general equilibrium model (Monash CGE)* is a computable dynamic model that projects the future economy from baseline and in the presence of shocks, such as the introduction of a new policy.^{2,3} The base case is derived from input/output data in a given year as well as other exogenous variables, such as population size; foreign currency prices of imports; tax and tariff rates; public consumption; and, at the industry and commodity level: outputs, employment, capital, investment, export, import, private consumption, and price deflators.³ Monash CGE also includes, as exogenous variables, projections prepared by experts in various dimensions of the economy, such as world commodity markets, international tourism, production technologies and economic policy. Forecasts of the base case are made for 107 industries over time and results reflect general conditions of the economy as well as commodity and industry-specific technological change.²

448. Under different diabetes prevention policies, the shocks imposed on the CGE model result from modifying the base case by the predicted annual percentage change in employment hours (from the labour supply model) and in expenditure on health (from the diabetes model) which acts as the measure of health care demand.

Projected variables, measurement units and time horizons

449. The Micro-Macro model projects a broad range of health and economic indicators including:

- Prevalence of risk factors for diabetes,
- Prevalence of diabetes,
- Disability-adjusted life years,
- Mortality associated with diabetes,
- Direct health care costs in 2005 constant dollars in total and by diabetes status,
- Gains or losses in the number of employed persons,
- Percentage change in total employment hours, and
- Percentage change in real GDP, consumption and investment.

450. Projections were produced from 2006 to 2026. This enables examination of both the short term impact of the intervention on health care expenditures and taxes as well as a longer-term view of the impact on health, health expenditure, employment and GDP.

Determinants of health expenditures

451. As this is a set of interconnected models, the drivers of direct health expenditure projections are a sub-set of the drivers of percentage change in GDP.

Drivers of health expenditures included in the model are:

- Population dynamics
- Risk factors (income, waist circumference, blood pressure, abnormal cholesterol, physical activity and smoking history)
- Prevalence of diabetes

Drivers of percentage change in GDP are:

- Population dynamics
- Socio-demographic factors
- Health expenditures (demand for care)
- Employment hours
- General conditions of the economy as well as commodity and industry-specific technological change

Assumptions, sensitivity analysis and criteria to assess forecasting methods performance

452. The diabetes model is a discrete time Markov chain that identifies the states that individuals can occupy and allows them to transition between states at fixed time intervals of three years. Unlike most models we have reviewed, risk factors, disease prevalence and functional health status are explicitly modelled, not assumed.

453. Estimates of total health care expenditures are allocated based on the following assumptions. A non-diabetic patient has an annual per capital direct cost of health care of 1.00. Individuals with diagnosed diabetes have a ratio of 1.7 (obtained from the literature); individuals with undiagnosed diabetes have a ratio of 1.5 and individuals with pre-diabetes 1.3. In the prevention scenario, newly diagnosed individuals were assigned a ratio of 1.6.

454. The diabetes model forecasts health expenditure using constant prices. Details on the financing of health expenditures, the organisation of health care and treatment pathways were not modelled. Implicitly, the impact of technological change or other factors on prices are assumed to be constant. In the Monash CGE model, however, technological change is modelled from historical trends for all industries and for each, price changes are modelled.

455. The CGE model depends on assumptions of economic equilibrium including that demand(s) equals supply(s); that demand and supply maximise utility and profits; that prices equal unit costs; and that end of year capital stocks equal beginning of the year capital stocks plus investment and minus depreciation. One of the challenges with this approach is that there are often multiple model solutions.

456. There is no explicit budget constraint in this CGE model; however, all costs of an intervention must be recovered through taxation. Therefore, maximum spending on a diabetes prevention program would occur when all taxable income is exhausted.

457. No feedbacks between the micro and macro-level were captured. Therefore changes in the broader economy, such as an increase in income taxes, would not change the behaviour of individuals.

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PRISM – Prevention Impacts Simulation Model

Organisation: Homer Consulting

458. Summary: PRISM is a system dynamics (SD) simulation model for evaluating multiple approaches to preventing and managing cardiovascular risks, developed (since 2007) under the auspices of the Centers for Disease Control and Prevention and the National Institutes of Health (Homer et al. 2010; Homer et al. 2008). SD models help decision makers anticipate the likely effects of interventions in dynamically complex situations, where the pathways from interventions to outcomes may be indirect, delayed, and possibly affected by nonlinearities or feedback loops. PRISM has been used in the US by public health leaders at the national and local levels to inform strategic planning, and will soon be broadly available as a web-based tool. It is also being used by the US government for evaluation of the half-billion dollar, 50-community stimulus program known as Communities Putting Prevention to Work.

459. PRISM, like most SD models, is compartmental, operating at the level of population subgroups rather than individuals, and consists of hundreds of interconnected differential and algebraic equations. PRISM incorporates data from many sources to represent leading cardiovascular risk factors in adults, including key chronic disorders (hypertension, hyperlipidemia, and hyperglycemia), smoking (and former smoking), soot, obesity, diet, exercise, and psychological distress. It also represents obesity, diet, and exercise in children. Dynamic stock (state) variables are used to model changes in the prevalence of many of these risk factors and in the total population. The population is subdivided by gender, age group (children ages 2-5y, 6-11y, and 12-17y; adults ages 18-29y, 30-64y, and >65 y), and cardiovascular disease status (non-CVD, post-CVD).

Multi-level Modular Agent-based Modelling for the Study of Childhood Obesity

Organisation: The Brookings Institution / McGill University

460. Summary: This is a multi-level modular individual-based model currently in development by the Center on Social Dynamics and Policy at The Brookings Institution (see Hammond, 2008; 2009). It is motivated by the complex set of drivers that are implicated in the obesity epidemic. Increasing calls for multilevel studies and systems approaches to obesity reflect a widespread perception that research paradigms focused on single factors in isolation have failed to provide the insights needed to stop the growing epidemic. The goal of this project is the development and application of a novel modular agent-based modelling approach for the multilevel study of childhood obesity. The technique of agent-based computational modelling (ABM) offers unparalleled flexibility to incorporate individual heterogeneity, complex social structures, and a range of dynamic adaptive behaviours. Our multi-level modular approach permits modelling of multiple mechanisms simultaneously, across several levels of scale, with inclusion of important sources of diversity. This effort is part of the newly assembled Comparative Modeling network of the National Collaborative on Childhood Obesity Research (a joint venture of the National Institutes of Health, the Centers for Disease Control, the US Department of Agriculture, and the Robert Wood Johnson Foundation). In addition to directing modelling on the Brookings/McGill project, Hammond serves on the steering committee of this innovative network which is applying diverse systems approaches to the common topic of childhood obesity.

DYNAMO-HIA

Organisation: DYNAMO-HIA

461. Summary: DYNAMO-HIA quantifies the impact of user-specified risk-factor changes – due to policy or interventions – on various and multiple diseases and in turn on overall population health, clearly comparing one reference scenario with one or more intervention scenarios. Using a Markov-based modelling approach that allows for explicit risk-factor states, it dynamically simulates a real-life population. The tool accommodates three different disease processes: chronic diseases, partly acutely fatal diseases, and diseases where the excess mortality depends on the duration of the diseases. The tool models explicit risk factor states and hence allows for mortality selection. Apart from health determinants (e.g. life style related or environmental risks), diseases can be risk factors for other diseases.

462. A built-in parameter estimation module ensures that only standard epidemiological evidence on the population level, i.e. data on disease incidence, disease prevalence, relative risks, and excess mortality is required. DYNAMO-HIA provides a rich output of summary measures – such as life expectancy and disease-free life expectancy – and detailed data – such as mortality/survival rates and prevalence numbers – by age, sex, and risk-factor status over time. DYNAMO-HIA is completely controlled via a graphical user interface and will be made publicly available from the internet ensuring general accessibility.

463. The tool includes data for three life-style related health-determinants (smoking, overweight and alcohol consumption) and resulting diseases (several cancer, Ischemic heart disease, stroke, diabetes and chronic obstructive pulmonary disease (COPD)) for a large number of EU countries. New data can be easily integrated with the existing software.

National Heart Forum micro-simulation project

Organisation: National Heart Forum

464. The National Heart Forum microsimulation model projects public health expenditures associated with leading diseases where obesity is a significant risk factor.¹ The model simulates and evaluates how future trends may change in response to policies to reduce the prevalence of obesity. New work has extended the model to focus on smoking and smoking-related diseases and the model is extensible to a broader range of risk factors and diseases.²

465. The NHS model for the projection of obesity disease burden, the Foresight Model, was developed for the UK Government Foresight Programme of the Government Office for Science.

Policy questions

466. What may be the future disease and public health-care cost burden associated with obesity in the future?

467. What would be the impact on obesity-related disease prevalence and public health care costs if we were to successfully constrain population BMI growth in some way?

Class of forecasting model

Microsimulation (dynamic)

Forecasting method

468. The NHS model focuses on individuals and builds a virtual population representative of England. Individuals are born into the simulation; experience health-related events, such as developing risk factors and disease; and eventually die. Based on current knowledge of the cost of disease treatment, future costs to the government National Health Service are projected. The model is developed in three steps: a regression analysis to project the future distribution of risk factors in the population; a microsimulation model to project the future disease burden associated with these risk factors; and an ex-post calculation to estimate public expenditures in current dollars associated with the projected future disease burden.

469. For published obesity projections¹, the model used 15 waves of data from the Health Survey of England, a cross-sectional survey (1993 to 2007), to develop multivariate categorical regression models where age group, sex and calendar year were independent predictors of body mass index (BMI) category. The equations were then used to predict the future distribution of BMI categories from 2008 to 2050. A dynamic microsimulation model probabilistically assigned a BMI category to each individual in a synthetic and representative population over the period 2008 to 2050. Population dynamics (births and deaths) were estimated using national census, vital statistics and official population projections. The assignment of BMI values was based on age, sex and calendar year.

470. Every year, each simulated individual faces the probability of getting a specific disease, if free of this disease at the beginning of the year. Probabilities depend on the individual's age, sex, and the presence of risk factors and were determined from the published literature. Disease pathways (recovery, continuance, death) were developed to match survival and case fatality statistics via a randomized or Monte Carlo process. The Monte Carlo process involves the generation of a random number that influences the occurrence of events and allows outcomes to vary from one individual to another. Survival probabilities are determined by the survival experience of individuals with a given disease, moderated by age and sex, and were obtained from the published literature.

471. The average NHS expenditure per patient for diseases associated with obesity is then used to calculate the future costs associated with these same diseases in constant dollars.

Health Expenditure Drivers

- Population dynamics
- Distribution of the body mass index
- Prevalence of diseases related to obesity
- Annual public costs of each incident disease (obtained from the literature and national data)

Projected variables, measurement units and time horizon

472. The model projects the future prevalence of obesity, chronic diseases associated with obesity (diabetes, coronary heart disease, stroke, colorectal cancer and breast cancer) and the public medical expenditures that may be associated with the future burden by disease type and total. Forecasts future public costs (NHS costs) in constant dollars attributed to increasing obesity rates. The time horizon of the projection is over forty years, with recent published projections from 2008 to 2050.

473. The model enables the testing of “what-if” policy scenarios, such as the potential future effects of different risk-factor interventions. Recent published work compared the potential impact of a universal strategy that reduces BMI across the population to a targeted strategy among overweight or obese people.

474. The model enables generation of projections at various levels of disaggregation, such as by country, age, sex, region, year, disease type, and risk factor status.

Assumptions, sensitivity analysis and criteria to assess the forecasting method

475. Once a BMI value has been assigned to the individual in the simulation, it is assumed that the individual’s BMI ranking (percentile), in the same age cohort, remains constant over time. Population dynamics in the model do not include immigration and emigration. There is no estimation of the potential impact of technological change on health care expenditures and, unlike other microsimulation models reviewed, no scenarios can be tested that relate to health-care treatments. Thus, all projections assume current technology and treatments are maintained in the future. Other drivers of health care expenditure seen in other models are not included, such as administration, infrastructure and human resource costs associated with a growing burden of disease. There is an assumption of constant prices.

476. Elements of model validation include comparing simulated results for current years with known population statistics and ensuring that projected population dynamics match official population projections from the Office for National Statistics.

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SESIM-LEV

Organisation: Ministry of Health and Social Affairs (Sweden)

477. The Swedish Microsimulation Model – Long-Term Demand for Welfare Services (SESIM-LEV) projects the future utilisation of and public expenditure on health and social care in Sweden, given current demographic, health status, disease and disability trends (Government Offices of Sweden, 2010).

478. SESIM was originally developed by the Ministry of Finance in Sweden and has been used to study educational financing and aging and pension policies. The health and social care utilisation dimensions of the model were developed by the Ministry of Health and Social Affairs.

Policy questions the model has supported

479. What will be the future health status and health expenditure utilisation of the population and what will then be the future cost of care?

480. How would utilisation and costs change under different assumptions of expansion or compression of morbidity?

481. How sensitive are forecasted health and social care expenditures as a share of GDP to assumptions about the future health status of the population, the cost pressure of technological advancement and the productivity of the health sector?

Class of forecasting model

Microsimulation (dynamic)

Forecasting method

482. SESIM-LEV is a dynamic microsimulation model that estimates and projects the life course of the population of Sweden including key life events related to family formation, education, employment, retirement and health and aging (Brouwers, L., A. Ekholm, N. Janlöv et al., 2011). The model evolves in discrete time intervals of one year. The model is initialised with a representative sample of 300,000 individuals from a longitudinal register (LINDA). LINDA brings together data from Censuses, Income tax and other registries to examine education, employment, income and pension information for individuals and families longitudinally over time. From analysis of LINDA, SESIM is able to include models of behavioural change over time, such as family formation, births of children, educational pathways, employment pathways, and transitions to retirement.³ Other datasets key to the LEV project included surveys of income and employment, living conditions, and patient registries. As the base population for SESIM did not contain information on health or utilisation of health and social care services, initial values were imputed conditioned on background characteristics of the individuals. Health status is a key variable in the model, both influencing the life course, such as participation in education and employment, and consumption of health and elderly care, while also, in turn, being influenced by social and demographic factors. Health status is an index from 1 (severe illness) to 4 (full health) derived from sets of responses to the ULF survey of living conditions.

483. Consumption of primary care, specialised or outpatient care, and inpatient care were measured in number of visits or days. As zeros are very frequent, negative binomial regression models were used to estimate the risk of health care events occurring. Prescription medicines were modelled as a binary variable using a logit model. To estimate probabilities of health care consumption, these regression models included variables such as age, health status, and consumption of the same type of care in the previous period, consumption of other types of care in the current and previous period, education, sex, and region. Risk of mortality was also estimated with a logit model influenced by a similar suite of variables. The presence of dementia and dependence in activities of daily living were also explicitly included and both influenced demand for elder care assistance which was captured as having two levels: home services and special housing with 24 hour care. In turn, these factors were significant predictors of mortality for those receiving elder care.

484. Sub modules were developed for focus diseases known to result in a high consumption of care: cancer, AMI, stroke and diabetes. Data on incidence, prevalence and health care use of patients were obtained from patient registers providing longitudinal histories for a six-year period. Age and disease-specific risks of mortality were used. Individuals surviving beyond the six year period were considered disease free and were returned to face the same risks of health care consumption and death as the disease-free population in the model. The exception was diabetes, which was assumed to be a life-long condition.

485. The model projects public expenditures for outpatient, in-patient and primary care. The exclusion of private payments has only a minor impact on the model, as patients cover only 2-3% of expenditures on these items. The model projects expenditures for pharmaceuticals including both public and private expenditures. For this item, private payments represent about 25% of total expenditure. Costs were estimated in 2010 prices for the average health care and elderly care expenditure by age for primary care,

specialised or outpatient care, inpatient care, prescription medicines, home care and special housing. These average prices were then multiplied by the number of persons in each age group in receipt of these care elements forecasted by the simulation model.

Projected variables, measurement units and time horizon

The projected variables include

- Population dynamics
- Health status (from levels 1 to 4)
- Prevalence of key diseases (cancer, AMI, stroke, diabetes, dementia)
- Prevalence of difficulties with activities of daily living
- Utilisation of health-care services (primary care, specialised or outpatient care, and inpatient care visits or days; use of prescribed medicines)
- Life expectancy
- QALY (quality-adjusted life years)
- Health and social care costs in total and per-capita in 2010 fixed prices
- Health and social care total costs as a percentage of GDP in 2010 fixed prices

All of these variables are projected from 2010 to 2050.

Assumptions, sensitivity analysis and criteria to assess the forecasting method

486. The impacts of three different assumptions about the health status of the future population on projected health-care utilisation were tested. An expansion of morbidity assumption, where additional years of life expectancy in the population over time are accompanied by almost as much of an increase in life lived in poor health; a dynamic equilibrium assumption, where care needed is postponed by an amount equal to increases in life expectancy; and a compression of morbidity assumption, where the number of years lived in good health increases even more than the growth in life expectancy. These first estimates, which forecast health care demand based on demographic trends alone, show the highest future health care costs under the expansion of morbidity assumption. Nonetheless, annual growth in costs from 2010 to 2050 averages narrowly across all of these assumptions from 0.6 to 0.7% for health care and 1.3 to 1.4% for elderly care.

487. In the baseline projection, SESIM-LEV makes no assumption of what future technological changes may be. Thus the baseline projections consider future health and health care cost trends using current technology. GDP is assumed to grow by 2.16% per year, according to forecasts of the Ministry of Finance. Under this assumption, projected health care costs as a proportion of GDP fall over time and elderly care costs plateau after 2030. The forecasts change greatly, however, after the introduction of an assumption about technological development. Drawing from the literature, an assumption of 0.8% annual growth in health care expenditures as a result of medical technologies and other related factors is assumed. This assumption causes health expenditures to take an increasing share of GDP each year, reaching about 12% by 2050.

488. Assumptions about the productivity of the health sector also influence results. If productivity increases match technological progress, the cost growth pressure associated with technological advancement could be neutralised.

489. The model enables projections of the number and type of health care treatments that may result from different policy scenarios, however, further costs that may result, such as the need to purchase additional equipment, to train new health-care providers or to build new health-care facilities are not part of the model. Projected volumes are translated into costs in a separate calculation. Administrative costs are not included. There is an assumption of constant prices using 2005 as the index year.

490. SESIM-LEV is developed in discrete time with most decisions occurring in order once per year. This is a limiting structure, as real-world events occur in continuous time, and more importantly, some decisions/transitions are joint, or occur together.

491. The model focuses on the demand for health care services and implicitly assumes no change in policies that may affect demand, such as health-care financing, as well as an assumption that the supply of health care services would be increased to meet future demand. The model also has no labour-supply dimension. There are models for labour-force participation, unemployment and retirement but no model of hours worked and the variables that influence those hours, including the family budget, tax rates, and health.

492. SESIM-LEV does not account for feedback loops between the health status and health-care utilisation of the population and market prices or the overall economy. Changes in the macro economy can be entered into the model as a scenario; however, there is no general equilibrium mechanism within the model itself. The Ministry of Finance in Sweden has, however, used a macro model of the public sector in parallel with SESIM for the household sector.³

493. Results of SISEM-LEV were verified during implementation of the model (de-bugging) by comparing model results for a sub-set of individuals with independent calculations for these same individuals using excel workbooks. Simulated output from SISEM-LEV for the years 2000-2008 were compared with observed values from empirical data to validate results. This included comparisons with observed values for health status and health-care consumption by age, sex and key socio-demographic characteristics. The stability of the model outputs were also tested to ensure that differences between model runs for the same scenario were not greater than differences between scenarios. Initially, ten simulations of the same scenario were estimated. Differences between simulation runs for the same scenario were found to be small and the number of simulations was reduced to three for each scenario, with the average of the runs used for publication. Calibration of death risks were undertaken to align the SESIM-LEV population projections to those of Statistics Sweden. Thus results replicated official estimates of increases in life expectancy. The demographic composition of the projected population was also examined over time at points in time in the future for 10-year age groups (including sex, age, income, education, health status, and level of dependency). This examination was to assure that projected results were reasonable.

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Comprehensive Assessment of Reform Efforts (COMPARE)

Organisation: RAND

494. The model projects how individuals, families and firms in the United States may respond to potential health care policy changes and has been used to estimate the potential future impact of the *Patient Protection and Affordable Care Act (PPACA)* (RAND, 2011). The model enables projection of the change in government spending following reforms related to health-care insurance.

495. The COMPARE model was developed by the RAND Corporation. COMPARE development has been sponsored by the US Departments of Labor and Health and Human Services (Ebner, C. et al., 2010).

Policy questions the model has supported

496. What may be the future impact of policy reforms related to health insurance coverage on the behaviour of individuals, households and firms?

497. Consequently, how will changes in behaviour impact on insurance coverage of individuals and their dependents and on expenditures of individuals, employers and the government?

Class of forecasting model

Microsimulation (static)

Forecasting method

498. COMPARE projects the effects of health reforms on health insurance coverage and costs, focussing on impacts on businesses of different sizes, workers and their dependents. The microsimulation model develops a synthetic population representative of the U.S. that is composed of individuals of working age and their dependents and firms. The model projects how individuals and their dependents and firms might respond to a policy reform by changing their decisions and considers interactions among these agents, with the decision of one agent potentially influencing the decision of another. For individuals, decision rules may include eligibility for different insurance options; the cost of employer-sponsored insurance; individual characteristics including family income and health; and whether the government offers an incentive to enrol in insurance, such as a tax credit or penalty. Similarly, firms in the model also follow decision rules and may make new decisions in light of changes introduced to health-care policy. These rules may include the contribution of health insurance to worker recruitment and retention; the expected cost of offering a policy; and any government regulations, incentives or penalties.

499. The initial population for the model is drawn from the 2001 Survey of Income and Program Participation (SIPP), a longitudinal study of U.S. households that contain data on demographics, household composition, health insurance status, income, assets, and labour-force participation. COMPARE incorporates estimates and demographic projections from the U.S. Census Bureau. Data from the SIPP are used to establish family units where members may be eligible for employer-sponsored health insurance (spouses and dependent children). Medical expenditures of individuals and families are provided by the Medical Expenditure Panel Survey, adjusted through calibration for known underestimation of expenditures to match published estimates. Statistical matching is used to assign health expenditures to SIPP family units. Firms in the model are based on data from the 2006 Kaiser/HRET Employer Health Benefits Annual Survey. These firms were matched to workers within the SIPP data based on census region, firm size, industry and whether the firm offered health insurance.

500. Baseline insurance premiums offered to workers and their families consist of an average plan adjusted for the size of the firm. Family premiums are 2.7 times individual premiums. To estimate employer premium contributions, a regression model developed from the Kaiser/HRET data was used to predict each employer's rank within the distribution of employer insurance contribution rates. Employers were then matched to Kaiser/HRET data based on their rank order within the distribution of contribution rates. Alternative insurance schemes, such as the introduction of health insurance exchanges were also modelled for use in policy reform scenarios.

501. A utility-maximization framework is used to decide how family units and firms make choices. Family unit's utility is a function of out-of-pocket health expenditures, a coefficient for risk aversion and the utility of consuming health services. The demand curve from the RAND Health Insurance Experiment (HIE) was used to model utilisation of health care services and health care expenditures of individuals related to different insurance plans. Plans are characterised by a deductible, co-insurance and a maximum out-of-pocket payment. Plans with co-pays were not considered, however, tests were done to determine that the inclusion of co-pays would not have made a statistically significant impact on results. A family unit selects the insurance options that maximize its utility. Given family units can make sub-optimal decisions; the predicted utilities are adjusted through calibration to produce observed insurance distributions.

502. The model evaluates the various insurance options that are available to firms of different sizes to maximize the firm's utility. In the base case, there are only two options: to offer or to not offer employer sponsored health insurance. A firm's decision to offer insurance is modelled as a group-choice utility maximization model which is a function of aggregate worker utility, the cost of insurance to the firm and the weight a firm places on worker's utility. There are three unknown parameters within this model: the fraction of the savings from not offering insurance that would be returned to workers as wages; the trade off between the cost of insurance and worker utility; and the administrative costs to firms resulting from offering health insurance.

503. Guided by the structural model, a reduced-form equation is estimated using a standard logit model. The reduced form model produces a vector of elasticities of firm demand for health insurance corresponding to different firm sizes, where values of the unknown parameters were restricted to those that best reproduced observed elasticities. For the final base case model, the parameter for the share of savings returned to workers as wages was set to 0.8, a value above the lower bound in the literature of 0.7 and less than the expected value of 1. The parameter for the weight a firm places on aggregate worker utility was set equal to 1. The value of the additional wage costs to a firm to administer health insurance was set to \$12,000.

Projected variables, measurement units and time horizon

504. COMPARE projects the change in total government spending related to health insurance for the working-age population (including workers and their dependents) following the implementation of a health-care policy reform. Projections of government spending include Medicaid expenditures, premium subsidies offered to individuals and families, cost-sharing subsidies offered to firms, and small business subsidies. The model also estimates government revenue from any penalties levied on firms that have not offered insurance coverage. COMPARE projects the number of employers offering insurance coverage; the proportion of workers employed by firms offering health insurance; the total population under age 65 with insurance; total employer spending on health insurance; premium prices and estimates of changes in insurance offerings of firms and insurance coverage of individuals and families following the introduction of a reform.

505. The model includes population dynamics that would enable it to generate projections to 2050, however, most analysis of the model are limited to 2010 to 2019. Published projections of the potential impact of the *PPACA* were for the year 2016 (Ebiner, C. et al., 2010).

Health expenditure drivers

506. The drivers of change in government spending relate directly to the impact of health insurance-related reforms. From health insurance decisions made by individuals and firms to maximize their utility (described above), the set of variables influencing the estimate of the change in government spending include:

- Number of workers and their dependents receiving Medicaid;
- Government insurance premium subsidies and cost-sharing subsidies; and
- Revenue from penalties for non-compliance with a reform.

Assumptions, sensitivity analysis and criteria to assess the forecasting method

507. COMPARE evolves the health system from one equilibrium, the status quo, to a new equilibrium, after a policy reform. It does not inform about how quickly the new equilibrium would be reached, although some researchers have made a deduction about the dynamics. The model is not intended to generate long-term projections of health expenditures and therefore is not comprehensive of the set of drivers of public health spending growth. The model also does not include the impact of broader macroeconomic effects such as firm births and deaths, changes in firm size, and changes in worker's employment statuses, either due to business cycles effects or to policy reforms. Therefore, it is best suited to short-term projections of the impact of health-care policy options, where other economic, health and social factors remain similar.

508. The model allows a worker and dependent family members to each have a different health insurance plan or no coverage. However, the model does not allow a single individual to have more than one source of insurance or a family unit to have more than one family insurance plan. The model assumes that firms offering an employer sponsored health insurance plan offer an average plan estimated from survey data.

509. Household medical expenditures are estimated from the MEPS survey and exclude spending on vision and dental care. All monetary amounts are expressed in 2010 constant dollars.

510. The firm utility function was validated by comparing estimated elasticities of firm insurance offerings in relation to the price of insurance premiums with estimates in the literature. Model results were found to be within the ranges reported in the literature and in conformance with the theoretical expectation that small firms would have a more elastic demand for health insurance than would larger firms. Sensitivity analysis, where different combinations of potential covariates were used to estimate firm utility, was undertaken and the base case model specification was determined to be the most appropriate.

511. The baseline results of the model assume no inertia in firm decision making, that is, firms will change insurance offerings to maximize utility. A sensitivity analysis was undertaken where the probability of offering a new insurance option (one of the options available through the new insurance exchanges) estimated from the model was adjusted downward to match other estimates in the literature.

512. Uncertainty was also quantified in the model by using results from multiple model iterations to generate standard deviations and confidence bands around the estimated output variables. Because there are many more workers than firms in the data used to estimate the model, results for workers are more stable. Firm offer rates were estimated with an error rate of plus or minus 6 percent and therefore small changes in behaviour following a policy reform were not detectable.

513. COMPARE model results for the change in coverage and government spending resulting from the introduction of the PPACA, were also compared with results generated by the Congressional Budget Office using a different methodology. Results were found to be similar, with the COMPARE model generating a 4% higher increase in government spending, driven by a higher estimate of spending on premium and cost-sharing subsidies related to the insurance exchanges.

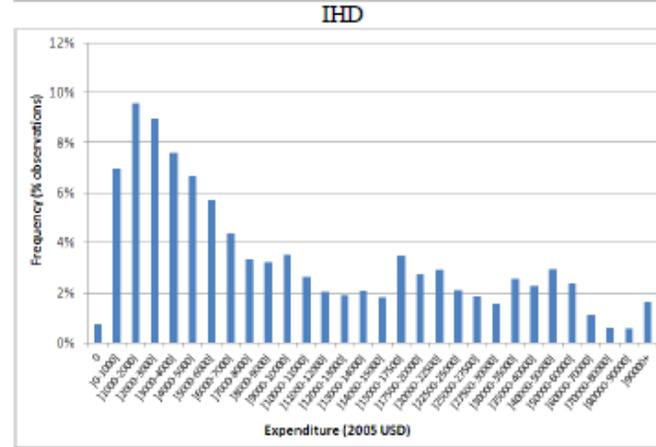
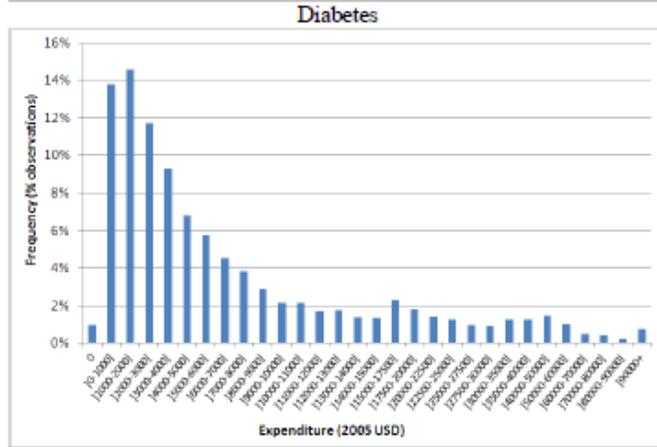
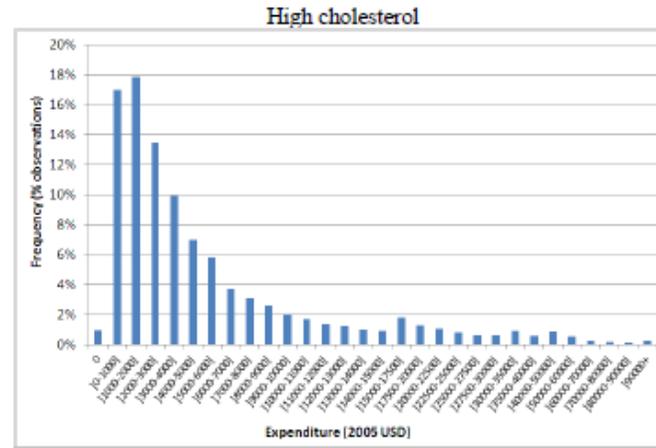
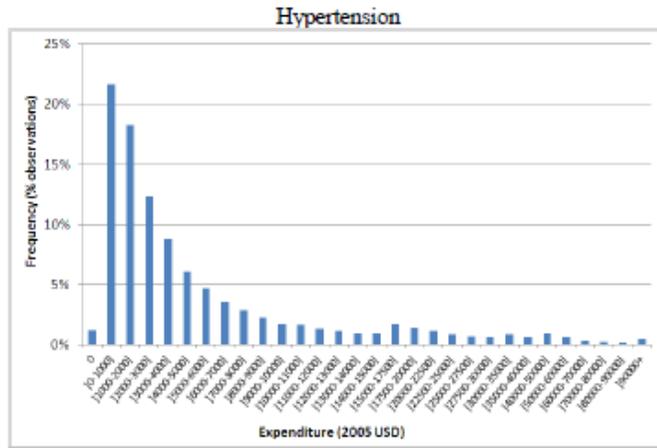
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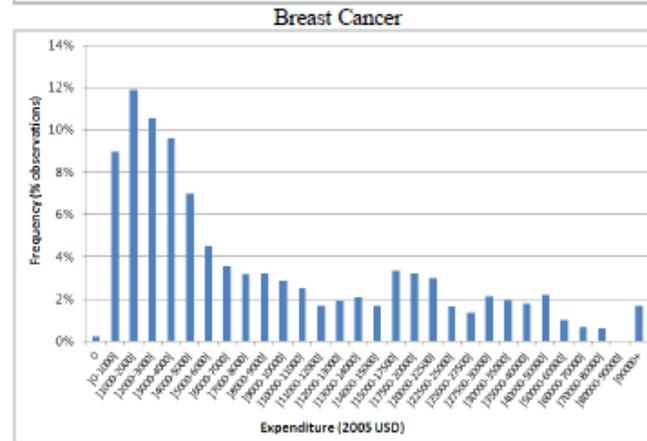
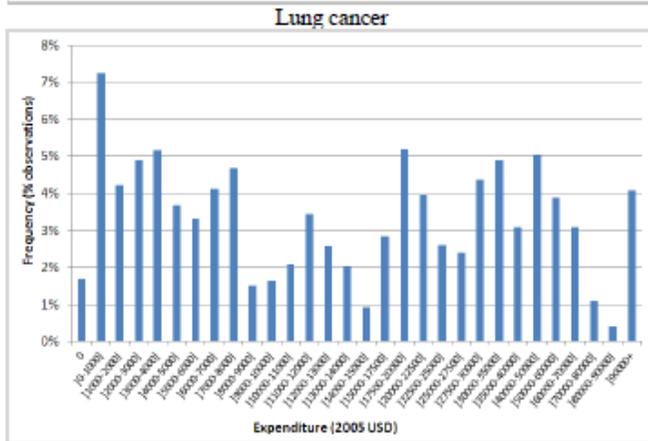
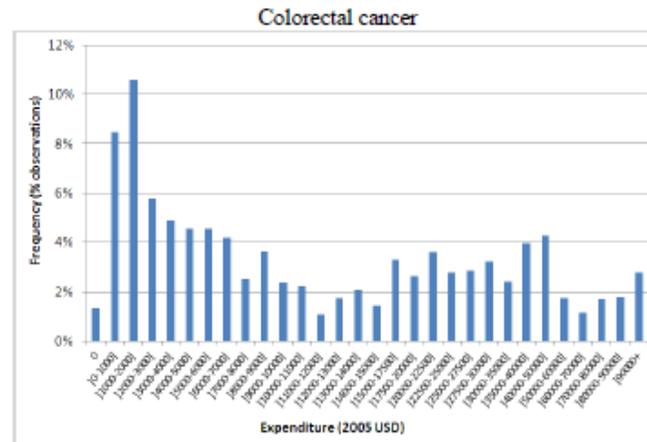
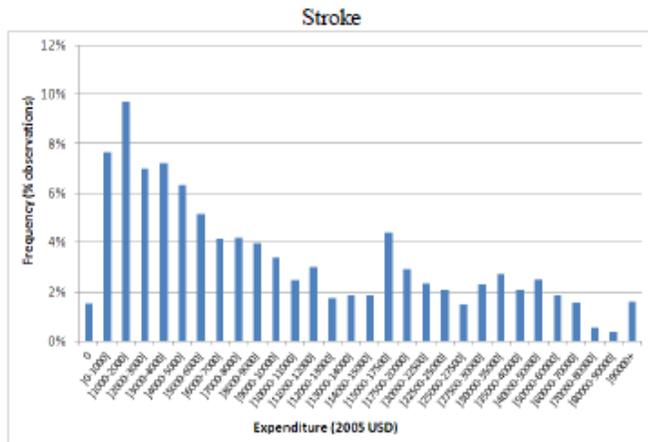
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RAND (2011). *How the RAND COMPARE microsimulation model works*.

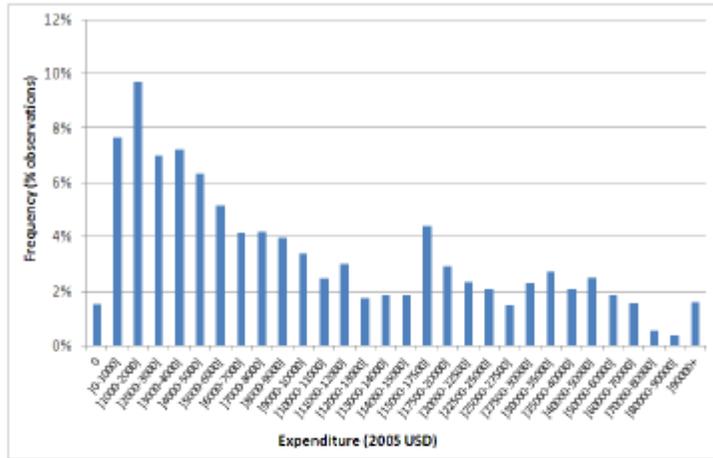
www.rand.org/health/projects/compare/how-it-works.html accessed January 2, 2012.

ANNEX 3: EXPLORATORY ANALYSIS OF THE UNITED STATES MEDICAL EXPENDITURES PANEL SURVEY (MEPS)

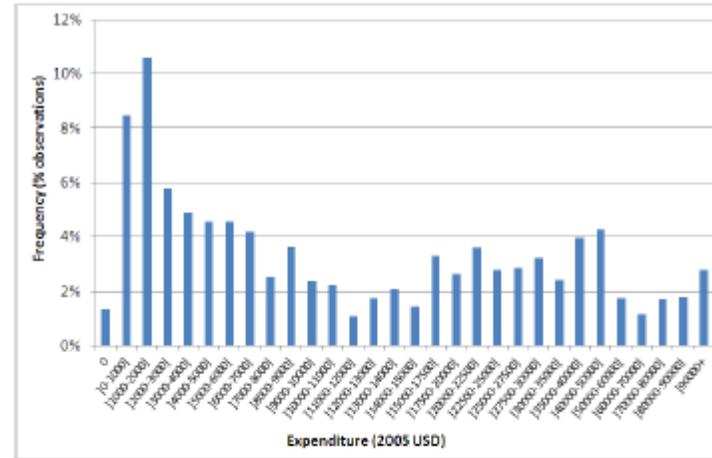




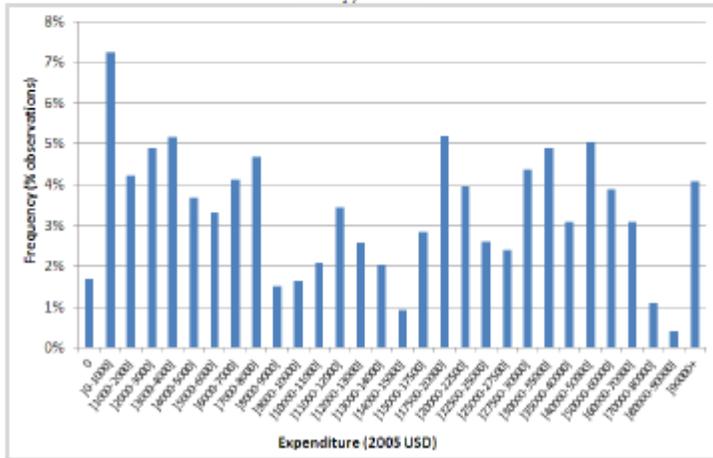
Stroke



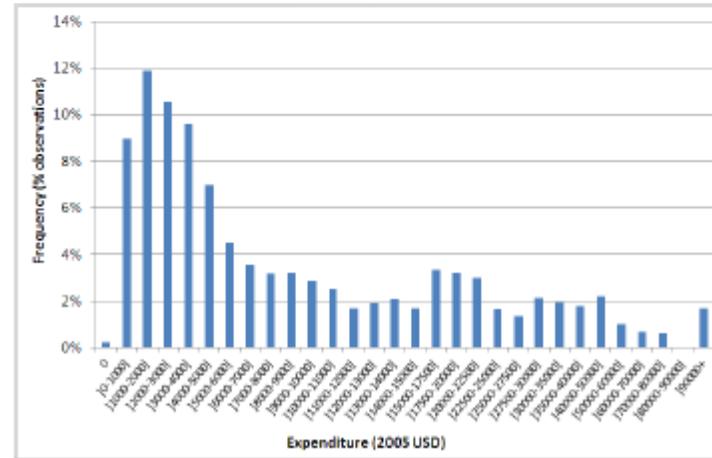
Colorectal cancer



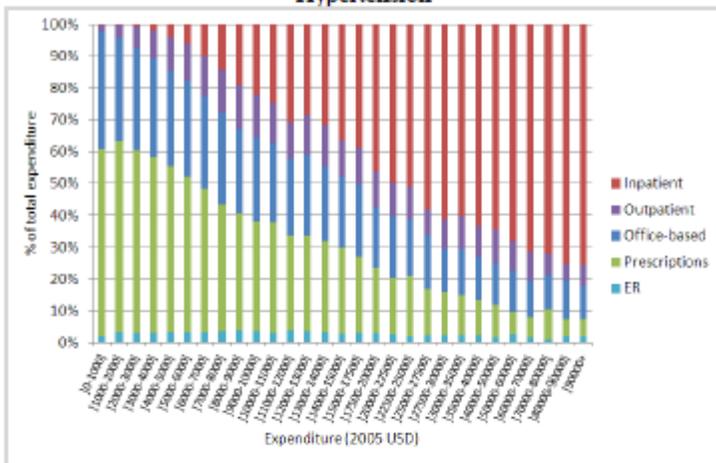
Lung cancer



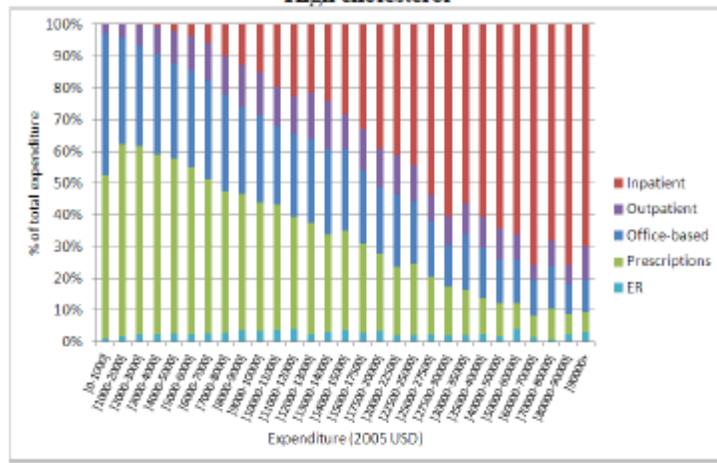
Breast Cancer



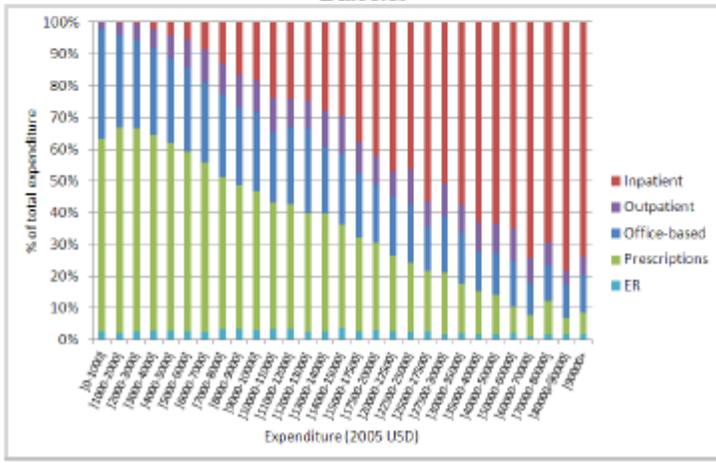
Hypertension



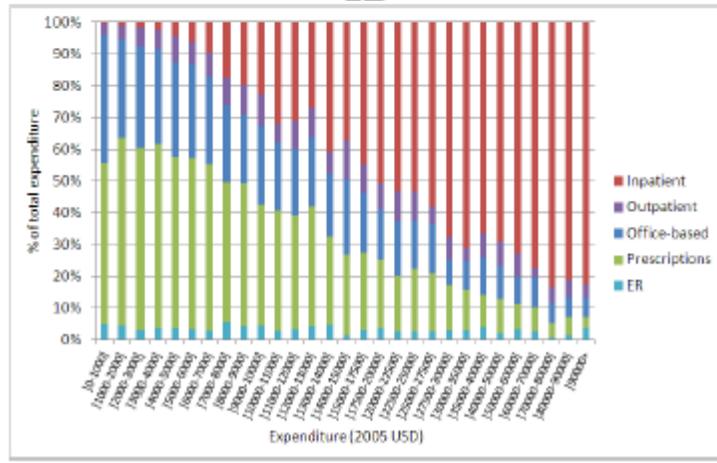
High cholesterol

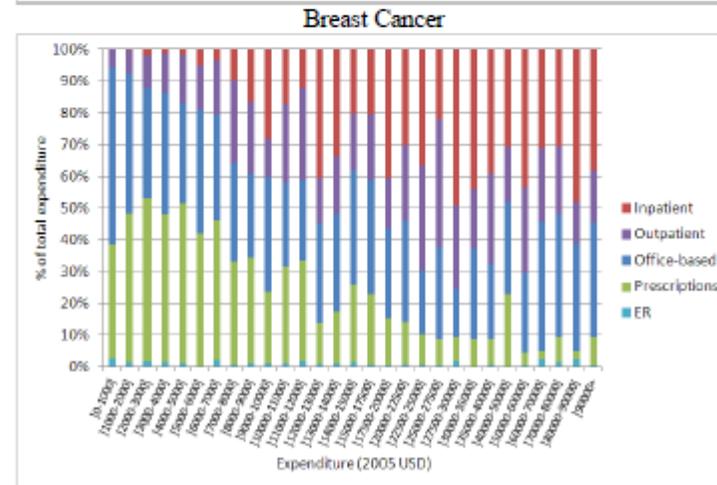
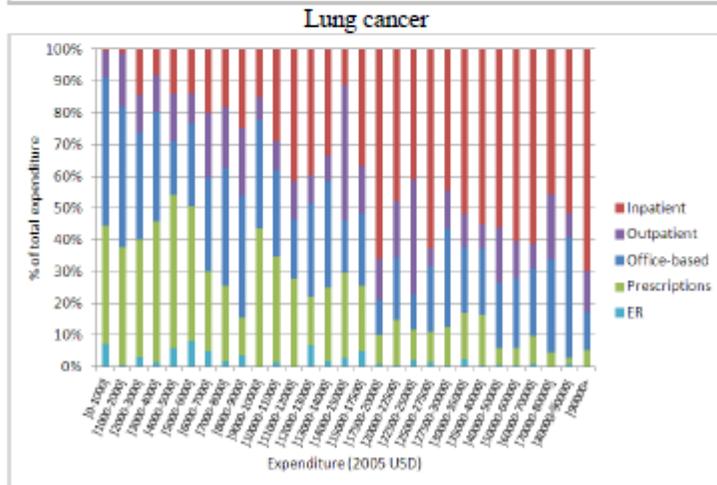
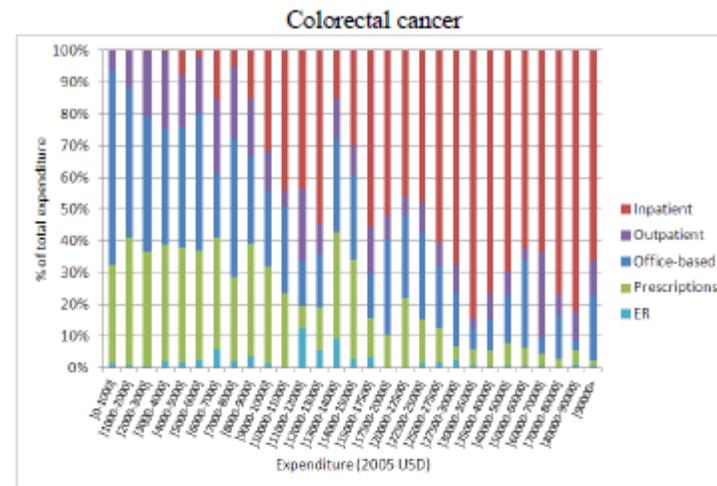
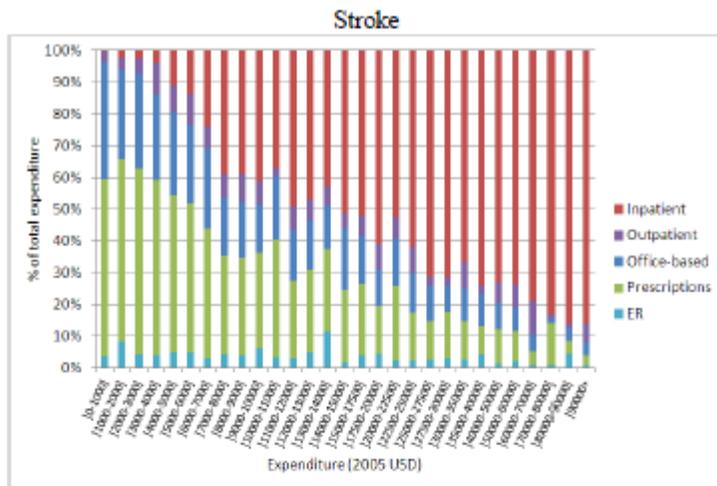


Diabetes

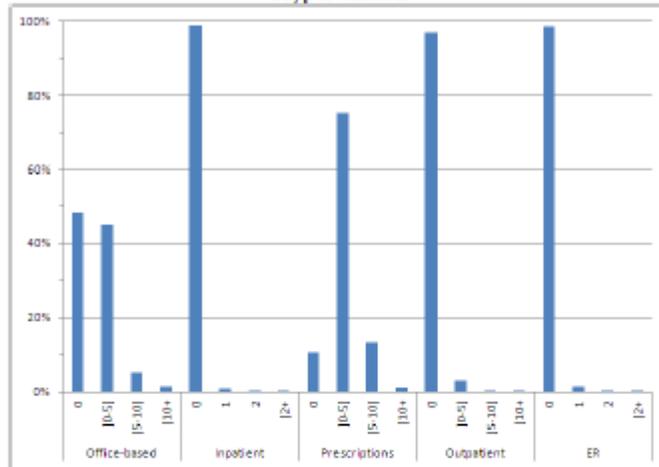


IHD

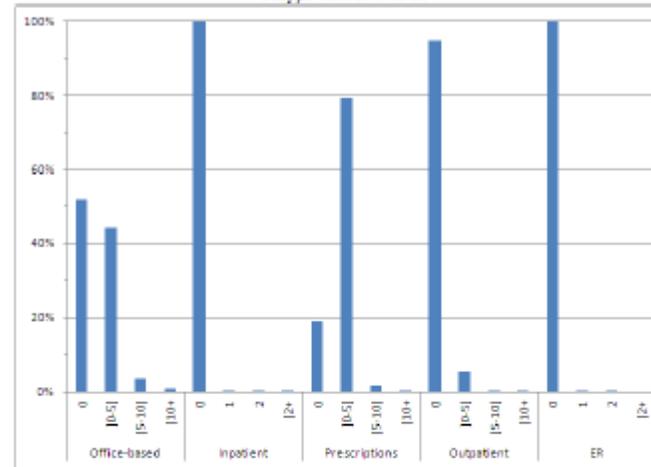




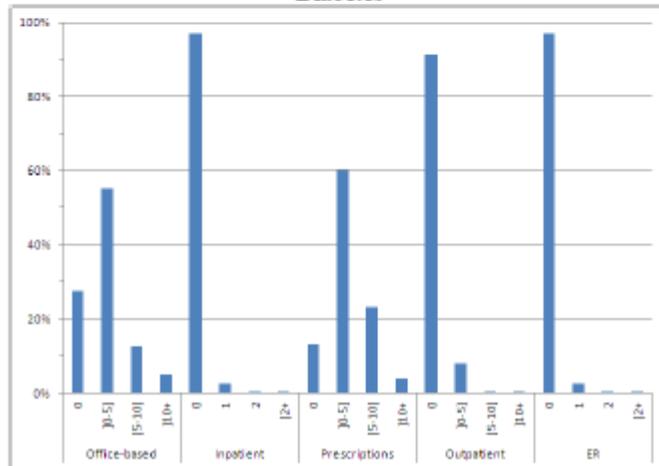
Hypertension



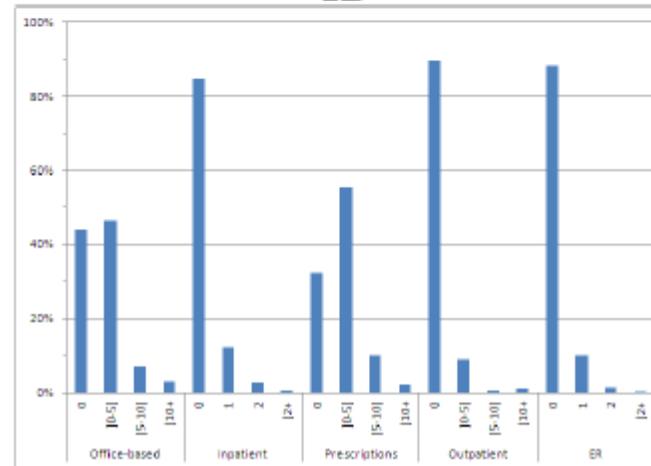
High cholesterol



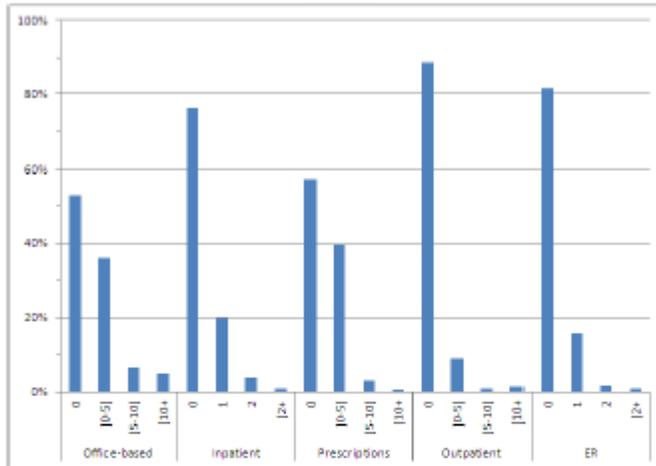
Diabetes



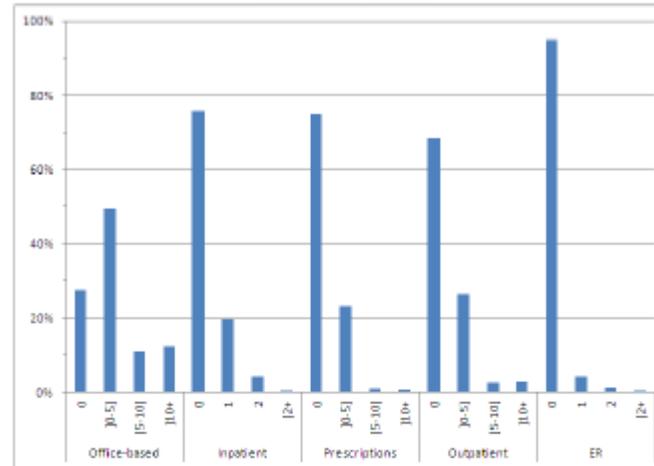
IHD



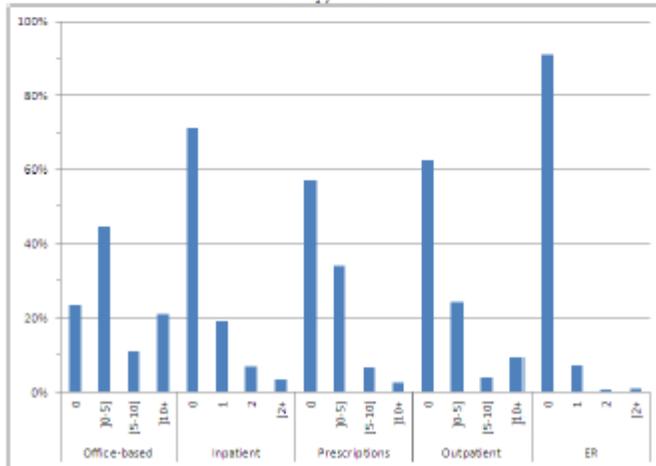
Stroke



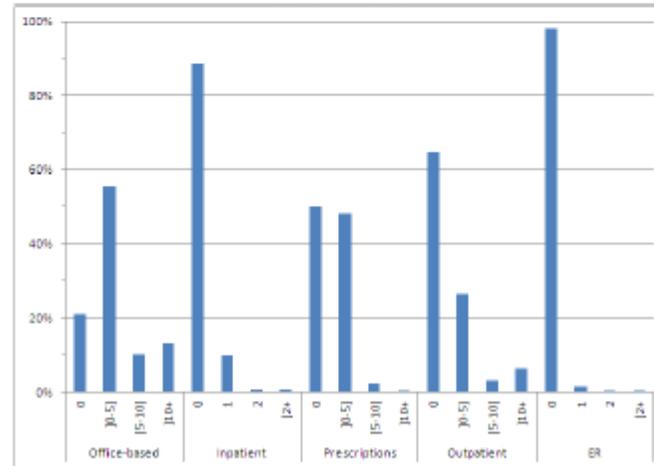
Colorectal cancer



Lung cancer



Breast Cancer



ANNEX 4: PILOT OF CDP 2.0 – EVALUATION OF ALCOHOL CONTROL POLICIES

514. Negative health effects and social harm caused by harmful alcohol consumption can be reduced through effective prevention strategies. In 1979, the World Health Assembly called upon WHO member states to develop and adopt appropriate legislation and measures to tackle alcohol misuse (WHO, 1979). Such efforts culminated with the endorsement, in 2010, of the global strategy on the harmful use of alcohol (WHO, 2011) that supports ten target areas for national actions including: health sector response, community actions, drink-driving policies, limitation of the availability of alcohol, action on the marketing and pricing policies, reducing the negative consequences of intoxication and reducing the public health effect of illegally and informally produced alcohol.

515. Policy makers and researchers agree that there is no silver bullet to limit harmful drinking. Rather, countries tend to adopt and combine a range of policies in different areas identified by WHO, with the aim of encouraging responsible drinking. However, even though alcohol policies are broadly comparable across countries in terms of types of measures used, they tend to vary significantly in terms of how they are implemented and in the legal limits for law enforcement. Table 22 summarizes the main features of the most common policies across OECD member countries and key partners. For instance, blood alcohol levels, often referred to as BAL (Lerner, 2012), can range from as low as zero tolerance (e.g. in Hungary, Czech Republic and Slovak Republic) up to 0.08% in the US, the UK and Mexico (WHO, 2011). On the other hand, the US has one of the most restrictive policies for minimum legal drinking age (21 years). At the opposite end of the spectrum, no minimum age limit for off-premises alcohol sales is set in Italy (Anderson, 2012).

Table 22. Summary of policies to tackle harmful alcohol consumption in OECD countries and partner economies

	Australia	Austria	Belgium	Brazil	Canada	Chile	China	Czech Republic	Denmark	Estonia
National Legal minimum age for off-premise sales										
<i>Beer</i>	18	16	N	18	subn	18	N	18	16	18
<i>Wine</i>	18	16	N	18	subn	18	N	18	16	18
<i>Spirits</i>	18	18	18	18	subn	18	N	18	16	18
National Legal minimum age for on-premise sales										
<i>Beer</i>	18	16	16	18	subn	18	N	18	18	18
<i>Wine</i>	18	16	16	18	subn	18	N	18	18	18
<i>Spirits</i>	18	18	18	18	subn	18	N	18	18	18
Restrictions for on-/off-premise sales of alcoholic beverages										
<i>time (hours/day)</i>	Y	N	Y/N	N / Y	N	N / A	N	N	Y/N	Y
<i>location (place/density)</i>	Y	N	Y/N	Y / N	N	N / A	N	N	Y	Y/N
<i>specific events</i>	Y	N	Y/N	Y	N	N / A	N	Y	Y	Y
<i>intoxicated persons</i>	Y	Y	Y/N	Y	N	N / A	N	Y	Y	Y
<i>petrol stations</i>	Y	N	N	Y	N	N / A		N	N	N
Taxation (Excises and VAT)										

<i>beer (excise per % alcohol)</i>	4.8-28.1	5.9	5.0	N / A	2-5	1 5 %	7. 7 %	4.5	6.4	N/A
<i>beer (VAT)</i>	10%	20%	21%	2 5 %	5- 13%	1 9 %	17 %	19%	25%	20%
<i>wine (excise per hectolitre)</i>	29%	0	54- 186	N / A	51.8	1 5 %	8. 4 %	0-173	77- 116	140. 1
<i>wine (VAT)</i>	10%	20%	21%	2 5 %	5%- 13%	1 9 %	17 %	19%	25%	20%
<i>spirits (excise per hectolitre)</i>	4442-4764	1183.6	2024 .0	N / A	976. 9	2 7 %	16 .7 %	1960.5	1885.0	271 9.5
<i>spirits (VAT)</i>	10%	20%	21%	2 5 %	5%- 13%	1 9 %	17 %	19%	25%	20%
National maximum legal blood alcohol concentration (%)										
<i>General</i>	0.05	0.05	0.05	0 .0 2	0.08	0 .0 5	0. 02	0	0.05	0.02
<i>Young</i>	0	0.01	0.05	0 .0 2	0.04	0 .0 5	0. 02	0	0.05	0.02
<i>Professional</i>	0	0.01	0.05	0 .0 2	0.08	0 .0 5	0. 02	0	0.05	0.02
Legally binding regulations										
<i>Advertisement</i>	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
<i>product placement</i>	N	Y	N	Y	N	N	N	N	Y	Y
<i>Sponsorship</i>	N	N	N	N	N	N	N	N	N	Y
<i>sales promotion</i>	Y	N	N	N	N	N	N	N	N	Y

	Finla	Franc	Germa	Gree	Hunga	Icelan	Ind	Indone	Ireland	Israel
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	nd	e	ny	ce	ry	d	ia	sia		
National Legal minimum age for off-premise sales										
Beer	18	18	16	18	18	20	sub n	21	18	18
Wine	18	18	16	18	18	20	sub n	21	18	18
Spirits	20	18	18	18	18	20	sub n	21	18	18
National Legal minimum age for on-premise sales										
Beer	18	18	16	18	18	20	sub n	21	18	18
Wine	18	18	16	18	18	20	sub n	21	18	18
Spirits	18	18	18	18	18	20	sub n	21	18	18
Restrictions for on-/off-premise sales of alcoholic beverages										
time (hours/day)	Y	Y	N	N	N	Y	Y	Y/N	N	N
location (place/density)	Y	Y	N	N	N	Y	Y	Y	Y/N	N
specific events	Y	Y	N	-	Y	Y	Y	Y	N	N
intoxicated persons	Y	Y	Y	-	Y	N	N	Y	Y	N
petrol stations	N	Y	N	-	N	Y	N	Y	N	Y
Taxation (Excises and VAT)										
beer (excise per % alcohol)	25.9	3.0	2.5	4.8	10.5	45.9	N/ A	N/A	22.0	133.9
beer (VAT)	22%	19.60 %	19%	19%	20%	24.50 %	N/ A	10%	21.05%	15.50%
wine (excise per hectolitre)	282.4	4-10	0-169	0	0-95	413- 403	N/ A	N/A	302-605	0
wine (VAT)	22%	19.6 %	19%	19%	20%	24.5%	N/ A	10%	21%- 21.5%	15.5%
spirits (excise per hectolitre)	3934. 1	1652. 4	1617.3	1840 .5	1841. 1	553.9	N/ A	N/A	4346.9	75%- 120%
spirits (VAT)	22%	19.6 %	19%	19%	20%	24.5%	N/ A	10%	21.5%	15.5%
National maximum legal blood alcohol concentration (%)										
General	0.05	0.05	0.05	0.05	0	0.05	0.0 3	N	0.08	0.05

Young	0.05	0.05	0	0.02	0	0.05	0.03	N	0.08	0.05
Professional	0.05	0.02	0.05	0.02	0	0.05	0.03	N	0.08	0
Legally binding regulations										
Advertisement	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
product placement	Y	Y	Y	-	Y	Y	Y	Y	N	Y
Sponsorship	Y	Y	N	-	Y	Y	Y	Y	N	-
sales promotion	Y	N	N	-	N	Y	Y	Y	Y	-

	Italy	Japan	Korea	Luxembourg	Mexico	Netherlands	New Zealand	Norway	Poland	Portugal
National Legal minimum age for off-premise sales										
Beer	N	20	19	16	18	16	18	18	18	16
Wine	N	20	19	16	18	16	18	18	18	16
Spirits	N	20	19	16	18	18	18	20	18	16
National Legal minimum age for on-premise sales										
Beer	16	20	19	16	18	16	18	18	18	16
Wine	16	20	19	16	18	16	18	18	18	16
Spirits	16	20	19	16	18	18	18	20	18	16
Restrictions for on-/off-premise sales of alcoholic beverages										
time (hours/day)	Y/N	N	N	N	Y	Y	Y/N	Y	N	N
location (place/density)	N	N	N	N	Y/N	Y/N	Y/N	Y	Y/N	Y/N
specific events	Y	N	N	Y	Y	Y	Y	Y	N	Y
intoxicated persons	Y	N	N	-	-	Y	Y	Y	Y	Y
petrol stations	Y	N	N	-	Y	Y	Y	Y	N	N
Taxation (Excises and VAT)										
beer (excise per % alcohol)	7.6	192	93.6 %	2.2	25%	6.2	16-24	11-45	9.2	4-9
beer (VAT)	20%	5%	10 %	15%	15%	19%	12.50%	25%	22%	20%
wine (excise per hectolitre)	0	69.8	33 %	0	25%-30%	70-237	159.5	537.1	84.9	0
wine (VAT)	20%	5%	10 %	12%-15%	15%	19%	12.5%	25%	22%	12%-20%

spirits (excise per hectolitre)	1027.3	218-349	93.6%	1154.1	50%	1773.6	2338-2905	6860.8	2665.9	1582.7
spirits (VAT)	20%	5%	10%	15%	15%	19%	12.5%	25%	22%	20%
National maximum legal blood alcohol concentration (%)										
General	0.05	0.03	0.05	0.05	0.08	0.05	0.08	0.02	0.02	0.05
Young	0.05	0.03	0.05	0.02	0.08	0.02	0.03	0.02	0.02	0.05
Professional	0.05	0.03	0.05	0.02	0.08	0.05	0.08	0	0.02	0.05
Legally binding regulations										
Advertisement	Y	N	Y	N	Y	Y	N	Y	Y	Y
product placement	Y	N	N	-	Y	Y	N	N	N	Y
Sponsorship	Y	N	N	-	Y	Y	N	Y	Y	Y
sales promotion	Y	N	N		Y	Y	Y	Y	Y	Y

	Russian Fed	Slovakia	Slovenia	South Africa	Spain	Sweden	Switzerland	Turkey	United Kingdom	United States
National Legal minimum age for off-premise sales										
Beer	18	18	18	18	16	20*	16	18	18	21
Wine	18	18	18	18	16	20	16	18	18	21
Spirits	18	18	18	18	16	20	18	18	18	21
National Legal minimum age for on-premise sales										
Beer	18	18	18	18	16	18	16	18	16	21
Wine	18	18	18	18	16	18	16	18	16	21
Spirits	18	18	18	18	16	18	18	18	18	21
Restrictions for on-/off-premise sales of alcoholic beverages										
time (hours/day)	Y	Y/N	Y/N	Y/N	Y/N	Y	Y/N	N	Y/N	N
location (place/density)	Y	Y/N	Y/N	Y/N	Y/N	Y/N	N	Y/N	Y/N	N
specific events	Y	N	Y	N	Y	Y	Y	Y	Y	N
intoxicated persons	Y	Y/N	Y	N	N	Y	N	N	Y	N
petrol stations	Y	N	Y	N	Y	Y	N	Y	Y	N
Taxation (Excises and VAT)										

beer (excise per % alcohol)	N/A	8.1	10.9	33%	1-3	18.6	0	35.6	25.2	21
beer (VAT)	18%	19%	20%	14%	16%	25%	7.60%	18%	17.5%	-
wine (excise per hectolitre)	N/A	0-157	0	23%	0	24.1.4	0	209-1331	255-436	46-113
wine (VAT)	18%	19%	20%	14%	16%	25%	7.6%	18%	17.5%	-
spirits (excise per hectolitre)	N/A	2122.5	1103.9	43%	11.67.0	56.09.2	1894.2	7084.5	34.6	923
spirits (VAT)	18%	19%	20%	14%	16%	25%	7.6%	18%	17.5%	-
National maximum legal blood alcohol concentration (%)										
General	0.03	0	0.05	0.05	0.05	0.02	0.05	0.05	0.08	0.08
Young	0.03	0	0	0.05	0.03	0.02	0.05	0.05	0.08	0.02
Professional	0.03	0	0	0.02	0.03	0.02	0.05	0	0.08	0.04
Legally binding regulations										
Advertisement	-	Y	Y	N	Y	Y	Y	Y	Y	N
product placement	-	Y	N	N	N	N	Y	Y	Y	N
Sponsorship	-	Y	Y	N	N	Y	Y	N	N	-
sales promotion	-	Y	Y	N	Y	Y	Y	Y	N	-

Notes: excise duties expressed in 2011 USD PPPs; 1% of alcohol equals to 2.5 degrees Plato; (*) minimum age in Sweden is 18 for beers with less than 3.5% of alcohol content.

Sources: WHO. Global Status Report on Alcohol and Health 2011; Greece and Luxembourg: Alcohol in the European Union - Consumption, harm and policy approaches and WHO Europe alcohol control database; Taxes: OECD. Consumption Tax Trends 2010: VAT/GST and Excise Rates, Trends and Administration Issues. Taxes for partner economies and Estonia from WHO Global Information System on Alcohol and Health.

516. One of the main goals of alcohol policies is to promote public health and social wellbeing. Additionally, policy can address market failures, for example by protecting vulnerable consumers (e.g. children) from exposure to alcohol, protecting people other than drinkers from harms caused by alcohol, and providing all consumers with information about the effects of alcohol. Our analysis is explicitly focused on policies whose primary objective is to reduce harmful alcohol consumption. However, policies in other domains may have important effects on alcohol consumption, although not primarily designed for this purpose. Examples include road safety measures, unemployment and social protection policies. A brief description of the most common policies in the OECD area is provided below, using the same broad categories as in WHO's Global Strategy.

517. *Information and education.* Campaigns to raise awareness of the risks of excessive drinking are common in OECD countries as a way to encourage responsible alcohol consumption. Information and education may be delivered by different means, covering different population subgroups. School-based interventions target children while worksite interventions target working-age adults. Reviews of existing evidence suggest that such campaigns do increase knowledge about the risks of harmful alcohol consumption (Anderson et al, 2012), but the change in drinking behaviours tends to be limited and short in duration. However, information and education campaigns can contribute to a package of measures to tackle harmful alcohol generating possible synergies with other measures. The delivery of education messages by private sponsors was found to have no significant public health effects (Christie et al., 2001; Smith et al., 2006; Barry & Goodson, 2010).

518. *Health sector response.* In most countries, treatments are available within the health sector for those with high levels of alcohol consumption or alcohol dependence problems (WHO, 2010). Two types of intervention are especially common. Brief advice delivered by a trained physician aims at informing the patient about the harms caused by excessive alcohol consumption and providing help in regaining control towards an acceptable use. For patients with more severe problems, such as dependence, interventions usually combine cognitive-behavioural therapies with pharmacological treatment. The main barrier to a greater effectiveness of this approach is represented by difficulties in reaching the target population, which limits overall coverage. A WHO-Europe (2009) review concludes that less than 10% of the population at risk for harmful alcohol consumption would be routinely identified, and less than half of those diagnosed would be offered advice.

519. *Community actions.* These include a heterogeneous set of interventions characterized by a bottom-up approach. Most often, community actions share many features of education and information policies. However, the former also include changes in the wider environment, and often also aim at moving alcohol up in the political agenda. The term "community" does not always mean that interventions are implemented at a neighbourhood or local level. For instance, workplace programmes and media advocacy both fall into this category. Community actions may usefully support broader alcohol prevention programmes (Anderson, 2012).

520. *Drink-driving policies.* A high blood alcohol concentration is a major risk factor for traffic accidents, injuries and death. Most countries have policies in place to prevent the utilization of motor vehicles under the influence of alcohol. A number of countries have different, usually more restrictive, thresholds for professional drivers and young people as they are at higher risk of traffic accidents. Enforcement is usually through check-points and random breath testing. Consequences for drivers identified with levels of alcohol beyond the tolerated threshold vary from fines to suspension or revocation of the driving licence to compulsory treatments for drivers with alcohol dependence. A strict enforcement strategy is key to effective drink-driving policies.

521. *Regulating alcohol availability.* Virtually all countries set a minimum legal age for the purchase of alcoholic beverages. Most of the countries in table 22 use the same minimum age threshold for both on-

premise (e.g. bars, restaurants) and off-premise (e.g. retail) sales while in few cases thresholds differ and, normally, are higher for on-premise sales. A second approach to limit alcohol availability is through controls on outlet density, either through State monopolies or commercial regulation. A further approach involves restrictions on licensing and outlet opening hours. Regulation of alcohol availability has the potential to produce significant effects on alcohol consumption (Stockwell & Chikritzhs, 2009; Livingston et al., 2007; Gruenewald, 2007) and health outcomes. However, a stringent policy on alcohol availability should be always coupled with effective enforcement, as informal market activities are likely to develop as a side effect.

522. *Regulation of marketing.* Countries use a range of policies to regulate the marketing of alcohol but, in general, these are largely based on self-regulation and co-regulation, which devolves responsibility for setting boundaries for marketing to the alcohol industry. However, existing evidence suggests that the effects of self-regulation of marketing are disappointing (WHO, 2007; Anderson et al., 2009). This is often due to poor participation and compliance, and to numerous breaches of self-imposed standards (Jones et al., 2008; KPMG LLP, 2008). When advertising bans are implemented, they are more likely to be partial, for example for certain products (e.g. only beverages with a higher alcohol content) or certain media (e.g. television) or during specific hours. Partial bans tend to have only limited effects on overall alcohol consumption, as advertising expenditure is simply shifted onto other media or targets. The increasing use of media that reach across national borders (e.g. internet) and social networks for marketing alcohol suggests the need to consider parallel cross-border regulation of advertising (WHO, 2011).

523. *Pricing policies.* Alcohol prices can be altered by using taxes or direct price controls, including minimum unit prices in order to change consumption. The most common approach is based on a combination of excise duties and value added taxes. Excise duties are applied to alcoholic beverages in two main ways, which in some cases may be combined. The charge may be specific to the alcoholic content of the product (e.g. percentage of alcohol in the drink) or calculated as a proportion of the "value" of the product (ad valorem excise). The effects of different taxes may vary substantially and changes in taxation require careful planning (e.g. Keen, 1998). Table 22 reports a concise summary of VAT and excise tax rates across OECD countries as of January 2009 (in some cases approximations were required because of the complexity of certain taxation systems). Potential substitution effects must be accounted for in designing taxation policies. For instance, the introduction of a tax on alcopops in Germany simply shifted consumption from spirit-based to beer-based beverages (Anderson et al., 2012b). Minimum unit pricing policies have also been in the spotlight in recent years. Time-series analyses in Canada (British Columbia) showed that a 10% increase in minimum price for alcohol reduces consumption of spirits by 6.8%, wine by 8.9%, alcopops by 13.9% and beer by 1.5% (Stockwell et al., 2012).

524. Patient-level costs involve face-to-face delivery by a health provider (broadly defined) to a recipient - e.g. medicines, outpatient visits, in-patient stays, individual health education messages. Programme-level costs include all resources required to establish and maintain an intervention - administration, publicity, training, delivery of supplies. Interventions like radio delivery of health education messages largely involve the former, while treatment at health centres largely involves the latter. A standardized ingredients approach is used, requiring information on the quantities of physical inputs needed and their unit cost (i.e. total costs are quantities of inputs multiplied by their unit costs). For programme-level costs, the physical inputs - human resources, office space, vehicles, electricity, other services, and a variety of consumables - required to introduce and run a programme are based on estimates by costing experts commissioned for this purpose, using a standard template (Johns et al., 2003, 2006). This was supplemented by information from programme managers in other countries known by WHO staff. These resource estimates represent a key building block for estimation of the costs of population based intervention strategies, such as tobacco control or salt reduction programmes.

525. For patient-level costs, quantities are taken from a variety of sources. Where effectiveness estimates were available from published studies, the resources necessary to ensure the observed level of effectiveness are identified. In other cases, the resources implied by the activities outlined in WHO treatment practice guidelines were estimated. Since it is not always possible to identify the exact quantities of primary inputs (human resources, consumables) necessary for patient-level costs, certain quantities and prices are estimated at an intermediate level for several inputs - inpatient days at different hospital levels, outpatient visits and health centre visits (WHO, 2003).

526. Unit costs for each input were derived from an extensive search of published and unpublished literature and databases along with consultation with costing experts. For goods that are traded internationally, the most competitive price available internationally was used. For example, estimates of drug prices were based on the median supply price published in the International Drug Price Indicator Guide, subsequently marked-up to account for transportation and distribution costs. For goods available only locally (e.g. human resources, inpatient bed days) unit costs have been shown to vary substantially across countries, although international comparisons found similar cost-of-illness patterns in several OECD countries (Heijink et al., 2004). As a result, cross country regressions, mainly accounting for country GDP and local characteristics of the supply of health care, have been run using the collected data to estimate the average cost (with adjustments for capacity utilization) for each setting (Adam et al., 2003, 2006).

527. Costs are reported in international dollars, or dollar purchasing power parities (\$PPPs) rather than US dollars, with 2008 as the base year. An international dollar has the same purchasing power as the US dollar has in the United States, and therefore provides a more appropriate basis for comparison of cost results across countries or world regions. Future costs are discounted using a 3% discount rate.

Modelling prevention policies

528. Prevention policies were identified and modelled on the basis of the WHO global alcohol strategies (WHO, 2010). In particular, our starting point was the list of potential interventions identified by Anderson and colleagues (2009) that are rearranged in table 22. Numbers in parentheses, next to any policy option, indicate the level of evidence available about the effectiveness of interventions. 1 indicates the highest level of evidence (i.e. more than one systematic review is available) while 5 signifies the lowest level of evidence (only observational evidence is available).

529. We ranked the eleven areas of interventions in order on the basis of policy importance, calculated on the supposed ability of the policy to modify behaviour and relevance in the political contest of countries, and on feasibility of the modelling of the policy. So for instance, policies for which we were able to find weaker evidence were ranked lower. As a result of this process we selected 6 policies as priority policies for modelling. These policies include: school based intervention, worksite intervention, drugs, primary care brief intervention, fiscal policies and regulation of advertising. A second group of policies that will be modelled in a second step include: random alcohol tests for drivers, minimum age for drinking, etc. Other, potentially promising, policies that could be modelled in the future include: environmental changes, etc.

Table 23. List of potential policies options to tackle alcohol consumption

Education and information	Health-sector response	Community programmes	Drink-driving policies and countermeasures	Addressing the availability of alcohol
School-based education (1)	Brief advice (1)	Media advocacy (5)	Introduction/reduction of BAL (1)	Government monopolies (2)
Parenting programmes (2)	Cognitive-behavioural therapies for dependence (2)	Community interventions (5)	Sobriety checkpoints and random breath testing (1)	Minimum purchase age (2)
Social marketing programmes (2)	Benzodiazepines for alcohol withdrawal (1)	Workplace policies (2)	Restrictions on young or inexperienced drivers (2)	Outlet density (2)
Public information campaigns (5)	Glutamate inhibitors for alcohol dependence (1)		Mandatory treatment (2)	Days and hours of sale (3)
Counteradvertising (5)	Opiate antagonists for alcohol dependence (1)		Alcohol locks (2)	
Drinking guidelines (6)			Designated driver and safe-ride programmes (2)	
Health warning (2)				
Marketing of alcohol beverages	Pricing policies	Harm reduction	Addressing illegal and informally-prod alcohol	
Volume of advertising (1)	Alcohol taxes (1)	Training of bar staff, safety-oriented premises (2)	Informal and surrogate alcohol (5)	

Education and information	Health-sector response	Community programmes	Drink-driving policies and countermeasures	Addressing the availability of alcohol
Self-regulation of alcohol marketing (5)			Strict tax labelling (5)	

Source: Adapted from Anderson et al., 2009

530. Modelling of policies is evidence-based. Therefore the first step was to retrieve quantitative evidence about the effectiveness of interventions. This entailed a literature review that, in the first instance, focused on meta-analyses and systematic reviews (e.g. Cochrane reviews). Retrieved data was then used to model the effectiveness of an average intervention and, based on the description of the intervention, to calculate the cost of implementing the intervention by employing the WHO-CHOICE approach (WHO, 2003). However, in some cases as, for instance, the school-based intervention, it was not possible to retrieve data that could be useful in modelling the interested intervention. Whenever this was the case, we retrieved the papers cited in the meta-analyses and the reviews and identified an intervention whose characteristics seemed to be representative for an average intervention for that domain. The choice of a single study was driven by its strength and its adaptability to multiple settings and was based on the following characteristics: representativeness of the sample, strength of the methodological approach, length of the follow-up, design of the intervention, adaptability to other countries, assessment of changes in alcohol consumption.

School-based interventions

531. Education and persuasion strategies are among the most popular approaches to avoid, or at least delay and reduce, the use of alcoholic drinks in youngsters. School-based interventions, in particular, are often seen a potentially effective approach to prevent alcohol-related problems. The principal objective of these kind of interventions is to raise the awareness of students about the dangers caused by alcohol misuse so that, as a result, young people are less likely to overindulge in drink. Generally, interventions tend to tackle a set of unhealthy behaviours together (usually, tobacco, alcohol and narcotics) rather than a specific one. Interventions may include both normative education (i.e. teaching) and resistance-skills training and may be exclusively directed to the students or include their family or the community into the activities. In general such programmes involve all the students in a class or a school but, in some cases, programmes have been carried out on specific subpopulation groups considered at a higher risk. In some cases, such interventions are implemented as one-off but the inclusion of “booster” sessions at later stages would favour the maintenance of positive behaviours over time (Foxcroft DR, et al. 2003; Foxcroft DR, et al. 2011).

532. *Selection of the evidence to model the intervention.* For this intervention, we identified nine high-quality meta-analyses (Ennet ST, et al., 1994; Bangert-Drowns LR, 1988; Tobler N. 1992; Rundall & Bruvold, 1988; Tobler & Tratton, 1997; Bruvold WH, 1988; Wilson DB, et al. 2001; Tobler NS, et al. 2000; Tobler N, 1986), two Cochrane reviews (Foxcroft D et al., 2002; Foxcroft D et al., 2011) and one review of reviews (Jones et a., 2007). Although extremely useful to develop an insight about school-based interventions, these publication were not judged practical for our modelling work, mainly for two reasons. First of all, studies in these area tend to use very different outcomes which is reflected in meta-analysis as aggregate effect sizes that are based on different outcomes (e.g. knowledge, intention to change, change in behaviour); and, then, interventions that tend to tackle alcohol together with other unhealthy behaviours (usually tobacco and/or narcotics). The final intervention was modelled on the School Health and Alcohol Harm Reduction Project (Mc Bride et al., 2000; McBride et al., 2004). Other papers that were considered in the process of definition of the interventions are cited at the end of this annex.

533. *Characteristics of the modelled intervention.* The intervention targets secondary school students aged 13 and follows them for two years, until they are 14. During the first year (phase one) the intervention consists of 17 skill-based activities conducted over 8-10 lessons. This is followed, in year 2, by other 12 activities conducted over a period of 5-7 weeks. All the programmed tasks entail active involvement of the participants and put an emphasis on identifying the harm caused by alcohol consumption and ways to reduce such harm. Example of activities carried out include: discussion of scenarios, small group decision making. Students are also provided with a workbook and watch a trigger video at the beginning of phase two. School teachers involved in the project undergo preparatory training which consists in two days of

briefings and interactive modelling. Teachers are also provided with a manual which contains detailed information on all the activities of the project.

534. *Effects of the intervention.* As most of the other studies assessing school-based intervention, the modelled approach would produce a positive effect on knowledge of the risks of alcohol abuse, on drinking attitude, on harm produced by alcohol and, finally on alcohol consumption. In particular, 17 months after the end of the intervention, students that have followed this kind of school-based action would have an alcohol consumption level which is 9.2% lower than the comparator group and are 4.2% less likely to have harmful/hazardous consumption levels (i.e. consumption of more than 2/4 standard drinks per occasion for females/males). The effectiveness of the intervention is based on data provided (Mc Bride et al., 2000; McBride et al., 2004) and the trend subsequently extrapolated with the best fitting polynomial until the point in time in which the intervention group has no significant difference with the control group in terms of drinking behaviours. Volume of alcohol consumption is the same for students aged 13 and reaches a low point of -36.35% for 14 year old students in the intervention group. After that, the positive effect starts fading out becoming -24.88% for 15 year olds, -3.12% for 16 year olds and completely disappears for 17 year olds. The effect on binge drinking follows a similar pattern. The low point is reached in students aged 14.5 (-35.03% of binge drinkers) and, then, decreases becoming -28.19% for 15 year olds and completely disappears when students become 16 year old.

535. *Cost of the intervention.* The estimated cost per target individual is 63.79 2008 US\$ PPP. Most of the data needed to model the cost of delivering the intervention at the school level were kindly provided by the principal investigator of the SHAHRP project (Mc Bride et al., 2000; McBride et al., 2004) and, subsequently, converted into US\$ PPP employing the appropriate conversion rates. In addition, we also included in the computation of the total costs, the cost of teaching hours and the overall organizing costs to scale up this intervention at the national level. The single most expensive item is extra teaching hours which have been estimated in about 10.10 2008 US\$ PPP per student per year (based on an average of 7 hours of extra teaching hours per classes of 26 students), followed by the provision of the equipment needed for skill-based activities which has been evaluated in about 7 2008 US\$ PPP. Training of the teachers costs 3.78 2008 US\$ PPP per child, under the assumption that teachers are trained at the beginning of the project and undergo 'booster sessions' every 5 years.

Fiscal measures

536. Sales taxes and excise duties are the most widely used fiscal measures affecting the price alcohol, virtually everywhere in the OECD area. Although taxes on alcohol were originally conceived as a means to raise revenues for the public sector (Smith A., 1776), they are increasingly seen as by some a public health measure (e.g. Rice, 2012). The impact of changes in the price of alcoholic beverages has been extensively studied and a consistent body of evidence shows that increases in taxation reduce alcohol consumption. In particular, the effects of taxation would be larger for moderate drinkers relative to heavier drinkers (Manning et al., 1995), for women (Elder et al., 2010), for young consumers (Xu X & Chaloupka, 2011) and for white people relative to other ethnic groups (An & Sturm, 2011). There is also good evidence demonstrating different levels of elasticity for different types of alcoholic drinks (Wagenaar A et al., 2009), while cross-country differences in elasticities were found to be insignificant when accounting for relevant confounding factors, such as per capita alcohol consumption and relative ethanol share of beverages in the relevant countries (Fogarty, 2006; 2008). Much of the effect of increased alcohol taxation on consumption depends on the degree to which the tax is passed on to consumers. In 1991, a 9\$ increase in the US Federal excise tax on beer resulted in an almost immediate increase in retail price by 15 to 17 USD (Young & Bielinska-Kwapisz, 2002). More recently, a comparison of how taxes on alcohol are passed on to consumers in Ireland, Finland, Latvia and Slovenia showed a more complex and heterogeneous pattern, with a pass-through ratio for beer ranging from 0 (i.e. no change in consumer price) for on-trade sales in Ireland to 2.5 for off-trade sales in Slovenia (i.e. a price increase of 2.5 times the tax

increase), and between 0.1 (on-trade in Ireland) and 1.4 (off-trade in Finland) for spirits (Rabinovich et al., 2012).

537. *Selection of the evidence to model the intervention.* We were able to identify 5 recent high quality review studies (two meta-analysis and four systematic reviews) examining the link between alcohol price and levels of drinking (Dhalwani N, 2011; Elder R et al., 2010; Gallet C., 2007; Wagenaar A et al., 2009; Wagenaar A et al., 2010). The modelling of this intervention in CDP-alcohol is mainly based on two studies. The overall effectiveness of increased price for alcoholic drinks is derived from a meta-analysis of 112 studies that took into account more than 1000 different estimates (Wagenaar et al., 2009) while the effect of gender and age groups have been calculated on a paper by Kuo and colleagues (2003). The full list of papers considered in the selection process is listed at the end of this annex.

538. *Characteristics of the modelled intervention.* The modelled intervention essentially consists of a change in existing alcohol taxes which would generate an average price increase of 10% at the point of consumption across all alcoholic beverages. No specific assumption is taken on whether such average price increase would be achieved by increasing excise duties, by modifying other existing taxes, or by introducing new fiscal measures. At the country level, a 10% price increase would entail, for the different types of alcoholic beverages, a precise assessment of how much the tax on alcohol should be augmented, keeping into consideration potential pass-through effects. The intervention also entails an accurate enforcement of the law and, therefore, this should avoid any significant increase in the consumption of alcohol that is produced, distributed and sold outside the usual systems of governmental control (e.g. homemade alcohol and smuggled drinks). Consistently with available evidence, this intervention also assumes that the increase of the tax almost immediately triggers an increase in the price of the alcoholic drinks (Young and Bielinska-Kwapisz 2002).

539. *Effects of the intervention.* A 10% increase in the price of all alcoholic drinks sold in a country would produce a decrease in the consumption that ranges from 2.8% for harmful drinkers to 5.4% for other drinkers. This estimation is of the same order of magnitude (and slightly more conservative) of elasticities employed in other modelling approaches. For instance, the Sheffield model (Meier P, 2008) assumes elasticities of -0.47 and -0.21 respectively for moderate and hazardous/harmful alcohol drinkers while the WHO-CHOICE study on Estonia (Lai et al., 2007) assumes an elasticity ranging from -0.4 to -1.2 according to the different types of alcoholic beverages (e.g. wine, beer, etc.).

540. *Cost of the intervention.* The estimated administrative cost of this intervention is 0.13 2008 US\$ PPP per capita. This estimate includes basic administration, planning, monitoring and enforcement at the national level, which, in particular, accounts for most of the total cost. The resulting revenues from the tax are not accounted for in the analysis as they represent transfers rather than costs. Nonetheless, these revenues may be substantial; for instance, in the US in 2008 the tax revenues from alcoholic beverages amounted to about 5.75 billion US\$ (Tax Policy Center, 2012), an implementation of a 10% increase in the tax would have increased revenues by 4.2%, i.e. about 0.84 US\$ per capita, which is more than 6 times the cost of implementation.

Regulation of advertising

541. Heavy marketing of alcohol is regarded as a causal factor in alcohol consumption, particularly because of its impact on the habits of teenagers and youngsters (Anderson et al., 2009; Snyder et al., 2006). Advertising is a global industry employing increasingly sophisticated marketing techniques in traditional media (e.g. television and print), branding and sponsorship of events, product placement in films and shows, point-of-sale displays and, more recently, new media like internet, social networks and smartphones. Regulation of advertising is a well-established intervention across the OECD. Most countries implement partial bans preventing the marketing of specific types of alcoholic beverages (e.g. spirits),

during certain times (e.g. when a large proportion of the audience is made up by youngsters) or for specific media (e.g. television). Regulation may also target the content and mode of delivery of advertising messages. For instance the EU Council Directive 89/552/EC of October 1989 asserts that television advertising for alcoholic beverages should not be specifically aimed at, or depict minors consuming alcohol, it should not link alcohol to enhanced physical performance, driving, social or sexual success and so on. In a number of cases, these restrictions operate alongside industry self-regulation codes.

542. *Selection of the evidence to model the intervention.* The evidence to model this intervention has been selected by reviewing papers referenced in 5 systematic reviews (Anderson et al., 2009; Bryden et al., 2012; Meier P, 2008; Pinsky et El Jundi, 2008; Smith et Foxcroft; 2009) and 2 meta-analyses (Gallet CA, 2007; Nelson JP., 2011). In general, there are two kinds of studies providing evidence to model the effectiveness of interventions aimed at regulating advertising. A first type provides elasticities calculated as changes in consumption of alcoholic beverages following changes in industry spending on advertising. A second type employs longitudinal approaches by following groups of people (usually teenagers) to estimate how exposure to advertising changes their drinking patterns. We modelled this intervention on the data provided by a meta-analysis of 322 estimates of advertising elasticities by Gallet (2007), supplemented with the results of a study by Saffer and Dave (2006). Other papers that we considered in the review process can be found at the end of this annex.

543. *Characteristics of the modelled intervention.* This intervention entails regulatory measures leading to a 10% reduction in advertising expenditure and a corresponding reduction of exposure to alcohol advertising for different types of consumers. The regulatory intervention assumes a comprehensive set of restrictions applied to all traditional and new media, sponsorships, branding and point-of-sale displays. Enforcement would be ensured by existing authorities/agencies at no additional cost, as most of the OECD countries are already equipped with the necessary infrastructure. This intervention also assumes that individuals living in a country are not exposed to a considerable amount of advertising from a neighbouring country that does not implement the same intervention. Finally, we also assume that the intervention becomes effective within the first year of its implementation.

544. *Effects of the intervention.* According to the available evidence (Gallet CA, 2007), a 10% decrease in advertising expenditure, produces a 0.32% decrease in alcohol demand. Consistently with the evidence showing that the effect of advertising would be stronger for youngsters compared to adults (Anderson P., 2009), we decided to employ a different elasticity for people under 18. In particular, we selected the most conservative estimates in a paper by Saffer and Dave (2006) reporting elasticities of 0.0341 and 0.0650, respectively for past month alcohol participation (i.e. any drinking) and past month binge participation. Other potential valuable dimensions that could be taken into account include level of drinking, with heavy drinkers supposedly being less influenced by advertising, and gender. However, we were not able to retrieve any strong quantitative estimation on how the elasticity estimates we employ could be affected by gender and level of drinking and, therefore, decided to employ the abovementioned values on all the drinking population, independently from their other socio-economic characteristics. Compared to previous modelling attempts, this is likely to be a conservative estimation. For example, a study on the impact of advertising control strategies in the European Union (Anderson and Baumberg, 2006) was based on a 2%-4% reduction in the incidence of hazardous alcohol use, while the Sheffield model (Meier P, 2008) along with the estimates by Gallett (2007) and Saffer and Dave (2006) also carries out analyses simulating a partial and a total ban (-5% and -9% in consumption levels) of alcohol advertising as suggested by relevant literature (Saffer and Dave, 2002).

545. *Cost of the intervention.* We estimated the cost of this intervention at 0.54 2008 US\$ PPP. The intervention involves basic administration and planning costs at the national and local levels. In addition, minor training may be required for the communication authority staff charged with the task of overseeing

the implementation of the scheme. Finally, our estimation includes the cost of monitoring and enforcing the new regulation which, actually, represent the most expensive components of the intervention.

Brief intervention (physician-nurse counselling)

546. Counselling services to individuals with harmful alcohol consumption are offered across OECD countries in a number of different ways, for instance, through the medical system (e.g. hospitals, residential facilities, out-patient services) or by social services. General practitioners in particular have a key role as first point of contact both for patients requiring healthcare services and as advisors on lifestyle and prevention for non-treatment seeking patients. Brief intervention in the alcohol domain usually targets this second category of patients with the aim of reducing alcohol consumption among problematic drinkers. A large body of evidence has been developed to assess a number of different approaches or combination of approaches. A number of quantitative and qualitative studies report about expected effectiveness of brief interventions implemented in different facilities, test the effects of interventions managed by non-physician personnel and show the importance of the screening component as complementary part of the intervention. Previous studies also suggest that the small coverage rates granted by this intervention (WHO-Europe, 2009) would be the result of lack of time of physicians and obstacles in reimbursement arrangements (NICE, 2010).

547. *Selection of the evidence to model the intervention.* A Cochrane review on the effectiveness of brief alcohol interventions in primary care (Kaner et al., 2009) is our primary source to model patient characteristics and the effectiveness of the intervention. This review reports and combine results from 24 controlled trials in general practice across 11 OECD member countries (11 studies from US, 5 in UK and Spain, 2 in Canada, Finland, Sweden, 1 in France and Australia). The primary care setting has been selected on the evidence presented in the review that stresses the strong beneficial effects of this policy in comparison to equivocal outcomes in emergency care (Nielsen et al, 2008), general hospital settings (McQueen et al, 2011), e-intervention (Khadjesari et al, 2010; Sullivan et al, 2011) and obstetric or antenatal care (Doggett et al, 2009). The five papers, cited in the review, that focus on motivational intervention were discarded so that our results are not influenced by a different intervention. The modeling of the delivery of the intervention, from patients' recruitment to the follow-up, is based on a paper by Wallace (1988) and a NICE report (2010). Some papers (NICE, 2010; Rehm et al., 2012) distinguish between brief intervention and extended brief intervention in which, following an ineffective brief intervention by a primary-care doctor, a specialist practitioner would provide an extended brief intervention with several forms of motivational interviewing or motivational enhancement therapy (Vasilaki et al, 2006; Senft et al, 1997; Carey et al, 2007; Lundahl et al, 2010). Our analysis focuses only on brief intervention because extended intervention was associated with a non-significantly greater reduction in alcohol consumption (Kaner et al, 2009) and brief intervention efficacy among patients with dependence has not been established (Saitz et al, 2010). Other papers that contribute to define brief intervention can be found at the end of this annex.

548. *Characteristics of the modelled intervention.* This intervention targets men and women with harmful alcohol consumption (Wallace et al, 1988) and with no alcohol dependency (Kaner et al, 2009) in the age range 17-69. Dependent users, eligible for the drug and counselling intervention, or patients already on a treatment programme are not eligible (Anderson et al, 2012). Patients' recruitment, as the intervention targets non-treatment seekers, typically occurs opportunistically by screening patients visiting a health care facility for a non-alcohol-related problem (Kaner et al, 2009). Screening is carried out by employing a questionnaire (AUDIT) asking information about health status and alcohol consumption in the last seven days; the questionnaire can be either handed during the registration or mailed at home. The paper by Wallace (1988) suggests that response rate would be 11% and 4.5% for men and women and that 32% and 17% of eligible individuals would accept to receive the treatment. Participating individuals meet a primary-care doctor for a visit and undergo a blood test (NICE, 2010). During the 20 minute visit, the

consultant explains the potential harm caused by drinking and suggests practical strategies to reduce alcohol consumption highlighting wellbeing benefits (Wallace et al, 1988). Some printed material (self-help leaflet, booklet to report consumption and a visual to compare own consumption with the average) is handed to participants. The 12 month follow-up is managed by a trained nurse that during each of the four visits (months 1, 3, 6 and 12) checks the booklet, performs a blood test and feedbacks on alcohol consumption and any alcohol-related harm (NICE, 2010). The common drop-out rate for this intervention is 27% (Kaner et al, 2009).

549. *Effects of the intervention.* Compared to a control group not undergoing the intervention, the Cochrane review (Kaner et al, 2009) suggests that, during the phase of the intervention, patients can be expected to reduce their alcohol consumption by 57 grams/week (i.e. about 6 standard drinks) and 10 grams/week respectively for men and women. Evidence about the long-term effectiveness of the intervention suggests a limited persistence. A recent Cochrane review (McQueen et al., 2011) reports that “results demonstrate a significant difference in favour of brief interventions in the reduction of alcohol consumption at six month and nine month follow up, but there was no significant difference between the groups at one year follow up”. Likewise, other authors (Burge et al., 1997; Wutzke et al., 2002) found a clear benefit until the 9th month after the treatment but no significant difference with the control group after 12-18 months. Based on these papers and a recent meta-analysis by Jonas and colleagues (2012), we decided to model a descending trend for the effectiveness of the intervention that completely fades out (i.e. 0 effectiveness) one year after the end of the intervention.

550. *Cost of the intervention.* The estimated cost per target individual is 345.69 2008 US\$ PPP. The main drivers of this figure are costs for the doctor and nurses (23%), followed by provision of printed material for patients (i.e. about 10 \$). This intervention involves basic expenses for administration, monitoring and training for doctors and nurses delivering the intervention. Even if brief intervention is provided by facilities already in place and delivered by specialized health personnel, programme and training costs account for about half of the total expenditure per target individual because all the fixed costs are borne by only a small fraction of the population.

Pharmacological treatment and psychosocial programme for alcohol dependence

551. Alcohol dependency affects millions of individuals in the OECD area. In the EU alone, it is calculated that between 11 million (Rehm et al., 2012) and 12 million (WHO, 2008) people, in large part males, are affected by this disease that is deemed responsible both for about three quarters of the mortality attributed to alcohol consumption and 60% of the social costs of alcohol. Pharmacological treatment combined with a psychosocial programme to cut down alcohol consumption or to maintain abstinence is the most commonly used approach to treat individual experiencing alcohol dependence.

552. *Selection of the evidence to model the intervention.* The evidence to model this intervention was primarily derived by papers referenced in four studies: two Cochrane reviews (Rösner et al, 2010; Rösner et al, 2011), a WHO report (Anderson et al, 2012) and a report published by the Centre for Addiction and Mental Health (Rehm et al, 2012). Given the systematic research process and their strong evidence-based vocation, after a selection process, we decided to model the effectiveness of the combined intervention on the evidence reported by the two Cochrane reviews and, in particular, we selected results for the intervention employing Naltrexone (rather than Acamprosate) based on a lower cost, a shorter treatment and an effectiveness no significantly different from Acamprosate drugs “on return to any drinking, return to heavy drinking and cumulative abstinence duration” (Rösner et al, 2010). The delivery of the behavioural component was based on the description of the interventions carried out in four clinical trials (Morley et al, 2006; Baltieri et al, 2003; Lui et al, 2008; Mason et al, 2006), whose results were included in the Cochrane review. Other papers considered in the review process are listed at the end of this annex.

553. *Characteristics of the modelled intervention.* The intervention targets all the individuals of age between 18 and 65 who fulfil the criteria of alcohol dependence or alcohol abuse according to Diagnostic and Statistical Manual of Mental Disorders (DSM) or the International Statistical Classification of Diseases (ICD). Candidates are recruited on a voluntary basis, when participating in a detoxification programme, or are identified among patients responding to advertising campaigns (Morley et al, 2006). According to the available evidence (WHO, 2004; VisionGain, 2008), the intervention was modelled only for a small fraction (i.e. 2%) of the patients that would potentially receive benefits from this intervention. Both sources agree that only between 10% and 20% of individuals with alcohol dependence are diagnosed and that, among these, only 10% receive treatment. Patients undergoing the treatment are first detoxified and must avoid alcohol intake for a period of 3 to 7 days. After this first phase, patients undergo a 3 month therapy of Naltrexone (50mg/day) combined with a psychosocial programme. The first, 20 minute-long, psychosocial intervention is carried out by a specialist doctor in a primary care setting and involves a medical assessment plus a motivational interview (Lui et al, 2008). This is then followed by additional 5 visits of 10 minutes each at week 1, 2, 4, 12 and 26, provided by a nurse, specifically trained for this task by videos. At the beginning of the programme, patients are handed a booklet with information on how to avoid drinking triggers and with techniques to enhance medication compliance (Morley et al, 2006). About 30% of patients beginning the intervention decide to withdraw before the end (Baltieri et al, 2003).

554. *Effects of the intervention.* Based on the above evidence built on the combination of results from 50 RCTs (Rösner et al, 2010 and 2011), this intervention reduces the risk of return to heavy drinking by 17% (while treated) / 14% (short post-treatment period). In addition, during the treatment, the amount of alcohol consumed per drinking day decreases by 10.83%; the number of drinking days by 4% and the number of heavy drinking days by 3.25%. The long-term effectiveness of Naltrexone has been assessed by several studies (Anton et al, 1999 and 2001; Paille et al, 1995a, 1995b; O'Malley et al, 1996; Heinala et al, 2001). Although few studies report that, compared to placebo, Naltrexone would maintain a long-term effectiveness, systematic reviews and studies with a larger sample (Krystal et al., 2001) have reservations about the long-term effectiveness of this intervention. For example, a systematic review by Roozen (2006) concludes that “there is also moderate evidence that there is no difference in the long-term effects of Naltrexone on percentage of drinking days and time to first relapse”. Based on this data, the intervention is modelled on the basis that half of the effectiveness is retained for the first year after the intervention, while no positive effect is retained afterwards.

555. *Cost of the intervention:* The estimated cost of the intervention is 511.94 2008 US\$ PPP per target individual. A large share of this figure (33%) is spent for the pharmaceutical product whose cost, for a three month treatment, has been evaluated in about 167 2008 US\$ PPP (Pharmacychecker, 2012). The psychosocial programme, primary care visit and follow-up visits managed by a nurse, accounts for about 20% of the total cost. The remaining part is spent for material handed to patients and other costs of organization.

Worksite-based intervention

556. Places of work have the potential to offer all the characteristics needed to carry out successful prevention programmes. The majority of the adult population is employed and spend a significant amount of time at the workplace where the environment and peer-pressure from colleagues shape individuals' behaviours and lifestyles, patterns of alcohol consumption included. From the point of view of the employers, implementing prevention programmes to tackle harmful alcohol consumption may present some positive economic effects. A number of studies emphasize the negative consequences that harmful patterns of alcohol consumption would have on absenteeism, presenteeism, loss of productivity, poor co-worker relations, unemployment and healthcare costs (Anderson et al, 2012). The implementation of preventing programmes could reinforce positive changes in the lifestyle of employees and decrease

employers' costs caused by the negative effects of workers' dangerous alcohol drinking behaviours (Dale et al, 2010).

557. *Selection of the evidence to model the intervention.* The evidence to model this intervention has been selected by reviewing papers referenced in one systematic review (Webb et al., 2009) and a recent review of the literature (Ames & Bennett, 2011). Webb and colleagues identify 10, mainly US-based, studies that analyze a heterogeneous set of interventions ranging from peer support programmes, to brief interventions and to counselling-based interventions. Of all the reviewed approaches, only brief intervention at workplace would show a small but clear positive effect (Cook et al, 1996; Richmond et al, 2000). The literature review by Ames and Bennett identifies four different programmes: health promotion, social health promotion, brief intervention and web-based interventions. The evidence to model the intervention assessed in this study is based on a paper by Richmond and colleagues (2000) reporting the effects of a brief intervention at the workplace in a big Australian postal network. This paper was selected because of the relatively large sample and because the careful description of all the phases of the intervention, from the recruitment to the action and the follow-up. Other papers were not included in our analysis because of the poor participation rates (e.g. an interactive web site intervention (Matano et al, 2007)) or because the intervention did not show statistically significant results (e.g. Hermansson et al., 2011). Probably, most of the uncertainty about what worksite-based interventions work will be resolved by an undergoing Cochrane review (Cercarelli, 2009). Other relevant papers analyzed during the process are cited at the end of this annex.

558. *Characteristics of the modelled intervention.* The intervention targets individuals of both sexes aged 18 to 65 working for companies with at least 50 employees. Participants are recruited anonymously and on a voluntary basis among workers reporting excessive levels of alcohol consumption or with a pattern of binge drinking (Richmond et al, 2000; NHMRC, 1992). Patients with a diagnosis of alcohol dependence are excluded from this intervention but are referred to an alcohol treatment agency. According to the available evidence (Richmond et al., 2000), this intervention would be able to reach 12.3% of the potential target in participating workplaces. The intervention consists in three phases plus a "kick off" period to promote participation by distributing brochures and posters. The initial screening process is carried out during the first phase that lasts 4 to 5 months. All the workers are handed a questionnaire enquiring about the general health status and the weekly alcohol consumption during the previous three months. Workers reporting an alcohol daily intake higher than the defined threshold (NHMRC 1992), are selected for the following phase. Workers that, based on their answers, would not be selected for phase two, may join in if they wish so. Phase two of the intervention consists in a second, more comprehensive, questionnaire about drinking pattern whose results are used to tailor a subsequent brief intervention (1 visit of 20 minutes) delivered by a general practitioner. During the visit the patient is provided with a booklet and receives information about the health effect of harmful patterns of consumption, national alcohol trends and advice on how to reduce consumption. This phase lasts for a maximum of two months. The final phase of follow up (10 months after the beginning of the action) consists in a final screening to be carried out with a procedure similar to phase one. The drop-out rate for this type of intervention has been estimated in about 20% (i.e. 80% of individuals beginning the intervention gets to completion) (Webb et al, 2009).

559. *Effects of the intervention.* This worksite-based intervention would be able to decrease the consumption of alcohol in men and women by, respectively, 4.8 and 0.7 standard drinks per week during the period in which the individual is undergoing the intervention. Evidence about the long-term effectiveness of worksite interventions (i.e. after the end of the intervention) is less abundant. As the main component in determining the effectiveness of the action is the brief intervention delivered by the health specialist, we decided to model the long-term effects of the intervention on this specific component. In particular, we were able to retrieve four relevant papers (McQueen et al., 2011; Burge et al., 1997; Wutzke et al., 2002 and Jonas et al., 2012) all of which suggesting that the positive effects of the brief intervention

would completely disappear within 9-12 months after the end of the intervention. Based on this evidence we decided to model half of the positive changes in alcohol drinking patterns for the year following the end of the intervention and no behavioural change thereafter.

560. *Cost of the intervention.* The estimated cost per target individual is 157.28 2008 US\$ PPP. Although the intervention is carried out at the workplace, we assume that this intervention is subsidized and coordinated by the government. However, we do not assume any reimbursement to the employers for the working time that participating employees may use to take part in the programme. The most expensive single component of this intervention is the brief intervention delivered by the general practitioner which account for about a fourth (i.e. 25%) of the total cost. Other drivers of the cost include printed material (booklet, leaflet, posters, questionnaire) and administrative support for the phases of screening and management of the patients.

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