FRAMEWORK PAPER

Life Science Innovation Forum VI

Lima, Peru, August 2008

Investing in the Future: An Assessment of the Returns to Investment in Health Innovation

Centre for Strategic Economic Studies
Victoria University, Melbourne

Institute of Population Research
Peking University, Beijing

Table of Contents

List of Tables

List of Figures

Investing in the Future: An Assessment of the Returns to Investment in Health Innovation[1]

Framework Paper

Executive Summary

This study examines the potential impact of increased investment in health innovation in APEC economies, and especially the developing ones, in the context of population ageing and increasing chronic disease. Together these two trends, while varying in their effect across economies, will raise acute issues of population health and health care costs, with flow on effects to the labour force, GDP growth and the budget position of governments.

One response available to governments is to foster large scale investment in health innovation, funded from both public and private sources. Such an investment program would pursue improved prevention, detection and cure of disease, with the aim of sustaining the health of ageing populations and enabling them to participate actively in economic and social life. We examine two increased investment scenarios, relative to a base case in which innovation is just sufficient to hold mortality rates by age, sex and cause at 2005 levels (the constant mortality rates scenario). The two investment scenarios are an 'ongoing innovation' one, in which innovation is sufficient to bring mortality rates down to the path described in the World Health Organisation (WHO) 2005 projections to 2030 (Mathers and Loncar 2005). The second is an 'enhanced innovation' scenario, in which further innovation leads to age, sex and cause specific mortality rates for chronic diseases being reduced by 1% per annum between 2010 and 2030, relative to this WHO scenario.

Our main focus is on the costs and benefits of such programs of investment, and on whether they provide a good return on investment in economic and social terms. We also examine whether, more generally, they would constitute an appropriate response to the challenge that APEC economies now face. In an open world economy, a wide array of cost effective innovations are now available, and massive ongoing R&D offers new products and methods in the future. Many studies have been undertaken on the cost of specific innovations, and we draw on this literature in forming our cost estimates.

In terms of the benefits, five forms of benefit are identified (reduced mortality and incidence of disease; lower treatment costs; increased labour force, productivity and GDP; improved government budgetary position; and broader dynamic economic and

[1] This report was prepared by Peter Sheehan, Bruce Rasmussen, Kim Sweeny, Ahmed Abdullahi, Bhajan Grewal and Neelam Maharaj of the Centre for Strategic Economic Studies, Victoria University, Melbourne and by Zheng Xiao-ying, Huang Chengli and Liu Lan of the Institute of Population Studies, Peking University, Beijing. Expert support from Margarita Kumnick and Alison Welsh is gratefully acknowledged.

industry effects). Of these quantitative estimates, the first three are reported, based on a simple model of health innovation in the APEC developing economies that has been constructed for the study, but the fourth and fifth is discussed in qualitative terms only. These estimates allow an assessment to be made of the likely overall return to such a program of investment in health innovation. Before summarising our results, the issues are placed in their broader global and regional context, in which many economies are being forced to rethink their existing development strategies.

The Global and Regional Context

In many APEC member economies the period in which rising labour supply and an open, pro-market approach to industrial development fuelled rapid growth is coming to an end. Population ageing will become pronounced in most developing economies in APEC, and this will in turn lead to a decline in the overall labour force in the region. Global competition for manufactured exports is now intense, as many countries have entered this space. Prices for food, energy and resources have risen in response to sharp increases in demand, and inflation is now a serious issue. Environmental problems are becoming acute, both for the world's climate and for pollution, water supply and the natural environment within economies. Lifestyles in developing economies are increasingly reflecting those of developed ones, with high and rising incidence of smoking, diabetes, and cardiovascular and respiratory diseases.

These changes do not imply the end of rapid development with improving standards of living, but do indicate that a revised development strategy will be needed for this to be achieved. This report focuses on one core element of this issue, namely the interplay between population ageing, the rising incidence of chronic disease and development strategy, with particular regard to the developing economies in APEC. Rapid ageing and rising levels of chronic disease imply that, in APEC developing economies as a whole:

- the labour force will begin to fall from about 2015, after doubling between 1975 and 2015;
- disability adjusted life years lost (DALYs) from chronic disease will rise rapidly, especially in the absence of extensive investment in innovation in health;
- as a consequence, and in addition to an increasing number of deaths, a rising share of the population will be living with a chronic disease, with lower work involvement and reduced productivity while at work; and
- health expenditure as a share of GDP will rise significantly under any scenario, as the costs of providing adequate treatment for chronic disease rise faster than GDP.

In this changing situation, investment in health innovation can become a key plank of the new approach to development, being seen not as an unavoidable cost but as a fundamental investment at the heart of future economic and social viability. In this report we seek to show that the returns to such investment, provided that it is carried out efficiently and with due regard to the specific needs of each economy, can be very high indeed.

Innovation is here defined as the creation and use of knowledge new to the specific context in which it is applied, across all dimensions of the health system, from new medicines and advanced detection and treatment to policy frameworks, insurance arrangements, rural and urban health infrastructure and governance structures. Hence investment in innovation refers to activities across the whole spectrum: improved sanitation and living conditions in poor areas; prevention programs, including lifestyle changes and preventive medicine based on known risk factors (such smoking, alcohol use, obesity and blood lipid levels) and systematic monitoring of such risk factors; health system reform and improved financing structures; expanded vaccination programs, with older proven vaccines or new ones in the pipeline; the more extensive use of existing and emerging medicines and procedures to treat disease; and advanced screening and biomarker projects to identify and treat the preconditions for disease. This applies both to the developed economies, where much chronic disease could still be averted by early action, and to the developing economies, many of whom have not yet had the time or resources to build appropriate programs.

There is now a vast repository of medical knowledge and of proven technologies available for use in APEC economies, and new products and methods are emerging all the time. We show that this existing and emerging knowledge can be the basis for cost-effective innovation, having regard to the specific needs and circumstances of each economy, to provide the best outcome in terms of health, development and fiscal sustainability. It can be readily accessed by economies in an open, globally integrated world, provided appropriate systems and infrastructure are in place. But economies wishing to build dynamic processes of health innovation, drawing on these knowledge resources and collaborating with institutions and organisations from around the world, will need to respect the market disciplines governing health knowledge. Just as the rapid growth of many economies over the past twenty years has been made possible by increasing integration into global trade in goods, so investment in health innovation can best drive development by being integrated into global processes for the creation, exchange, protection and use of intellectual property pertaining to health.

The trend towards increased spending on health and increased investment in health innovation is, and will continue to be, a world-wide trend, not just one appropriate for some economies in APEC. The share of health in GDP is rising in most countries, and will continue to do so. Health is both a superior good (one the demand for which increases more rapidly than the growth of income) and the central locus of global R&D at the present time, as the scientific and technological foundations of health care continue to be transformed. In a recent important paper, Hall and Jones (2007) have shown, using standard economic principles and recent data, that the share of US health spending in GDP is likely to be about 30% by 2050, and that this will reflect the preferences of population. Health is increasingly at the centre of all economies. This being the case, it is important for economies to invest pro-actively in health innovation to generate the best health and economic outcomes possible, rather than to simply to meet the rising level of health costs arising from a growing burden of chronic disease.

Health Outcomes in APEC Developing Economies: Three Scenarios

Impact on population, deaths and DALYs

As noted above, we examine the costs and benefits of investment in health innovation in the APEC developing economies taken as a whole for two innovation scenarios, relative to the constant mortality rates scenario. The two innovation scenarios are taken to involve systemic investment in health innovation, across the whole spectrum of activities outlined above, to achieve the outcomes which define the scenarios – the WHO projection path of mortality rates and a path 1% lower than the WHO projection path. We do not attempt to define the specific composition of these innovation investments, other than to note two key points. One is that the history of innovation in medical technologies and practices and in public health infrastructure suggests that such outcomes are indeed achievable, given appropriate levels of investment (see Section 4 below). The other is that the investment in health innovation must be appropriate to the needs of individual economies and be targeted to achieve sharply improved health outcomes, using both existing and emerging global knowledge resources.

The broader patterns of health outcomes consistent with these three scenarios are explored in Section 2, and summarised below. Table 1 summarises the key impacts on deaths and the overall population, including:

- in the enhanced innovation scenario relative to the constant mortality rates one, total population is 61.7 million higher in 2030, while for the ongoing innovation scenario the increment is 39.4 million;
- in 2030 there will be 2.0 million fewer deaths of persons less than 60 years of age per year in the enhanced scenario (relative to the constant scenario), with 4.7 million fewer deaths of persons less than 70 years, and 7.2 million fewer deaths below 80 years.

Table 1. Increase in population and decline in deaths, two innovation scenarios relative to constant mortality rates scenario, 2010 to 2030, APEC developing economies

	Increase in population (million)			Decline in deaths below given age ('000s)			
	Males	Females	Persons	<60 years	<70 years	<80 years	Total
Ongoing innovation							
2010	0.5	1.5	2.0	519	796	952	919
2015	1.9	5.2	7.2	751	1335	1679	1485
2020	4.4	10.6	15.0	1018	1985	2565	2134
2025	7.6	17.7	25.3	1275	2613	3506	2785
2030	12.4	27.0	39.4	1477	3368	4597	3434
Enhanced innovation							
2010	0.5	1.5	2.0	519	796	952	919
2015	2.5	6.1	8.6	886	1616	2163	1959
2020	6.7	14.0	20.7	1313	2629	3672	3107
2025	12.8	24.9	37.7	1690	3544	5285	4250
2030	22.0	39.7	61.7	1993	4647	7196	5514

Source: Estimates of the authors, based on unpublished data provided by Dr Colin Mathers of WHO.

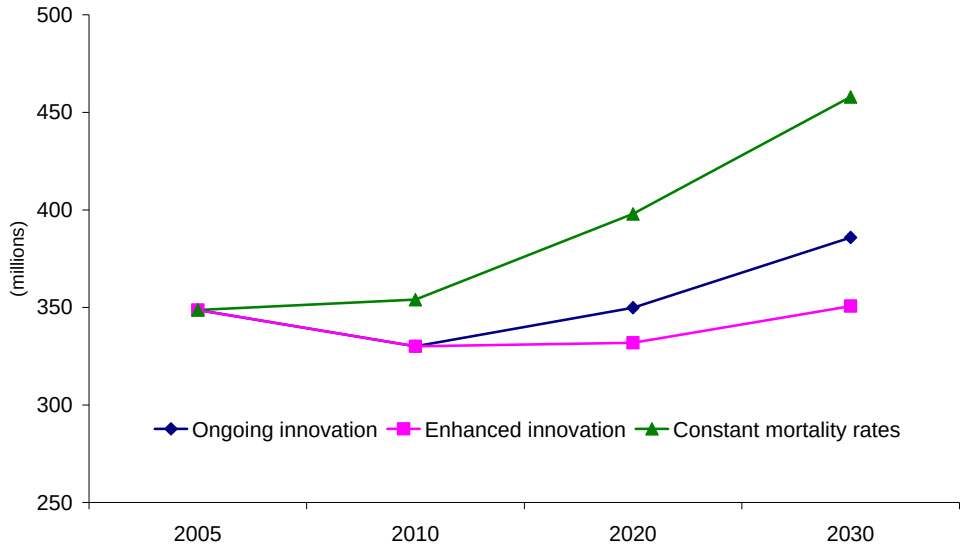
These figures are for a single year, so the cumulative saving in deaths from the innovation scenarios over the period 2010-30 is very large.

Figure 1 summarises the impact of the innovation paths on trends in DALYs for the different scenarios:

- the enhanced innovation scenario enables DALYs to be held reasonably flat out to 2030, by contrast with both of the other scenarios; and
- by comparison with the constant mortality rates scenario, 72 million DALYs are avoided in 2030 under the ongoing innovation scenario and 127 million under the enhanced scenario.

It should be noted that the disability adjusted life years (DALYs) lost in a given year are those years of healthy life lost as a result of the onset of disease or injury in that year. Again these figures are for a single year; they refer, for example, to the DALYs lost from the onset of disease or injury in 2030, so the cumulative saving in DALYs from the incidents over a period of years is much larger.

Figure 1. Disability adjusted life years lost (DALYs) under the three innovation scenarios, 2010 to 2030, APEC developing economies (millions of DALYs)



Source: Estimates of the authors, based on unpublished data provided by Dr Colin Mathers of WHO.

Economy specific estimates: The case of China

These projections of mortality, population and the incidence of disease are available only for the APEC developing countries, as the underlying data for the WHO projections are available only for this regional aggregate, rather than for individual economies. To understand these matters more fully a detailed analysis at the economy level is highly desirable, but has not been possible for this study. However, in Section 3 we present

some projections for China undertaken for this study by the Institute of Population Research at Peking University. It is clear that some of the key risk factors for chronic disease (such as overweight and obesity, hypertension and dyslipidaemia) are rising rapidly in China. The projections suggest that, on an 'unchanged mortality rate' basis, the incidence of the major chronic diseases may rise more rapidly in China than for APEC developing regions out to 2030. Furthermore the estimated cost of treating these in China is projected to rise strongly, even assuming that the cost per health service for each disease is held fixed at real 2003 levels.

These projections for China both reinforce the need for major investment in that economy and point to the value of undertaking the overall exercise reported in this paper on data for individual economies.

Individual benefit and reduced treatment costs from a lower incidence of disease

Every DALY saved is a benefit to the individual concerned, who enjoys the additional year of life without disability, and also to the community, in terms of a reduction in treatment costs or a gain from that individual's ability to contribute to economic and social affairs. There is an extensive literature on the value of a year of life. Several studies for the US have estimated this value of the order of US$150,000 (e.g. Murphy and Topel 2003; Nordhaus 2003), but there are other competing views and methods. It is beyond the scope of this project to address this issue for the APEC developing economies, so we take a very conservative valuation, that the value of a DALY is equal to average GDP per capita in the APEC developing economies region in the year in question. Even on this conservative basis the value of DALYs saved in the two innovation scenario is substantial – for the enhanced innovation scenarios about 4.2% of GDP in 2030 (Table 2, upper panel).

One important component of the benefit from greater investment in innovation, and the resulting lower incidence of chronic disease, is the reduced costs of treating the overall burden of chronic diseases. We use Australian data on the distribution of costs across diseases, together with other information, to estimate the likely relative level of treatment costs per DALY by cause for the region in 2005. For that year total health spending by the economies in the region was US$735 billion, and the total number of DALYs was 349 million. These data, together with the estimated relative cost per DALY by cause, are used to produce estimates of cost per DALY by cause for the region in 2005.

As economies get richer, a greater proportion of disease is treated, and more sophisticated and costly methods of treatment are employed. Thus there is a positive relationship between economic growth and health spending, with the rate of growth in health spending with respect to GDP considerably higher than one (that is, an elasticity greater than one). While this finding is relevant, it relates to total health spending rather than to treatment costs per DALY, which is the relevant variable here. For these estimates it is therefore assumed that real treatment costs per DALY in the region will rise over time at a rate broadly related to the growth rate of GDP. Table 2 reports treatment cost estimates for three elasticities of real treatment costs per DALY with respect to GDP (0.8, 1.0 and 1.2), and the treatment cost estimates are sensitive to this assumption. On this basis the

model uses the projected pattern of disease to estimate total treatment costs (taken here to equal total health expenditure) for the region to 2030 for the three health innovation scenarios. Further details are provided in Section 6.

Table 2. Benefits from higher innovation, 2010-2030; value of DALYs saved, reduced treatment costs and increase in GDP from labour force and productivity effects, two innovation scenarios

	2010	2020	2030	2010	2020	2030
	Value of DALYs saved, relative to constant mortality rates scenario					
	(US$b 2005 prices)			(share of GDP, %)		
Ongoing innovation	202	663	1614	1.04	1.98	2.85
Enhanced innovation	202	910	2403	1.04	2.71	4.24
	Reduction in treatment costs, relative to constant mortality rates scenario					
	(US$b 2005 prices)			(share of GDP, %)		
Elasticity 1.2						
Ongoing innovation	76	252	662	0.39	0.75	1.17
Enhanced innovation	76	343	972	0.39	1.02	1.72
Elasticity 1.0						
Ongoing innovation	61	182	436	0.31	0.54	0.77
Enhanced innovation	61	248	639	0.31	0.74	1.13
Elasticity 0.8						
Ongoing innovation	46	126	274	0.24	0.38	0.48
Enhanced innovation	46	172	403	0.24	0.51	0.71
	Increase in GDP, labour force and productivity effects					
	(US$b 2005 prices)			(share of GDP, %)		
Enhanced innovation	58	536	1530	0.33	1.57	2.68

Source: Estimates of the authors.

Estimates of treatment cost savings are reported in the middle panel of Table 2 for the three elasticity assumptions and for the two innovation scenarios. On the central elasticity case (1.0) savings in 2030 are estimated at US$ 436 billion (0.77% of GDP) for the ongoing innovation scenario and at US$639 billion (1.13% of GDP) for the enhanced innovation scenario. These savings rise over time, as the number of DALYs saved increases, and vary significantly with the elasticity assumption.

Increases in the labour force, productivity and GDP

If individuals die early, their potential future contribution to GDP through being in the labour force is lost. However, if they continue to live with disease, and suffer some disability from that disease, they may withdraw prematurely from the labour force or they may continue to work with somewhat impaired productivity. On the other hand, if individuals in the older age-groups are healthier they will be more likely to be involved in the labour force. Estimating these impacts on labour force and productivity, and hence on GDP, in the region is therefore an important aspect of this study.

There are several components to the estimates summarised in the lower panel of Table 2. For given participation rates by age and sex, an increased population of working age means an increase in the labour force. In addition, if the incidence of disease within the

population is reduced, this leads to two effects: both greater workforce participation, and increased productivity while at work, arising from the lower incidence of disease. We also assume that better health in older age groups leads to increased participation by older workers, a phenomenon evident in a number of developed countries. Table 3 shows that in total these effects are substantial, with the combination of greater involvement in the workforce and greater productivity while at work leading to an increase in GDP of 2.7% by 2030 in the enhanced innovation scenario.

Impact on government budget

In further work it would be appropriate to generate estimates of the impact of the two innovation scenarios on the overall government budget. Three factors need to be considered – the proportion of savings from lower treatment costs accruing to government, reduced pension payments arising from greater workforce involvement and increase revenue from higher GDP growth. These financial benefits need to be assessed against the government's share of the investment in greater health innovation.

Dynamic growth and industry benefits

Two other benefits from increased investment in health innovation have been widely discussed. The first is that general expectations, arising out of such a program, of a healthier, longer-lived population (and for individuals of longer working lives) is likely to stimulate increased investment in physical and human capital, and hence contribute to more rapid economic growth. The recent Milken Institute study (DeVol and Bedroussian 2007) modelled this effect for the USA and found that it was highly significant. The second is the impact of much increased investment in health innovation in spurring innovation in an economy more generally, and integrating it more closely into global processes for knowledge based development. This is also likely to contribute to higher growth, but neither of these effects are been modelled in this study.

The Costs of Health Innovation

There is an extensive literature on the cost of interventions that might reduce the burden of disease, and this effort has been co-ordinated in part through the Disease Control Priorities Project, which is supported by the World Bank, the World Health Organisation and the Gates Foundation (DCPP 2008). This literature is reviewed in Section 5, and we draw on it to prepare some estimates of the likely cost of innovation to achieve the goals of both the ongoing innovation and the enhanced innovation scenarios.

The cost of health innovation is mainly measured, in this literature, in terms of cost per DALY saved, and this approach is also adopted here. As reported below, we estimate the DALYs saved in the two innovation scenarios, relative to the constant mortality rates scenario, and hence can calculate the total cost of innovation if an estimate of the cost per DALY saved is available. Several things are clear from the literature. First, there is a wide range of potential innovations available to economies, at both the population and individual health levels. Second, there is wide variation in the cost of these innovations, some with a cost as low as US$100 per DALY and other ranging up to US$50,000 per

DALY, although the majority cited are below US$3000-4000. Thirdly, most of these estimates are drawn from studies in the developed countries, and to the extent that local labour costs are involved the overall costs should be lower in developing countries.

Table 3. Cost of innovation, by scenario and for alternative cost per DALY assumptions, developing countries, 2010-20 (US$ billion and per cent of GDP)

	2010	2020	2030	2010	2020	2030
Costs (US$ per DALY)	**Ongoing innovation scenario**					
	Total cost (US$b 2005 prices)			Total cost (share of GDP, %)		
1000	26	53	79	0.14	0.16	0.14
2500	66	133	199	0.34	0.40	0.35
5000	132	266	397	0.68	0.79	0.70
7500	198	399	596	1.02	1.19	1.05
Costs (US$ per DALY)	**Enhanced innovation scenario**					
	Total cost (US$b 2005 prices)			Total cost (share of GDP, %)		
1000	26	73	118	0.14	0.22	0.21
2500	66	182	296	0.34	0.54	0.52
5000	132	365	592	0.68	1.09	1.04
7500	198	547	888	1.02	1.63	1.57

Source: Estimates of the authors.

Table 3 summarises our estimates of the cost of the two innovation scenarios, for a range of assumptions about the average cost per DALY across the whole intervention spectrum. These costs are in 2005 prices and are assumed to increase by 2% per annum in real terms. For the enhanced innovation scenario the cost estimates for 2030 vary from 0.2% of GDP to 1.6% of GDP, with a most likely range of about 1-2% of GDP, or about US$300-600 billion (in 2005 dollars) by that time. Thus these are substantial investments in health innovation, but these figures must be placed in the context that total health spending in the APEC developing economies in 2005 was US$735 billion.

The Return to Increased Investment in Health Innovation

Leaving aside the dynamic growth and industry benefits from increased investment in health innovation, which are not covered here, the costs, economic benefits and individual health benefits are summarised in Table 4 for the enhanced innovation scenario and for the central cases of the critical assumptions (an average cost per DALY saved of US$2500 in 2005 prices and an elasticity of treatment costs per DALY with respect to GDP of unity). On this basis estimated innovation costs by 2030 are 0.5% of GDP, while the reduction in treatment costs is put at 1.1% of GDP and the gains from labour force and productivity effects is 2.7% of GDP, a total benefit of 3.8% of GDP. Thus on these parameters estimates the economic benefits are more than seven times the estimated costs. In addition, the individual benefits amount to some 4.2% of GDP, on a very conservative valuation of a DALY, more than eight times estimated costs.

This estimate of the costs and benefits of much enhanced investment in health innovation is preliminary, and the estimates vary significantly with the assumptions made. But on the central cases summarised in Table 4, both the economic benefits and the individual health benefits are by 2030 more than seven times the estimated innovation costs, and total benefits are fifteen times costs. It is highly likely that the economic and social

returns to the investments studied here are very high, and that this conclusion is not likely to change with reasonable variations in the assumptions.

Table 4. Overall benefits of increased innovation, enhanced innovation scenario relative to constant mortality rates scenario, 2010 to 2030, APEC developing economies REVISE

	2010	2020	2030	2010	2020	2030
	(US$b 2005 prices)			(share of GDP, %)		
Innovation Costs[1]	66	182	296	0.34	0.54	0.52
Economic benefits						
Reduction in treatment costs[2]	61	248	639	0.31	0.74	1.13
Labour force and productivity	58	536	1530	0.33	1.57	2.68
Individual health benefits[3]	202	910	2403	1.04	2.71	4.24

[1]Estimated on the basis of an average cost per DALY saved of US$2500 in 2005 prices.
[2]Evaluated at a treatment cost elasticity with respect to GDP of unity.
[3]Estimated on the basis that the value of a DALY saved is equal to GDP per capita in the year is which the disease is averted.
Source: Estimates of the authors.

Health and Development Strategy

The new centrality of health policy to both economic outcomes and to financial sustainability is a fundamental fact of the 21st Century. Much will depend, for both economic growth and health budgets, on the wellbeing of large cohorts of people as they age. If effective health innovation allows them to remain healthy and active, labour supply will increase and future health and pension costs will be contained, even as the growth dividend provides more resources to meet those health costs. But if effective innovation is not achieved, high health and pension costs will be a drag on economies with limited ability to generate additional resources to meet these costs.

These factors go to the heart not only of health policy but of the economic and social development strategy being pursued by these economies. More of the same – policies directed at strong growth based on industry and exports, with only limited attention to health and the environment – will no longer do. These policies have been very effective in their own terms, but are being undermined by the consequences of their very success. New strategies are needed, placing much greater emphasis on investment in health and in environmental protection and sustainability. Such investment, taking place in an open economy and drawing on the powerful knowledge resources available globally in both areas, can help to drive continuing strong growth. It can also improve the quality of growth, and hence increase the benefits that development provides to enrich the lives of ordinary citizens. Indeed, reshaping energy and environmental systems and building modern but responsive health systems can provide the central growth dynamic for APEC economies, both developing and developed, over the period to 2050.

This effective innovation will not be achieved by economic or finance experts or by health professionals working alone, or by government or business independently of one another. An integrated approach is required, bringing together expertise in health policy

and management, economic and financial analysis and science and technology from government, academia and the business community. Many elements of such an approach have been spelled out in the LSIF Strategic Plan.

1. Introduction

At their October 2002 meeting the APEC Leaders, in establishing LSIF, stressed the need 'to be more effective with our investment at every stage of the health care process, including primary prevention against disease risks, and focusing on most vulnerable populations'. Given its overall remit, and the progress that has been made in other areas, LSIF IV in 2006 adopted as a key theme the efficient and effective allocation of resources to promote innovation, and of regulatory frameworks that facilitate access to new technologies, as a response to the challenges facing health care systems. A central outcome of the discussions at LSIF IV was need to develop an integrated approach to the emerging health challenges facing APEC economies, one which brought together scientific, economic and health policy expertise and drew on the resources of government, business and academia. The key theme for LSIF V in 2007 was set as *Developing an Integrated and Innovative Approach to Emerging Challenges*, and a background for the discussion of these issues at LSIF V was prepared (CSES 2007), building on the framework paper prepared for LSIF IV (CSES 2006).

The paper for LSIF V drew attention to challenges that APEC economies face from projected trends in mortality and the burden of disease to 2030, and explored the ways in which health innovation could play a critical role in economies' response to these challenges. During the discussion of these issues at LSIF V the issue of investment in health innovation emerged as central, and it was decided to base LSIF VI on the theme *Investment in Health: Driving Innovation through Capacity Building to Implement the LSIF Strategic Plan*. This paper aims to provide a framework for the discussion of this issue at LSIF VI. It sets out to define more closely the challenges facing APEC economies, document some experiences with innovation in health, and to assess increased investment in health innovation in the terms appropriate to an investment decision, namely to examine the costs and benefits of such an investment, and the likely returns to it. The paper also sets this discussion in the context of some of the broader issues that have arisen for existing development strategies in many APEC economies, and examine the role of enhanced investment in health innovation in a revised development strategy.

The context of this analysis remains, as earlier, one of health care systems under considerable stress in most economies, with growing demand for services, including those using new technologies, and limits on financial resources even in the richest economies. At the same time, innovation in health systems has contributed greatly to increased longevity and quality of life in recent decades, and there is strong potential for further gains.

2. Ageing and the Rise Incidence of Chronic Disease

This section discusses the relationship between ageing of the populations of the APEC countries and rising burden of chronic disease. The previous LISF framework paper, *Developing an Integrated Approach to Emerging Health Challenges* (CSES 2007) highlighted the two trends, ageing and chronic disease without making the relationship between the two explicit. This section will seek to be more specific about that link.

Ageing

The earlier paper contrasted the pattern of actual population growth for the period 1950 to 2005 to the projected growth for the period to 2050. For the APEC region the total population more than doubled from 1.2 billion to 2.8 billion over the period 1950-2005, an increase of 1.6% per annum. While the number of young people (less than 25 years old) also more than doubled, increasing by 1.4% per annum, it was the growth in the population aged 25-54 years which almost trebled, rising from 0.43 billion to 1.23 billion, an increase of 800 million persons or 1.9% per annum, that was crucial to the rapid economic growth of the region. The rapid growth in this prime age cohort provided the growing workforce to service that growth, and the spending power of the increasing number of workers sustained domestic demand.

The APEC economies face very different population dynamics over the period to 2050 as a result of population ageing. Crucially many of the APEC economies will face a future in which the prime age population declines in absolute terms while for others the decline is relative to other age groups. As argued in the earlier paper this places particular importance on the health of the cohort aged 55-74, who may need to stay in the workforce for personal reasons, as well as to support continued national economic growth.

The earlier paper demonstrated a wide disparity in the pattern of ageing between APEC economies, not so much in terms of the developing and developed dichotomy, but rather between economies that had low population growth and closed immigration policies and those that had high population growth, either through natural increase or relatively high levels of immigration. This dynamic had a major influence on the pattern of ageing and is illustrated by the year at which the prime age population has or will peak (Table 5).

Table 5. Peak year for prime age population, selected APEC economies

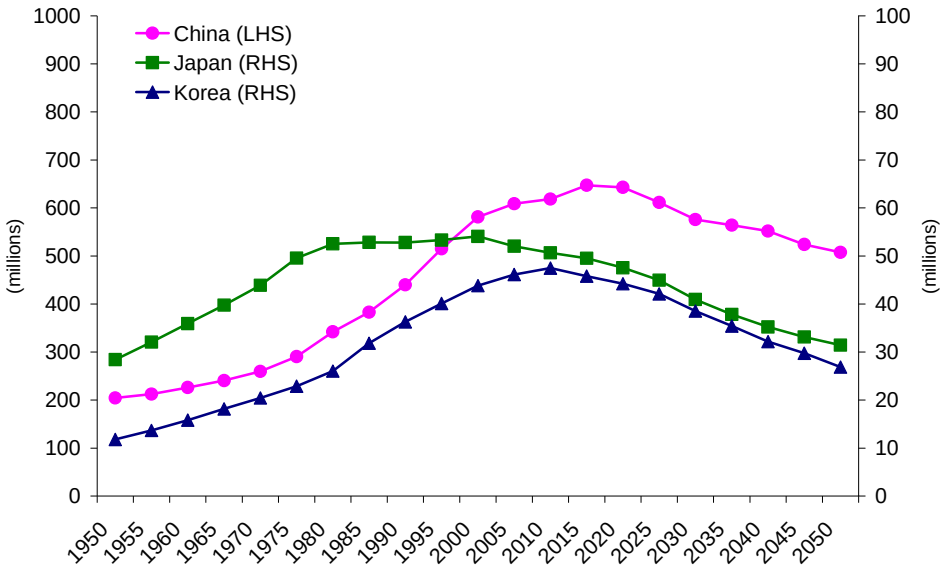
APEC economy	Year (approximately)
Japan	2000
Singapore	2005
Korea	2010
China	2015
Indonesia	2035
Vietnam	2035
Australia	2050 (no peak)
United States	2050 (no peak)

Source: UN Population Projections (2006).

Neither Indonesia nor Vietnam has actively reduced their population growth rates and their prime age populations will continue to grow until about 2035. Both the United States and Australia have received high levels of immigration and this has bolstered their population growth rates. Although prime age population will decline as a proportion of total population, in absolute terms it will continue to grow at least until the end of the period.

As shown in Figure 2 below, the prime age population for Japan and Korea have each reached or about reach their peaks. The participation of older age groups in the work force has already become an important issue for labour supply. China will reach its prime age peak in 2015. Each of these economies has actively sought to reduce their population growth rates and to date permitted little or negligible immigration. Japan's prime age population is expected to decline from a peak of 54 million in 2000 to 31 million by 2050 about the same level as in 1950. Korea's prime age population is expected to peak at 47 million in 2010 and decline to 27 million by 2050, still more than double the 1950 level, while China's prime age population is expected to peak in 2015 at 647 million and decline to 507million by 2050.

Figure 2. Prime age population, China, Japan and Korea*



Note: *Right-hand scale (RHS) 10 times left-hand scale (LHS).
Source: UN Population Projections (2006).

These two quite different ageing dynamics place more immediate importance on the health of ageing workers for the 'closed population' group of economies compared with those that are more rapidly growing. Japan, Korea, China are each facing declining prime age population which makes the health status of their 'ageing workers' cohort (55-74) and continued workforce participation a particular priority.

Rising Burden of Chronic Disease

The April 2007 paper identified chronic diseases as the main cause of death in both developing and developed economies. Using the unpublished baseline projections of global mortality and the burden of disease to 2030 for the two groups of APEC economies provided by Dr Colin Mathers of the Evidence and Information for Policy Cluster of WHO, the earlier paper showed that not only were chronic diseases the largest cause of death they were also expected to grow rapidly as the cause of death as shown in Table 6.

Table 6. Deaths in APEC developed and developing economies, 2005-2030, by broad cause

	APEC developed economies			APEC developing economies			All APEC		
	Number		Change in period	Number		Change in period	Number		Change in period
	2005	2030		2005	2030		2005	2030	
	(million)		(%)	(million)		(%)	(million)		(%)
Communicable	0.3	0.3	-1.3	1.9	1.7	-13.1	2.3	2.0	-15.2
Chronic	3.7	4.6	26.1	12.0	17.5	46.1	15.7	22.2	41.1
Other	0.3	0.3	10.2	1.8	1.9	3.9	2.0	2.2	9.4
Total	4.3	5.2	23.1	15.8	21.1	33.3	20.4	26.3	28.9

Source: Unpublished WHO data consistent with Mathers and Loncar (2006).

While deaths from communicable diseases are projected to decline deaths from chronic diseases are expected to increase by 26.1% between 2005 and 2030 in APEC developed economies and 46.1% in developing economies. The most significant cause of this large and growing segment of cause of death is shown in Table 7.

Table 7. Deaths and rates of change in numbers of deaths, by cause of death, APEC developed and developing economies, 2005-2030

Cause of death	Developed economies			Developing economies		
	Number of deaths		Change in period	Number of deaths		Change in Period
	(million)		(%)	(million)		(%)
	2005	2030		2005	2030	
Cardiovascular	1.5	1.8	18.7	5.7	7.0	23.0
Neoplasms	1.1	1.4	19.8	2.7	4.5	62.5
Respiratory diseases	0.3	0.3	18.8	1.9	3.8	97.5
Digestive diseases	0.2	0.2	45.7	0.6	0.7	13.4
Diabetes mellitus	0.1	0.3	105.7	0.3	0.7	110.9
Genitourinary diseases	0.1	0.2	47.4	0.3	0.4	36.4
Nervous system	0.2	0.3	44.1	0.2	0.3	37.8

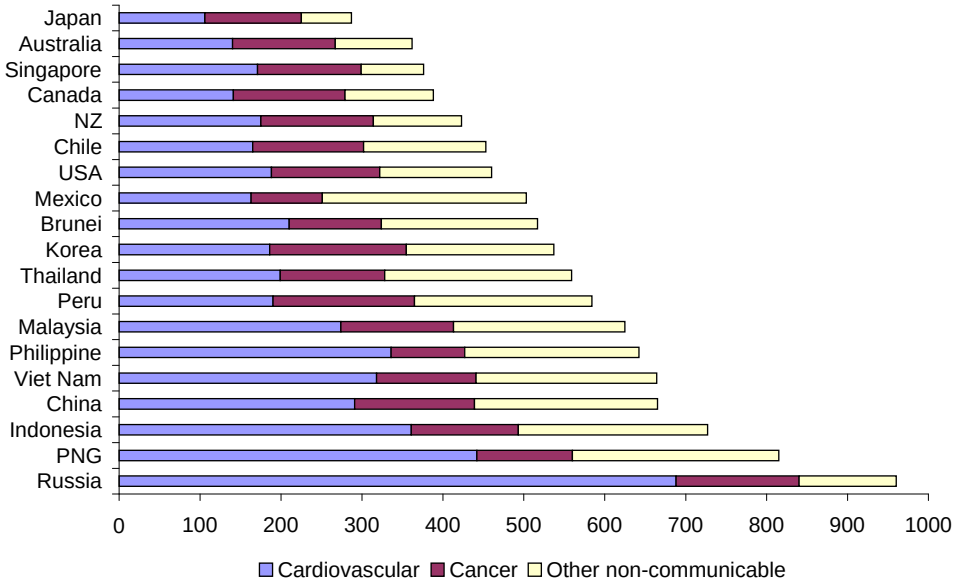
Source: Unpublished WHO data consistent with Mathers and Loncar (2006).

For the developed economies two causes of death dominate, namely cardiovascular diseases and cancer (neoplasms). In these economies deaths from these diseases are expected to rise by 19% (to 1.8 million in 2030) and by 20% (to just on 1.4 million) for cardiovascular diseases and cancer respectively, and together to account for 60% of deaths in 2030. A number of other chronic diseases, while small in terms of the overall share of deaths, are projected to rise rapidly. These include digestive diseases, diabetes (deaths from which are expected to more than double between 2005 and 2030), genitourinary diseases and diseases of the nervous system, such as dementia.

For the developing economies of APEC, cardiovascular diseases and cancer are still by far the largest cause of death by 2030, deaths from these two causes increasing by 23% to 7.0 million for cardiovascular disease and by 63% to 4.5 million for cancer. However, there are other respects in which the patterns are quite different. Respiratory diseases, which for developed economies are one of a cluster of lower ranked diseases, are the third most important cause of death for developing economies by 2010 and are projected to grow rapidly. Deaths from respiratory diseases are projected to rise to 3.8 million in these economies in 2030, an increase of 98% on 2005. This is likely to reflect continuing high levels of smoking and air pollution in some of these economies. Deaths from diabetes, while still below those from the major causes, are projected to grow by 111% over 2005-50, presumably reflecting the expected impact of changing lifestyles and diets.

Figure 3 shows death rates, standardised for differences in age for each of the APEC economies, for two of the most important chronic diseases, cancer and cardiovascular diseases. While on the whole the advanced economies have low death rates, a number of developing economies, such as Chile, Mexico and Thailand, have modest death rates from these diseases. The greatest differences between economies are for cardiovascular diseases. Some economies such as Russia have death rates several times those in developed economies. This reflects high risk behaviours, such as high levels of smoking in those countries, but also the lack of specialised treatment for these conditions.

Figure 3. Age standardised death rates by chronic disease, for selected APEC economies, 2002, per 100,000 population



Source: WHO Burden of Disease (2004).

Methodological issues

The methodology used by the authors of the WHO projections of age specific death rates for major causes is based on the assumption that the past positive impact of growth in GDP, the increase in human capital and technology and related factors (proxied by a time trend) on health outcomes will continue in the projection period, on an individual economy basis and for age and gender group. This was in preference to a methodology which attempted to model the effects of the many separate direct determinants or risk factors for diseases from the limited data available. However for a number of diseases, including most importantly for this analysis, a number of chronic diseases, the authors supplemented the broader projections with those for death and disability arising from specific diseases (Mathers and Loncar 2006)

This involved modelling specific disease risk factors including obesity for diabetes, and making a series of adjustments to the projections based on smoking intensity. For instance deaths from cardiovascular disease were modified to reflect declining levels of smoking in high income countries (Mathers and Loncar 2005).

While cause of death is highly relevant to any discussion of health, the ability of potential workers to participate in the labour force is more strongly related to the burden of disease, i.e. the gap between current health status and an ideal situation where everyone lives into old age free of disease and disability. The generally accepted measure of disease burden is the DALY (disability adjusted life year) which combines in one measure the time lived with disability and the time lost due to premature mortality. One DALY can be thought of as one lost year of 'healthy' life. It is the years of life lost (to early) mortality (YLL) plus years lost to disability (YLD) (WHO 2008). The estimation of DALYs includes a series of normative judgments about the relative severity of

different diseases and disabilities. In the original global burden of disease study this was based on the collective judgement of a cross section of international health care workers from a wide range of countries (Murray 1996).

The estimates of changes in YLD, disease and injury causes were divided into three distinct categories.

1. For causes with significant case-fatality YLD rates were generally assumed to change in line with projected mortality rates.
2. For non-communicable disease causes without significant mortality, age-sex-specific prevalence rates were generally assumed to remain constant into the future.
3. The prevalences of non-fatal communicable diseases and nutritional deficiencies were assumed to decline at between 50% to 100% of the mortality rate declines for Group I causes.
4. HIV/AIDS was treated separately

Adjustments were also made to the projections of disability based on differences in the causes of particular disabilities. For instance in low income countries the disability due to vision and hearing loss is higher because of the higher prevalence of vision disorders (glaucoma, cataracts) and lower prevalence of hearing aid use. Accordingly prevalence rates and disability weights were assumed to decline with improvements in income per capita in line with the cross regional variations. For ischaemic heart disease and stroke, future case-fatality rates were assumed to decline with improvements in income per capita in line with the cross-regional variations (Mathers and Loncar 2005, pp. 48, 49).

DALYs for APEC economies

Chronic disease is the largest component of disability as shown in Table 8. For developing economies two thirds of disability is due to chronic disease while for developed economies the proportion rises to 84.per cent

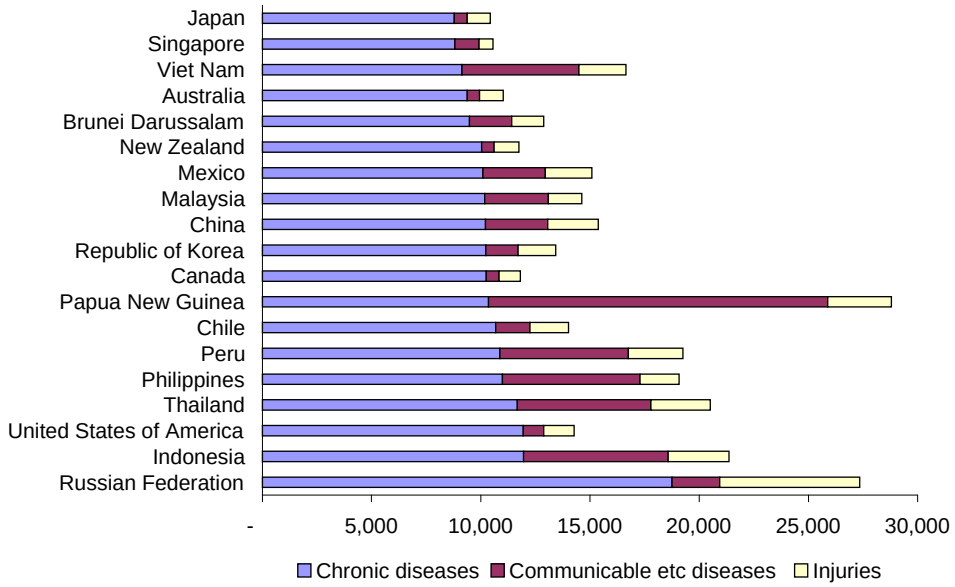
Table 8. DALYs for developing and developed APEC economies, 2005 (million)

	Chronic	Total	% total
Developed	58.0	68.8	84.4%
Developing	232.6	348.7	66.7%

Source: Unpublished WHO data consistent with Mathers and Loncar (2006).

Figure 4 shows DALYs per 100,000 population for each of the APEC economies. This confirms that the incidence of chronic disease is the most important determinant of DALYs. This is especially true of most developed countries which have very low levels of disability relating to communicable diseases. These remain important for a number of developing economies such as PNG, Indonesia, Thailand, Philippines and Peru even though the impact of chronic disease may be larger. The United States has one of the highest rates of disability from chronic disease within the APEC region, while economies such as Vietnam and Mexico have relatively low rates.

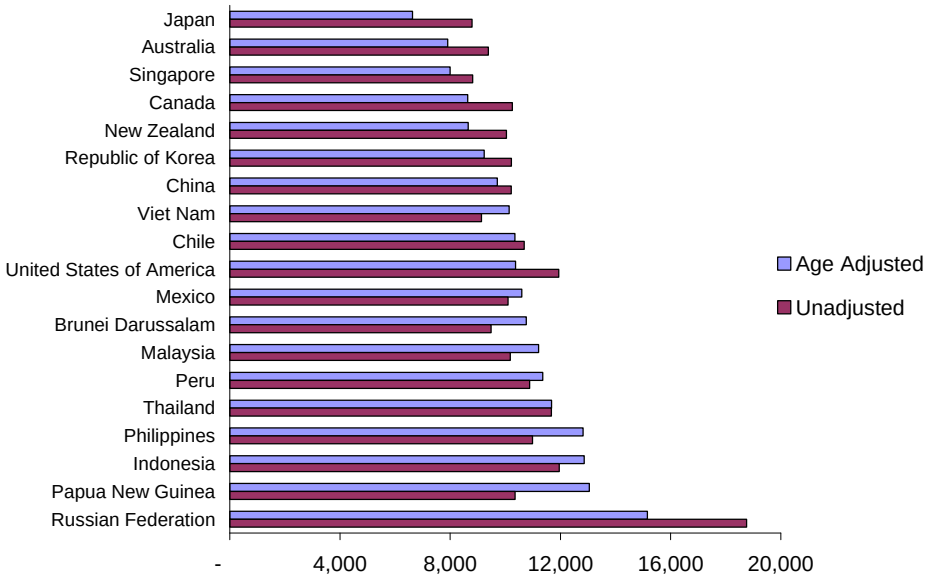
Figure 4. Estimated DALYs per 100,000 population by cause, for selected APEC economies, 2002



Source: WHO Burden of Disease (2004).

As will be further explored later in the section, population structure has a sizeable influence on the incidence of chronic disease and economies with older populations tend to have higher levels of chronic disease burden as a result. This effect is shown in Figure 5, which compares the estimates of DALYs due to chronic disease, adjusted and unadjusted for age, ranked by age adjusted DALYs.

Figure 5. Estimated DALYs per 100,000 population due to chronic disease, for selected APEC economies, adjusted and unadjusted for age, 2002

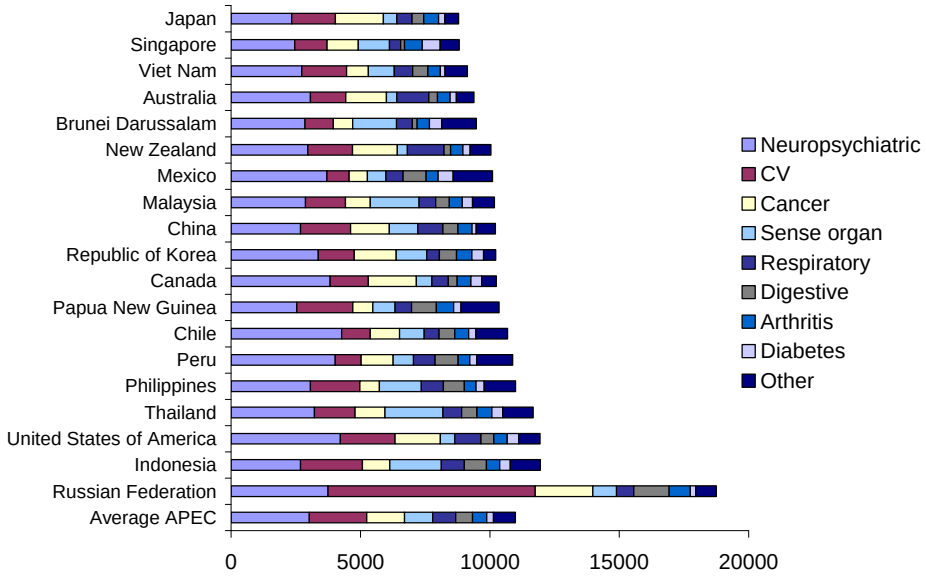


Source: WHO Burden of Disease (2004).

This shows economies with older populations, such as Canada and the United States, moving up in the ranking and Vietnam and Brunei, with younger populations, being ranked lower in the chart. Abstracting from the age structure reveals a more direct relationship between the burden of chronic disease and level of economic development, with the 'top five' positions being occupied by developed countries. Nonetheless the relatively low position of the United States and Russia on the chart is indicative of the seriousness of chronic disease for these countries.

The seriousness with which individual diseases contribute to disability varies between APEC economies (see Figure 6). However for all economies, except Russia, the largest contributor is neuropsychiatric disorders making up about 30% of total DALYs. Most prominent among them is unipolar depression, but alcohol abuse, Alzheimer's disease and dementia are also significant. Next in significance are cardiovascular diseases and as noted above as a cause of death, these are particularly significant for Russia, where they represent about 40% of the chronic disease burden, compared with the regional average of 20%. It is associated with high risk behaviours, such as smoking and where this has been reduced by public health programs, as in a number of developed countries, such as Australia and Canada, the disease burden has been reduced to less than 15% of the total chronic disease burden for those countries.

Figure 6. Estimated DALYs per 100,000 population by type of chronic disease, for selected APEC economies (not adjusted for age), 2002



Source: WHO Burden of Disease (2004).

On the other hand cancer represents a relatively high proportion of DALYs for developed economies such as Canada and Australia at about 18% of the total, but a relatively low proportion in developing countries such as Indonesia, Philippines and Thailand where it is less than 10%. There are also marked differences in the burden of sense organ disabilities between developed and developing economies. This is largely due to a high prevalence of cataracts in economies such as Thailand, Indonesia and Malaysia.

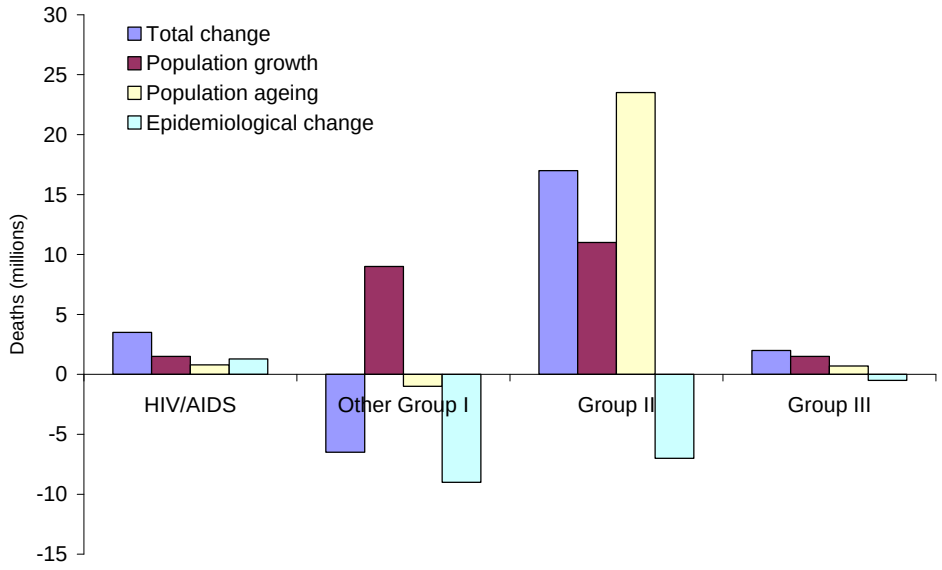
Respiratory diseases are especially prominent in a number of developed countries, most notably Australia and New Zealand. They are above average in China, being linked to high level of smoking and air pollution. Other chronic diseases of significance include diabetes, arthritis and digestive diseases such as cirrhosis of the liver.

Chronic disease and ageing

Chronic disease rises with age and the combination of the two is a major reason for increasing burden of disease.

Figure 7 shows the decomposition of the projections for world mortality 2002 to 2030 by Mathers and Loncar (2006). It divides the total change into three components, population growth, population ageing and epidemiological change for each of the broad causes of death. Group II, that is chronic diseases, account for most of the increase and population ageing, despite some epidemiological advances in treatment, comprises the largest component.

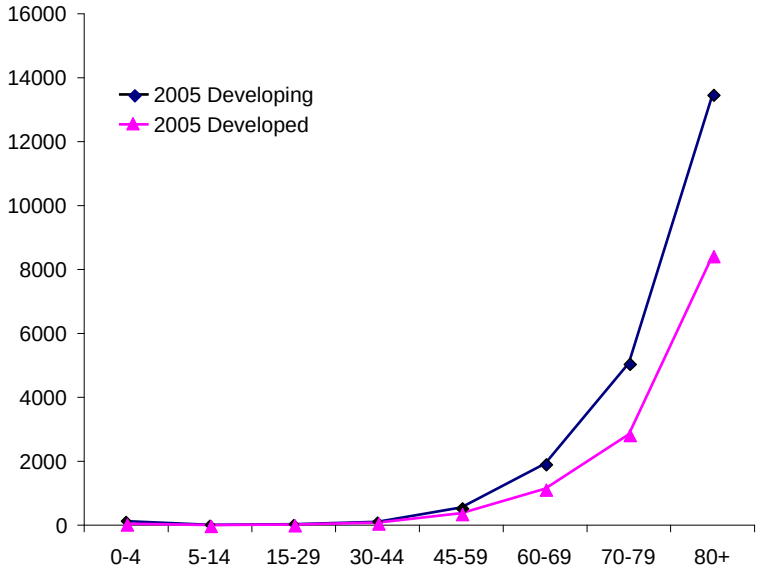
Figure 7. Decomposition of projected change in numbers of deaths into demographic and epidemiological components, by broad cause group, 2002–2030



Source: Mathers and Loncar (2006, p. 2024).

This relationship between age and chronic disease is illustrated in greater detail in Figure 7 for deaths and 1.7 for DALYs, showing the rising death rates with age from chronic disease. The rates for developing countries are significantly higher than for developed as increases.

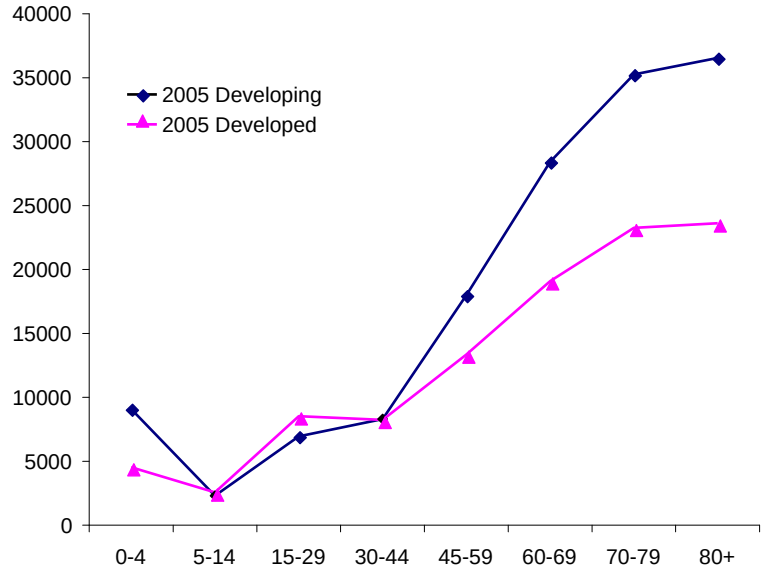
Figure 8. Deaths rates per 100,000 population, chronic disease by age group for developing and developed APEC economies, 2005



Source: Unpublished WHO data consistent with Mathers and Loncar (2006).

Figure 9 shows DALYs per 100,000 population for chronic disease by age for developed and developing APEC economies for 2005. Although the rates in infancy are relatively high, DALYs per 100,000 population increase rapidly with age after age 45, before levelling off for ages over 70. Chronic disease is also relatively high for young adults as they deal with depression and other mental disorders. For all the concern in developed countries about lifestyle related diseases such as diabetes, the disability rates from chronic disease are significantly higher for developing economies, than developed, particularly for older age groups. Indeed the margin is larger than for deaths.

Figure 9. DALYs per 100,000 population for chronic disease by age group for developing and developed APEC economies, 2005



Source: Unpublished WHO data consistent with Mathers and Loncar (2006).

In view of the seriousness of chronic disease for ageing populations in the developing economies a series of projections were undertaken of disability for the APEC developing region.

Projections of Disability in APEC Developing Economies

We develop projections of incidence of disease and disability for three scenarios defined by health outcomes in terms of mortality rates by age, sex and cause of death. As noted above, the three scenarios are:

- one using constant mortality rates at their estimated 2005 level (the 'constant mortality rates' scenario);
- one using the mortality rate in the WHO projections of the incidence of disease (the 'ongoing innovation' scenario); and
- one assuming a 1% per annum reduction in chronic disease mortality rates (specific to age, sex and cause) relative to the WHO projections (the 'enhanced innovation' scenario).

A critical element in this work is the unpublished WHO projections of death by cause and of DALYs by cause for 2005-30 for the APEC developing regions. We use the model described in Section 6 to recalculate the population and the number of deaths for each of these scenarios. The procedure for calculating DALYs is described below.

DALYs are to a considerable degree derived from deaths. The components of DALYs, YLLs are years lost from premature death while YLDs reflect early onset of disease prior to death. While the relationship between deaths and DALYs varies significantly with disease, e.g. mental disease causes significant disability without causing a high number of

deaths, while cardiovascular disease is a major cause of death, the ratio of DALYs to death for particular diseases are reasonably constant over time. This relationship is used to project DALYs by disease for a range of forecasts of population and deaths based on the three scenarios indicated above. A distribution of deaths by disease was based on the WHO data on deaths by disease and these were used to project a set of DALYs by disease for the period 2005 to 2030.

The unpublished data on disabilities is available only for the total developing and developed economies. So accordingly the projections of deaths and disabilities are for total developing APEC economies and no breakdown by economy is available. However the likelihood that health outcomes in China would have a major influence on these results is indicated by its population share of the APEC developing region. Table 9 below shows the total of population for each APEC developing economy for 2005. The population of China represented 61.8 per cent of the population of APEC developing economies in 2005. Indonesia is next with 10.6 percent. The health outcomes for China receive special attention in Section 3.

Table 9. Population APEC developing economies, thousands, 2005

Brunei	374	0.0%
Chile	16,295	0.8%
China	1,312,979	61.8%
Chinese Taipei	22,750	1.1%
Hong Kong	7,057	0.3%
Indonesia	226,063	10.6%
Malaysia	25,653	1.2%
Mexico	104,266	4.9%
PNG	6,070	0.3%
Peru	27,274	1.3%
Philippines	84,566	4.0%
Russia	143,953	6.8%
Thailand	63,003	3.0%
Vietnam	85,029	4.0%
Total developing	2,125,332	100.0%

Source: UN Population Projections (2006).

Table 10. Projection of deaths and DALYs for 3 scenarios, 2005 to 2030

	2005	2010	2020	2030
Deaths				
Ongoing innovation	16.2	15.4	18.5	23.3
Enhanced innovation	16.2	15.4	17.5	21.2
Constant mortality rates	16.2	16.3	20.6	26.8
DALYs				
Ongoing innovation	348.7	330.1	349.8	385.9
Enhanced innovation	348.7	330.1	331.9	350.7
Constant mortality rates	348.7	354.0	398.0	457.9

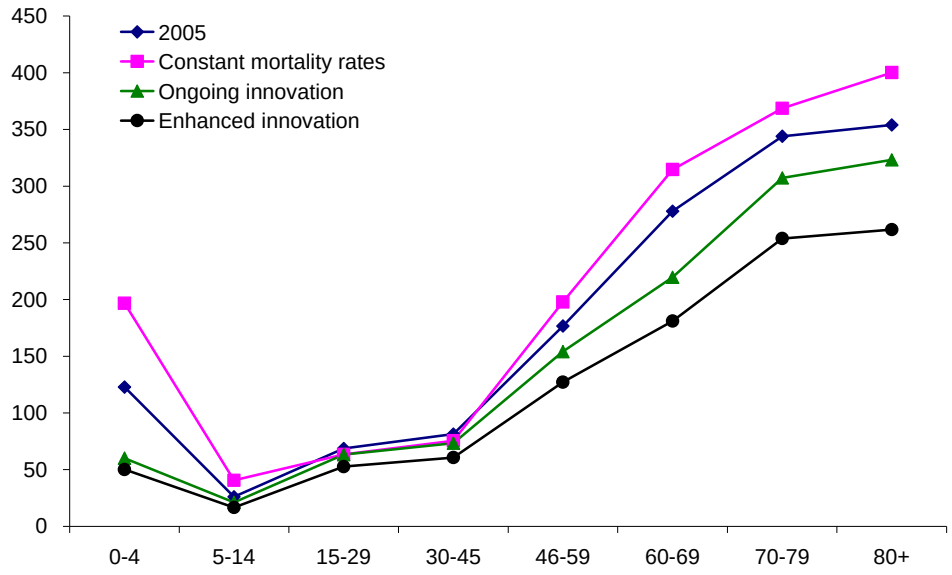
Source: Estimates of the authors.

The results of the projections for both deaths and DALYs for the period 2005 to 2030 for each of the three scenarios is set out above in Table 10.

The scenario, 'constant mortality rates' shows the full impact of population growth and no improvement in treatment. While the ongoing innovation assumptions of declining death rates would save 3.5 million lives or 13% by 2030, the more aggressive application of treatment methods and available drugs would achieve a saving of an additional 2.1 million lives in 2030. The reduction in DALYs is somewhat greater, with Mathers' assumptions reducing DALYs by 15.7% by 2030 and the additional 1% per annum reduction in deaths due to chronic disease, reducing DALYs compared with unchanged mortality rates by 25%.

Figure 9 showed the impact of age on chronic disease for 2005 for both developed and developing countries. Figure 10 shows the DALY rates per 100,000 population for the developing APEC region for 2005 and the projections to 2030 for the 3 scenarios. If mortality rates were to remain unchanged, the DALY rates in 2030 would be higher than those in 2005, while both the ongoing nnovation scenario and the enhanced innovation scenario would be particularly marked at the 0-4 and older age groups. The high DALY rates for the constant mortality rates scenario are in part a product of the assumption that the ratio of DALYs to deaths will rise over the period. That may be less likely in a constant mortality rates scenario.

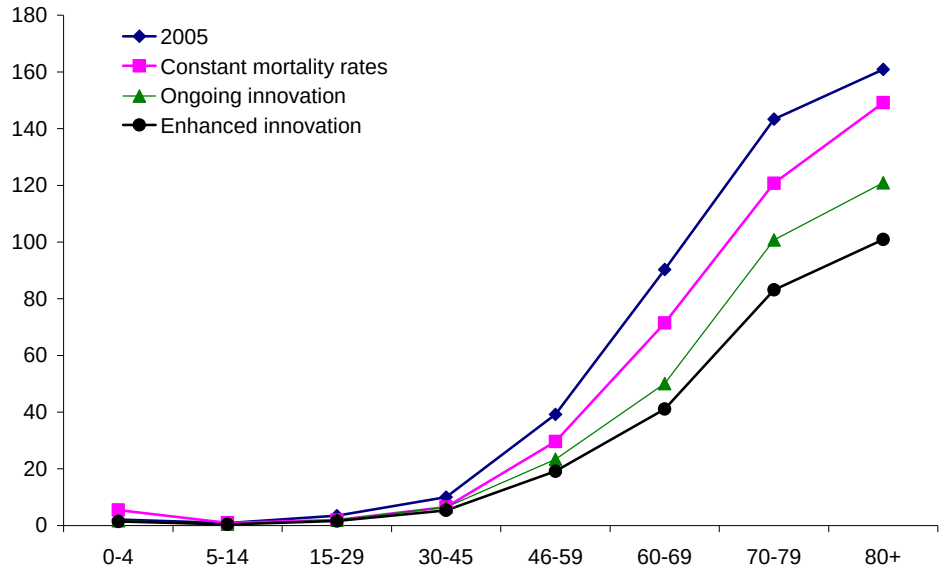
Figure 10. DALYs per 100,000 population for chronic disease by age group for developing APEC economies for 2005 and the 3 scenarios to 2030



Source: Estimates of the authors.

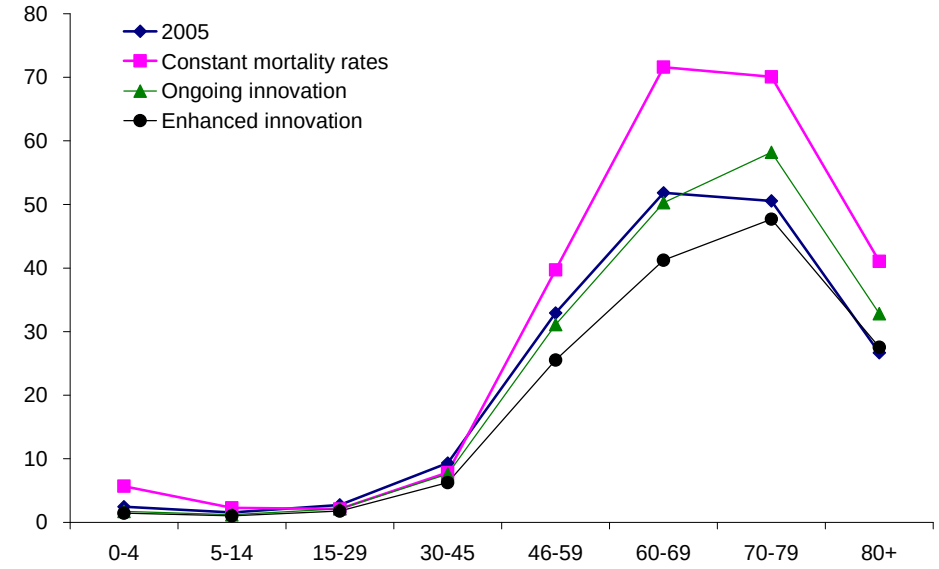
Disability rates as a function of age can be markedly different for individual diseases. The results for two different diseases, cardiovascular and cancer are shown below in figures 11 and 12. Disabilities for cardiovascular disease and cancer are strongly associated with older age groups.

Figure 11. DALYs per 100,000 population for cardiovascular disease by age group for developing APEC economies for 2005 and the 3 scenarios to 2030



Source: Estimates of the authors.

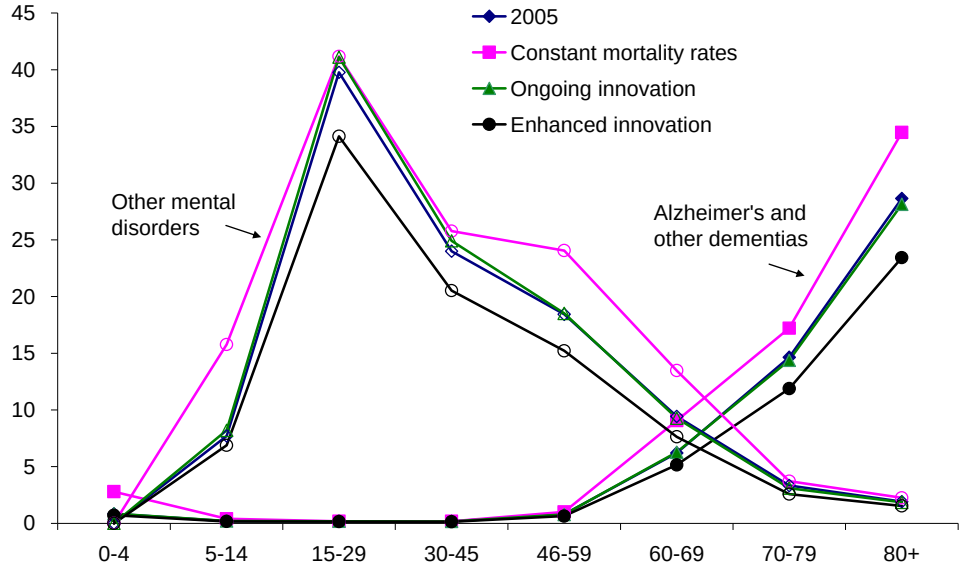
Figure 12. DALYs per 100,000 population for cancer by age group for developing APEC economies for 2005 and the 3 scenarios to 2030



Source: Estimates of the authors.

As discussed above and shown in figure 6, about 30% of chronic disabilities are a result of neuropsychiatric disorders. Some of these, such as depression are an affliction, in particular, of young adults, while others such as Alzheimer's disease and other dementias are a problem for the aged. Figure 13 shows the quite dissimilar impact across different age groups of these two types of neuropsychiatric disorders.

Figure 13. DALYs per 100,000 population for neuropsychiatric disorders by age group for developing APEC economies for 2005 and the 3 scenarios to 2030



Source: Estimates of the authors.

The combination of the high levels of chronic disease and ageing is projected to cause a significant proportion of the disease burden to shift to the older age groups, as shown in Table 11 for each of the scenarios. The proportion of the burden of disease is projected to increase from 21.8 per cent in 2005 to over 30 per cent for each of the projections. Only the enhanced scenario is of sufficient magnitude to have any marked impact on the proportion of aged disabilities.

Table 11. Proportion of DALYs for older age groups for 2005 and the three scenarios in 2030

	2005	2030		
		Constant mortality rates	Ongoing innovation	Enhanced innovation
60-69	11.2%	17.2%	17.2%	15.6%
70-79	8.0%	12.0%	12.0%	10.6%
80+	2.6%	4.7%	4.7%	5.6%
Total 60 and over	21.8%	33.9%	33.9%	31.8%

Source: Estimates of the authors.

Conclusion

The purpose of this section has been to demonstrate the relationship between ageing of the population and the increasing burden of disease in the APEC region. With the ageing of the prime age populations of most APEC economies, the health of older potential

workers is becoming of increasing strategic significance, especially for the 'closed population' APEC economies that have depended on high rates of labour supply growth to facilitate their economic transformations.

As this section makes clear, there is a strong relationship between disease burden and age. A large majority of the disease burden arises from chronic disease, 84% in developed and 67% in developing APEC economies. Cardiovascular diseases, cancer and neuropsychiatric conditions account, on average for the APEC region, for over 60% of the chronic disease burden. Although the age pattern of each of these diseases is different, disability tends to rise significantly with age. While the projections of disability adopted in this section assume that rates of disability will fall over time, the combined effect of an ageing population structure and the higher rates of disability for older age groups lead to an increase in disability from chronic disease. This effect is expected to lead to a pronounced shift in the burden of disease from the younger to older age groups.

3. Demographic, Health and Expenditure Projections for China

Among the APEC developing economies, China is by far the largest accounting for about 61% of the population of these economies with Indonesia in second place at 11%. What happens in China therefore will have major consequences for the course of the burden of disease within APEC developing economies. Because of their sizes, China and India were the only two countries in the original burden of disease study (Murray and Lopez 1996) for which separate country-specific estimates were reported.

China has continued to attract attention from researchers who have produced more detailed estimates of both the burden of disease by cause and of the risk factors contributing to disease. As both mortality and morbidity associated with infectious diseases and other acute disease have become much less important in the overall burden of disease in China, attention has focused on chronic disease, in particular cardiovascular disease, diabetes, and cancer.

Most of this research has drawn upon two sources of data on health in China. The China Health and Nutrition Survey (CHNS) has been conducted seven times between 1989 and 2006 and has collected longitudinal health and expenditure data on a sample of about 4,400 households across 9 provinces (CHNS 2008). The other principal source of information on health status and health expenditure is the National Nutrition and Health Survey conducted by the Ministry of Health, the most recent survey being for 2003. This survey of around 100,000 households enables population estimates to be made of the incidence of about 100 diseases using a classification similar to the International Classification of Diseases (ICD). The survey also gathered some information about the use of health services by patients to obtain treatment for these diseases and the cost they incurred for this treatment.

Using these data sources, Popkin et al. (2006) (see also Popkin 2008) have estimated that the costs of chronic diseases related to poor diet, physical inactivity and obesity were equal to 4% of GDP in China in 2000 and are expected to rise to 9% of GDP in 2025. Around three quarters of this cost is due to productivity losses due to ill-health or premature retirement. Zhao et al. 2008 have estimated that the direct costs of hypertension, diabetes, chronic heart disease and strokes due to overweight and obesity was 21.1 billion yuan in 2003. In 2002, the prevalence of overweight adults was 22.8% in China compared to 6% in 1982 (Ward 2008). Similarly Popkin et al. (2006) estimate that the prevalence of risk factors will rise markedly in China between 2000 and 2025 as follows in Table 12.

Table 12. Change in selected health risk factors, China

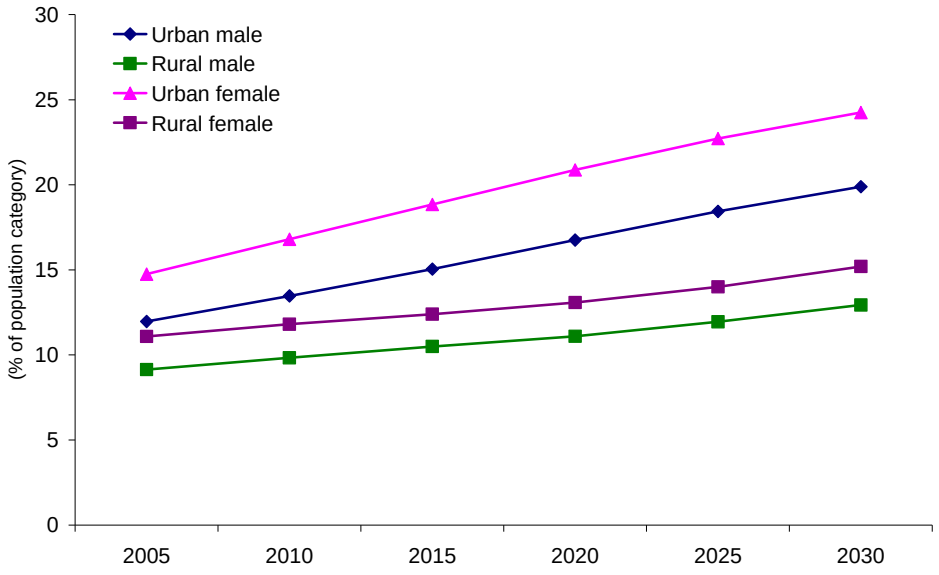
	2000	2025
Overweight and obesity	24	58
Hypertension	26	44
Dyslipidaemia	27	54
Insulin resistance	7	25

Source: Popkin et al. (2006).

The growing evidence about the extent of the challenge to the Chinese health system posed by population ageing, and the increase in chronic disease and associated risk factors has caused the Institute of Population Health, Peking University and the Centre for Strategic Economic Studies at Victoria University to co-operate on a long-term project to understand the demographic dynamics in China and to relate this to the expected change in health status of the Chinese urban and rural population and the growth in living standards that will occur in China over the next few decades. The project will model the causes and impact of changes in diagnosis and treatment of disease, the growth of health services and the cost of these services, as well as the effects on labour force participation, productivity and output. To date work has concentrated on the development of systems for projecting a base case of population growth, labour force participation, health status and health costs for the period from 2005 to 2030.

This section reports on some preliminary demographic, health status and health cost results for the base case of this project. It charts the likely course of chronic disease in China over the period, in parallel to the projections of the burden of disease in for APEC developing countries in Section 2. The Institute of Population Health at Peking University has developed a detailed and sophisticated multi-state model for projecting population by age, sex, urbanisation, and education status (Zheng et al. 2007). Using this model, the Institute has produced projections of the labour force, the incidence of chronic disease, medical utilisation and medical expenditure for years 2005, 2010, 2020 and 2030, using base line data from the 2003 national health survey.

Figure 14. Percentage of Chinese population within category with chronic disease



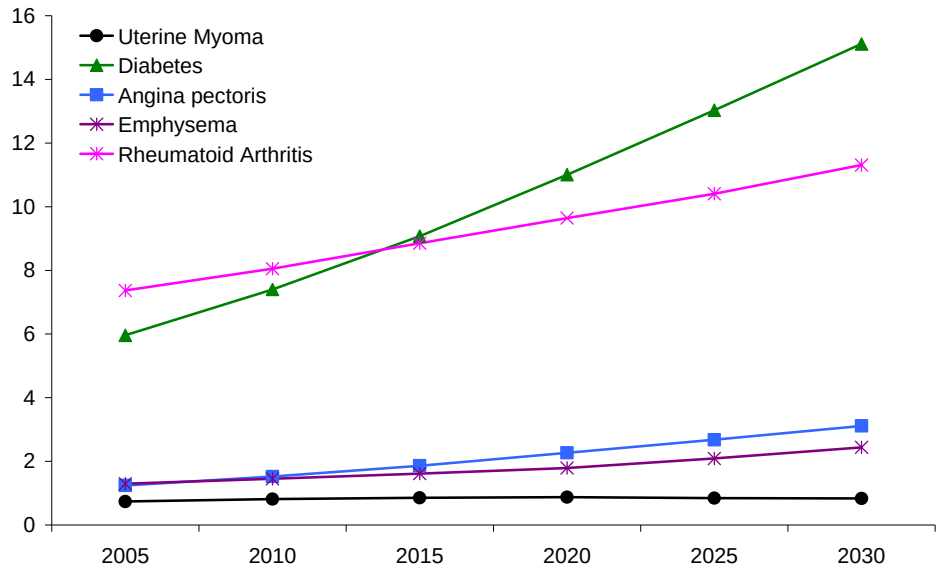
Source: Institute of Population Health, unpublished estimates, 2008.

Figure 14 shows the percentage of the population with chronic diseases from 2005 to 2030. This percentage rises in both urban and rural China and for males and females, as

the average age of the population increases. The proportion of the population with chronic disease is higher for females and males and higher in urban settings than in rural settings. Overall the prevalence of chronic disease increase from about 11.4% in 2005 to 19.0% in 2030, assuming that the rates of diagnosis and treatment are unchanged. The implied rate of increase in the burden of disease from chronic conditions is about 67% or somewhat more than the overall increase in DALYs implicit in the 'constant mortality rates' projections reported in Table 9 for all APEC developing economies. In that table the implied increase is 31% although the methodologies used are somewhat different.

The relative importance of different causes of disease in the overall burden is expected to shift over the period. Figure 15 shows the rate per thousand of population for a selection of chronic diseases – uterine myoma (fibroids), diabetes, angina pectoris, emphysema and rheumatoid arthritis.

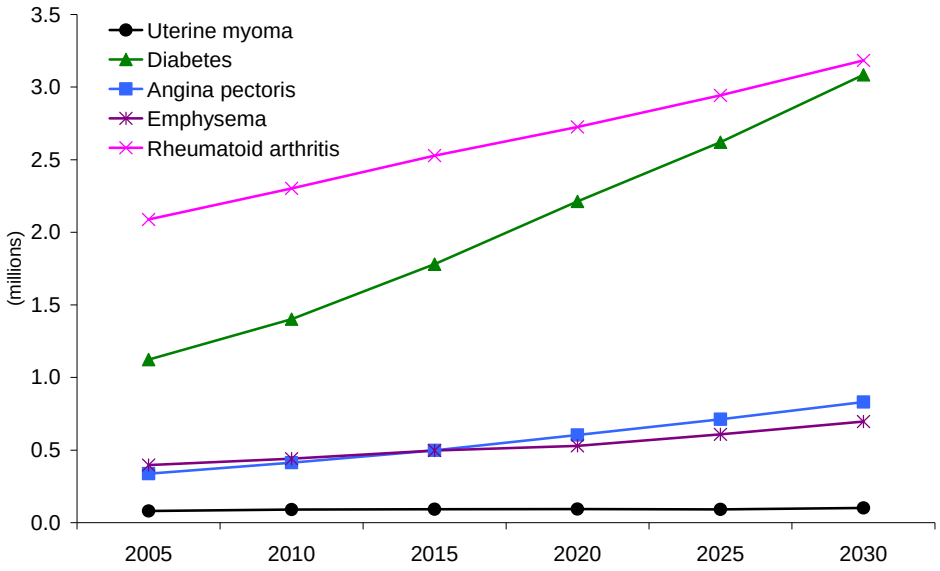
Figure 15. Incidence of chronic diseases in China, per 1000 population



Source: Institute of Population Health, unpublished estimates, 2008.

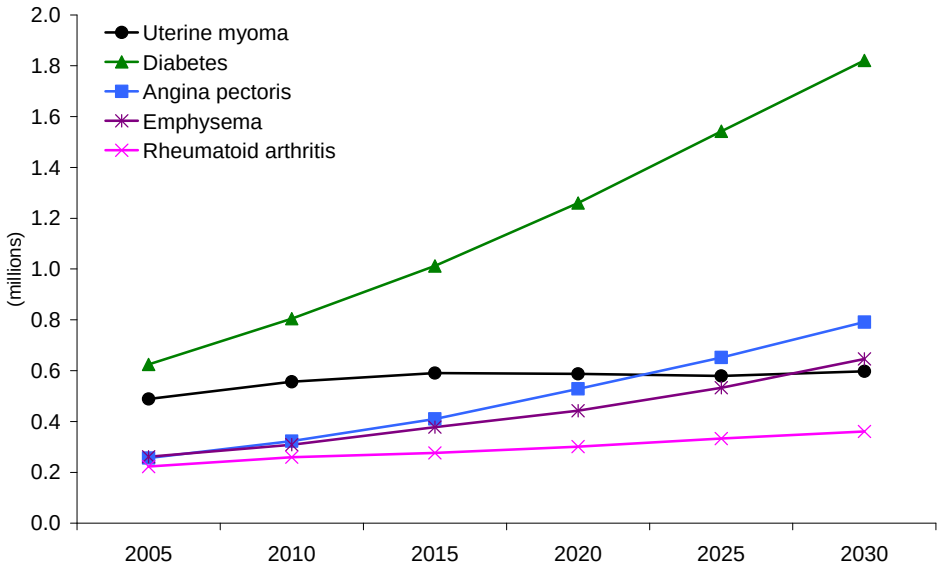
These diseases vary both in importance and their growth over time. The fastest growth is in diabetes with an incidence in 2030 about 2.5 times that in 2005. A similar increase is expected in angina pectoris. Emphysema and rheumatoid arthritis are projected to have incidence rates in 2030 1.9 and 1.5 times their levels in 2005 while the rate for uterine myoma is expected to increase only slightly. The detailed burden of disease outcomes for the 'ongoing innovation' scenario described in Section 2, and based on the unpublished WHO projections for the APEC developing economies, highlight the expected strong growth in the number of DALYs due to diabetes and respiratory diseases such as emphysema, and the significant increase due to musculoskeletal conditions such as rheumatoid arthritis. The preliminary projections for these diseases in China are therefore in line with the earlier WHO estimates for the broader region.

Figure 16. Patients seeking treatment for selected chronic diseases, out-patients, millions



Source: Institute of Population Health, unpublished estimates, 2008.

Figure 17. Patients seeking treatment for selected chronic diseases, in-patients, millions



Source: Institute of Population Health, unpublished estimates, 2008.

The availability of health services in the form of both inpatient and out-patient treatment varies greatly among the regions of China and between urban and rural settings. This affects the projected usage of health services and can be seen in Figures 16 and 17 which show how the health services utilisation due to the 5 chronic diseases is expected to grow. Figure 16 shows the projected number of patients seeking out-patient health services for each disease based on the propensity to seek health services in 2003. Diabetes and rheumatoid arthritis are clearly more important in this type of treatment. This contrasts

with Figure 17 which shows the number of patients seeking in-patient health services. Here diabetes is still the most important disease but rheumatoid arthritis is relatively unimportant while patients with uterine myoma seek treatment as in-patients rather than as out-patients. In general the demand for in-patient services grows more rapidly than for out-patient services as more people move to the cities from the countryside.

Table 13. Projected health expenditure in China by disease, million yuan RMB

	2005	2010	2015	2020	2025	2030
Outpatient						
All diseases	57.2	65.2	74.2	82.6	91.1	100.6
Uterine myoma	1.1	1.4	1.6	1.8	1.8	2.2
Diabetes	6.8	8.5	10.6	13.4	16.7	19.7
Angina pectoris	3.0	3.9	4.8	6.4	8.2	9.9
Emphysema	2.7	2.9	3.3	3.4	4.0	4.4
Rheumatoid arthritis	7.0	7.9	8.8	9.4	10.5	11.5
Inpatient						
All diseases	204.3	229.8	257.5	281.1	320.7	361.7
Uterine myoma	2.2	2.6	2.8	2.9	2.9	3.0
Diabetes	4.7	6.3	8.2	10.5	13.5	16.6
Angina pectoris	1.9	2.5	3.2	4.2	5.3	6.7
Emphysema	1.0	1.2	1.5	1.9	2.4	3.1
Rheumatoid arthritis	0.9	1.0	1.1	1.3	1.5	1.6
Total						
All diseases	261.5	295.1	331.7	363.8	411.8	462.3
Uterine myoma	3.3	4.0	4.4	4.6	4.7	5.2
Diabetes	11.4	14.9	18.8	23.9	30.1	36.3
Angina pectoris	4.9	6.4	8.1	10.5	13.6	16.6
Emphysema	3.7	4.1	4.8	5.3	6.5	7.5
Rheumatoid arthritis	7.8	8.9	10.0	10.7	12.0	13.1
Total as index, 2005 = 1.00						
All diseases	1.0	1.1	1.3	1.4	1.6	1.8
Uterine myoma	1.0	1.2	1.3	1.4	1.4	1.6
Diabetes	1.0	1.3	1.6	2.1	2.6	3.2
Angina pectoris	1.0	1.3	1.7	2.2	2.8	3.4
Emphysema	1.0	1.1	1.3	1.4	1.8	2.0
Rheumatoid arthritis	1.0	1.1	1.3	1.4	1.5	1.7

Source: Institute of Population Health, unpublished estimates, 2008.

The impact that this has on health expenditure can be estimated using the cost per health service for each disease and for inpatient and outpatient settings reported in the 2003 survey. Applying these costs to the utilisation estimates gives an indication of how the health expenditure in China might be expected to grow over the next 25 years. Table 13 reports the estimates for inpatient and outpatient settings and as a total for the 5 chronic diseases and for all diseases. Overall, health expenditure in 2030 is expected to be about 1.8 times its 2005 level although diabetes will grow more quickly as will angina pectoris. Expenditure on the other 3 chronic diseases will grow less strongly.

Because in-patient services are more expensive than out-patient services and as treatment is more expensive in urban than rural locations, the increase in health expenditure is somewhat greater than the increase in the burden of disease. Future modelling will concentrate on developing realistic assumptions about the rate of diagnosis, treatment and cost of services based on expected changes in income per capita and other variables. This will provide the basis for the development of intervention options based on initiatives at the population-level such as tobacco control programs and at the personal level through the use of both established and new medicines.

4. Innovation and the Changing Burden of Disease

This section is concerned with how innovation has both reduced and changed the nature of the burden of disease in most countries and the challenges that remain in understanding and treating disease. Fundamental to the progress that has been achieved is the development of new knowledge about the causes and mechanisms of disease and the resulting technological innovations that have occurred which use this knowledge. The principal technological innovations have been the discovery and development of new medicines, the improvements in medical and surgical practices, and better diagnostic and treatment technologies. At the system level, innovations have been made in ensuring safe water supply and sewage disposal, mass immunisation against infectious diseases, and education programs aimed at changing unhealthy behaviour such as smoking, consumption of high levels of fat, and unsafe driving. Investment in physical infrastructure such as hospitals and clinics has been important in being able to deliver better health care as has the investment in developing and maintaining skills among health care personnel.

The impact of innovation on the major causes of death and morbidity is illustrated using Australian data on mortality over the past 100 years (AIHW 2008) and burden of disease estimates for Australia for 2003 (Begg et al. 2007) (Tables 14 and 15). Data are readily available for Australia and it is reasonably typical of most developed economies in terms of the major causes of death and morbidity. As such it provides an indication of how health status might be expected to evolve in APEC developed economies over the next few decades.

Table 14. Burden of disease in Australia 2003, major disease categories, DALYs

Disease category	Number	%
Cancers	499,416	19.0
Cardiovascular disease	473,794	18.0
Mental disorders	350,545	13.3
Neurological & sense disorders	312,766	11.9
Chronic respiratory diseases	186,737	7.1
Diabetes mellitus	143,831	5.5
Unintentional injuries	125,862	4.8
Musculoskeletal diseases	105,508	4.0
Other	434,311	16.5
Total	2,632,770	100.0

Source: Begg et al. (2007).

Table 15. Burden of disease in Australia 2003, specific diseases, DALYs

Specific disease	DALYs	%
Ischaemic heart disease	263,497	10.0
Anxiety and depression	191,786	7.3
Type 2 diabetes	132,940	5.0
Stroke	118,462	4.5
Sense organ disorders	112,728	4.3
Dementia	94,399	3.6
Lung cancer	88,904	3.4
Chronic obstructive pulmonary disease (COPD)	86,751	3.3
Colorectal cancer	63,605	2.4
Asthma	63,100	2.4
Substance use disorders	60,782	2.3
Breast cancer	60,654	2.3
Suicide and self-inflicted injuries	49,916	1.9
Road traffic accidents	42,425	1.6
Other chronic respiratory diseases	36,887	1.4
Prostate cancer	36,547	1.4
Osteoarthritis	34,578	1.3
Personality disorders (isolated)	32,587	1.2
Back pain (acute and chronic)	29,658	1.1
Schizophrenia	27,502	1.0
Other	1,005,063	38.2
Total	2,632,770	100.0

Source: Begg et al. (2007).

Infectious Diseases

In their paper 'The Determinants of Mortality', Cutler, Deaton and Lleras-Muney (2006) describe the different contributions made by a variety of factors to the reduction in mortality evident from the middle of the eighteenth century in Western countries. There is still considerable debate as to why mortality declined in the first half of the nineteenth century but better nutrition arising from greater availability of food seems to be the principal reason. During this time the predominant causes of death were infectious diseases and further improvements in mortality only occurred after measures were introduced to limit the spread of infectious diseases with acceptance of the germ theory of disease. At the personal level this led to improvements in areas such as personal hygiene, better preparation and storage of food, and better housing ventilation while at the public level health benefits were associated with the widespread introduction of safe water supply and sewerage systems from the 1880s onwards. Cutler and Miller (2005) estimate that water purification was responsible for half of the reduction in mortality in the United States in the first 3 decade of the twentieth century.

An important contributor to the reduction in deaths (and even more so in morbidity) from infectious diseases was the introduction of vaccination. Although vaccination is believed to have originated in China in 200 BCE, smallpox vaccination was introduced to Europe and the United States from Turkey in the eighteenth century. However vaccination only

began in earnest in the 1880s with the introduction of vaccines against smallpox, rabies and plague. This was followed by vaccines for diphtheria (1923), pertussis (1926), tuberculosis (1927), polio (1955), measles (1964), mumps (1967), rubella (1970 and hepatitis B (1981). In all there are now vaccines available for most major communicable diseases.

The final major contribution to the decline in both mortality and morbidity due to infectious diseases was the discovery and introduction of antibiotics firstly with sulfonamides in the 1930s and then with penicillins from the 1940s onwards. These were followed by other types of antibiotics such as the cephalosporin, macrolides and quinolones.

Innovation in the form of knowledge about disease processes, public health infrastructure, vaccination and antibiotic medicines are therefore responsible for most of the reduction in the burden of disease due to infectious disease over the last 100 years or more. The result is that in 2005 communicable, maternal, perinatal and nutritional causes were responsible for only 7.1% of deaths in developed APEC countries and 12.5% in developing APEC countries. The respective shares of the overall burden of disease were 6.1% and 18.1% in 2005 and these are expected to fall further to 4.3% and 14.0% by 2020.

While there have been major gains in the control of communicable diseases in developed countries, there is still a significant problem in APEC developing countries. Rates of HIV/AIDS, tuberculosis and malaria for instance are significantly higher, as are a cluster of conditions mainly affecting children such as diarrhoeal diseases, lower respiratory conditions, perinatal conditions and nutritional deficiencies. These latter conditions might be expected to reduce further through improved nutrition and with the use of established technologies such as continuing improvements in water quality and sanitation, oral rehydration formulations and antibiotics.

HIV/AIDS has been controlled in the developed countries through initiatives such as public education campaigns targeted at at-risk groups and needle exchange programs, and the availability of highly active antiretroviral therapy, i.e. combinations of antiviral medications. The rise of tuberculosis is associated closely with HIV/AIDS and is also largely controllable with existing tuberculosis treatments. Success in treating these diseases depends to a large extent on the presence of a significant health infrastructure and providing this can be a challenge in developing countries.

The price of medicines to treat both HIV/AIDS and tuberculosis has become less of an issue as patents expire on medicines and as international initiatives have been created to make medicines more readily affordable, such as the Global Fund to Fight AIDS, Tuberculosis and Malaria.

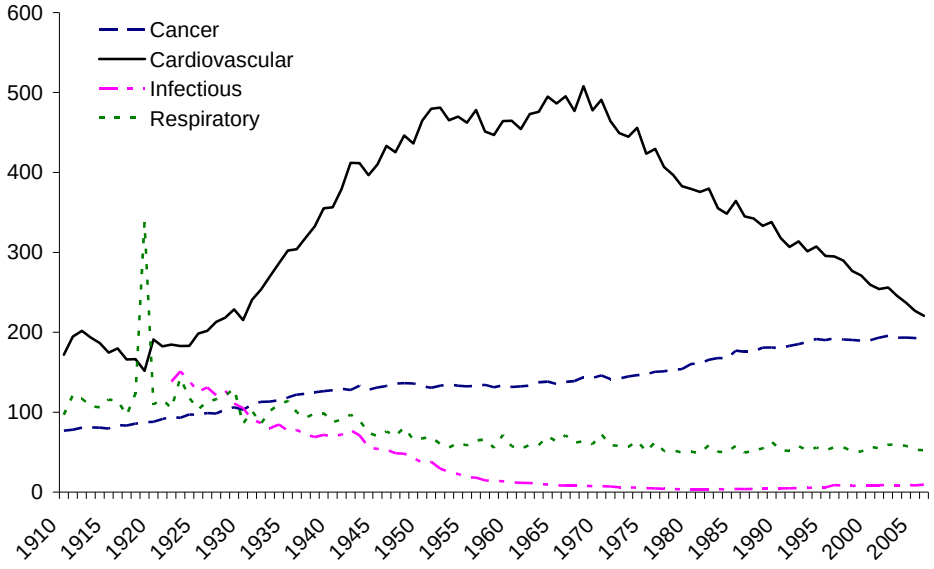
Several major international initiatives such as the Global Alliance for Vaccines and Immunization supported by the Bill and Melinda Gates Foundation, the WHO and the

World Bank among others are aimed at developing vaccines for malaria, tuberculosis and HIV/AIDS.

As technology has reduced the incidence and severity of communicable diseases, the burden of disease has shifted towards chronic diseases in both developed and developing countries.

This can be illustrated using Australia as an example. Figure 18 shows deaths per 100,000 population by major causes of death over the period 1910 to 2006. The death rate from infectious diseases has fallen consistently over the past century particularly through to the 1960s. Although not shown the death rate from maternal and neonatal causes fell to almost negligible levels. The striking feature of Figure 18 is the rapid rise in the death rate from cardiovascular disease and its subsequent decline from the end of the 1960s. The death rate from respiratory causes also fell consistently over the period but more slowly than for other causes of death. The other major cause of death is that due to external causes – principally traffic accidents, and this has fallen consistently as well.

Figure 18. Australian mortality trends 1910 to 2006, deaths per 100,000 population



Source: AIHW (2008).

The significant cause of death that has increased is that due to cancer although this has remained fairly steady over the past 10-15 years.

Cardiovascular Disease

Cardiovascular disease is still the largest cause of death and the second largest contributor to the burden of disease after neuropsychiatric conditions. As with infectious disease cardiovascular mortality has fallen substantially over the last 50 years. In the

United States, mortality fell by 50% from 1960 and 2000 and was responsible for 70% of the 7 year increase in life expectancy over that period.

Cutler (2004) has calculated that about two-thirds of this reduction is due to improvements in medical technology while the largest additional contributor was the reduction in smoking resulting from public health campaigns.

In Australia cardiovascular disease is responsible for about 37% of all deaths with ischemic heart disease accounting for about 54% of this and stroke responsible for another 25%, the remainder being spread among a number of other causes, such as congestive heart disease, and rheumatic heart disease.

Gaziano et al. (2006) and Chandra et al. (2006) describe both IHD and stroke and their causes and treatments. IHD is caused by partial or complete blocking of the coronary arteries while stroke is caused by blocking or rupture of the vessels supplying blood to the brain. Once IHD has occurred, the standard treatments can be either: (i) medicines in the form of beta-blockers that reduce oxygen demand and arrhythmias, aspirin to inhibit platelet aggregation or thrombolytics to dissolve blood clots; or (ii) surgical in the form of cardiac catheterisation and angioplasty. The treatments for stroke are likewise, aspirin, aspirin and dypyridamole or clopidogrel and thrombolytics and carotid endarterectomy.

Once patients have been treated for IHD or stoke in this manner their longer term survival also relies on: (i) surgery in the form of coronary artery bypass graft (CABG), or percutaneous transluminal coronary angioplasty (PTCA) with and without stents; and/or (ii) medicines such as aspirin that dissolves clots or those that reduce the major risk factors associated with cardiovascular disease (CVD) – high blood pressure (hypertension) and elevated levels of cholesterol.

The antihypertensive medicines include diuretics, beta-blockers, calcium channel blockers, ACE inhibitors and AIIRAs while the principal ones for lowering cholesterol are the statins. While these medicines are used in the treatment for patients that have suffered IHD or stroke their wider benefits comes from the prevention of CVD in patients with high blood pressure or high cholesterol. Suboptimal levels of cholesterol contribute to around two-thirds of the global cardiovascular risk (Gaziano et al. 2006).

A complex set of factors contribute to an increased risk of CVD and to increased blood pressure and high cholesterol. The principal risk factors are smoking tobacco, bodyweight, physical inactivity, excess consumption of sodium typically as salt, low fruit and vegetable intake, and excess consumption of saturated fats (Rodgers et al. 2006).

In developed countries, public health programs aimed at reducing smoking and salt intake have been reasonably successful, while those aimed at reducing saturated fats and encouraging greater consumption of fruit and vegetables have had more moderate success. However bodyweight and physical inactivity have both increased over time and these risk factors along with smoking are the main targets of public health programs.

Medicines have been developed to assist in giving up smoking and for dieting, and surgical techniques such as gastric bypass surgery have been used to help in weight reduction.

Other Causes of Death

The rate of death from conditions that were at one time major causes of death have fallen steadily over time in Australia. Mortality related to childbirth and pregnancy fell dramatically once antibiotics and better childbirth techniques were introduced and are now at negligible levels. Deaths from acute respiratory diseases such as influenza and pneumonia on the one hand and chronic respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD) on the other hand have also fallen steadily. Influenza has become much less important in the burden of disease as effective vaccination has become available. Similarly pneumonia is well controlled with antibiotics and other medications.

The first line of treatment for both asthma and COPD is a bronchodilator such as salbutamol or terbutaline. Second line treatments are inhaled corticosteroids for persistent asthma and ipratropium for COPD. Newer generation medicines are also available for both conditions (Speizer et al. 2006). Smoking is a major cause of COPD so reduction in smoking will produce significant benefits in reduced COPD.

Deaths from external causes such as traffic accidents have fallen rapidly since the 1970s under the influence of a number of factors such as safer design of roads and motor vehicles and the introduction of seat belts and other safety devices in cars. Deaths from digestive conditions have likewise fallen – for ulcers this is associated with the introduction of peptic ulcer treatments combined with antibiotics in the 1980s while for appendicitis both antibiotics and improved surgical techniques have been important. Deaths from genitourinary causes fell dramatically during the 1970s with the new medical and surgical techniques such as kidney dialysis and liver transplants. Cirrhosis of the liver has also fallen as excess alcohol consumption has become less common.

The impact of these interventions has meant that a number of conditions have become more prominent in the overall causes of death and morbidity. Death rates from cancer have fallen much less than from these other causes and consequently is now the largest contributor to the overall burden of disease. Partly this is due to the prevention of other causes of death and partly because the treatments for cancer have been less successful in preventing death rather than extending life.

Although still low in absolute terms, the death rates from nervous conditions and mental conditions have increased over the past two decades. More importantly perhaps is that they have become the most important sources of burden of disease after cancers and cardiovascular disease. For the former this is because dementia has increased strongly over the past two decades as has Parkinson's disease and motor neurone disease. Again this is associated with the general ageing of the population and the control over other causes of death and morbidity. Acetylcholinesterase inhibitors can improve cognitive

performance for dementia patients but do not prevent long term deterioration. Patients with moderate to severe dementia usually require long term care in an aged care facility. The symptoms of Parkinson's disease can be treated with medicines such as levodopa and in some cases with deep brain stimulation and physical therapy.

Deaths associated with mental conditions rose strongly from the 1970s through to the mid-1990s but have fallen significantly over the past decade. This is due in part to the development of better medicines and cognitive therapies for treating depression and newer medicines for controlling schizophrenia. The first medicines to effectively treat depression, the tricyclic antidepressants were developed in the 1950s but were largely replaced by the selective seretonin reuptake inhibitors and similar antidepressants beginning in the 1980s. The recommended treatments for depression are now a combination of SSRIs and cognitive behavioural therapy.

Over the past 50 years medicines have become available to treat schizophrenia and other psychoses initially the neuroleptic drugs such as the phenothiazines and the thioxanthenes which were replaced by the more recent second and third generation atypical antipsychotics with less side effects. Psychosocial interventions such as group therapy and family interventions also improve outcomes (Hyman et al. 2006).

Other causes of disease such as diabetes and musculoskeletal conditions only contribute in a minor way to deaths but are more significant in the burden of disease. Type II diabetes has been increasing as a cause of morbidity and is expected to be the fastest growing contributor to the burden of disease over the next few decades. Effective medicines exist for treating both type I and type II diabetes and reduction of the prevalence of diabetes is likely to occur through reduction in its associated risk factors, such as obesity and physical inactivity and inappropriate diet. Musculoskeletal conditions such as arthritis, gout and osteoporosis are strongly linked to ageing.

Challenges in Medical Innovation

The major causes of disease are in the main well treated with the existing range of medicines and medical treatments discussed in the previous section. This is certainly the case for cardiovascular disease where progress in the development of new technologies and the reduction in the burden of disease is likely to be incremental. This is also expected to be the case with medicines for treating other common conditions such as depression, diabetes, and respiratory diseases.

There is a range of conditions however where existing strategies for developing effective medicines have been less successful. Partly this is due to the intrinsic difficulty of developing medicines for these chronic conditions and future progress is therefore likely to be expensive and uncertain in outcomes. In the face of decreasing productivity from traditional methods of drug discovery, companies are increasingly turning to biotechnology-based approaches and to developing personalised medicines which can be more effectively tailored to an individual patient's needs. These approaches to developing new medicine were described in earlier papers for LSIF (CSES 2006, 2007) and will be

more expensive than traditional approaches and require innovation in the way medicines are reimbursed.

The progress in treating cancer in particular has been less than that achieved in cardiovascular disease and consequently much of the research and development in medicines is aimed at this target. Around 24% of drug candidates in the pipeline are for anticancer medicines as shown by Pharmaproject's (2008) analysis of the pipeline at May 2008 (Table 16). While there is still a significant presence in the pipeline of candidates for medicines to treat conditions where there are already effective treatments, the pipeline shows that the industry is concentrating on areas where new treatments are required most.

This includes treatments for schizophrenia, dementia and other neurological conditions, and for musculoskeletal conditions such as arthritis. Vaccines are also prominent in the pipeline.

Table 16. Pharmaprojects R&D pipeline, May 2008

Therapeutic category	Number of products
Anticancer, other	1,373
Anticancer, immunological	771
Antidiabetic	503
Analgesic, other	450
Prophylactic vaccine	414
Anti-inflammatory	356
Cardiovascular	354
Cognition enhancer	321
GI inflammatory/bowel disorders	313
Antiasthma	313
Antiviral, other	302
Ophthalmological	299
Recombinant vaccine	298
Immunosuppressant	289
Formulation, fixed-dose combination	285
Recombinant, other	265
Neuroprotective	261
Antiarthritic, other	257
Hypolipidaemic/antiatherosclerosis	239
Monoclonal antibody, fully-human	238
Symptomatic antidiabetic	232
Monoclonal antibody, other	231
Gene therapy	223
Urological	219
Antiparkinsonian	215

Source: Pharmaporjects (2008).

5. Cost-effective Innovation for Increased Health

This section examines the likely costs involved in substantial programs of increased health innovation to achieve the two outcomes scenarios defined earlier. Building on extensive work undertaken over the past decade or more to describe the burden of disease in both developed and developing countries, used in the previous section, much has also been done to identify appropriate innovation to reduce that disease burden and to assess the costs of particular innovations. A large part of this effort has concentrated on interventions for reducing disease and risk factors in developing countries, particularly the poorer countries where communicable diseases are still a significant part of the burden of disease. This effort has been co-ordinated in part through the Disease Control Priorities Project which is 'an ongoing effort to assess disease control priorities and produce evidence-based analysis and resource materials to inform health policymaking in developing countries' (DCPP 2008).

For example, Ezzatti et al. (2003) have estimated the health gains from reducing major risk factors in various regions of the world, while Murray et al. (2003) have looked at the cost-effectiveness of interventions to lower blood pressure and cholesterol. The costs of achieving the goals of the Global Immunization Strategy have been estimated by Wolfson et al. (2008), while Asaria et al. (2007) have estimated the financial costs and health benefits of public health programs to reduce salt intake and reduce tobacco use. Chisholm et al 2004 have calculated that up to 30% of the burden of depression can be reduced through the use of established therapies. There is a further body of literature which estimates the cost and benefits of various health interventions for individual countries. Some of the studies for China are cited in Section 3.

The report by Jamison et al. (2006) on *Disease Control Priorities in Developing Countries* (hereafter the DCPP study) provides a very comprehensive overview of the cost-effectiveness of many different interventions to reduce the burden of disease from most of the significant causes of mortality and morbidity, including infectious diseases, non-communicable diseases and injuries and from the major risk factors, including those arising from water supply and hygiene, indoor air pollution, diet and lifestyle, blood pressure, cholesterol and obesity, tobacco use and alcohol use. While the emphasis in the DCPP study is on developing countries, evidence on the cost-effectiveness of the interventions described draws on findings from studies conducted in the main in developed countries. The cost of specific innovations is typically described in terms of US$ per DALY saved. This approach is followed here, although there are issues about how to adjust cost estimates mainly drawn from the developed countries for APEC developing countries.

The interventions described in the report can be classified as either personal or population-based. Personal interventions are directed towards individuals and population based interventions are directed towards entire populations. The DCPP study found that personal interventions are not necessarily less cost effective than population based interventions. Population based interventions are cost effective when targeted to

populations among whom a particular disease has high prevalence and mortality would be high if the intervention was not implemented. In general, personal interventions are effective in high risk patients. For example, primary prevention of acute myocardial infarction using aspirin is not nearly as cost effective as secondary prevention in patients who have already suffered a stroke or myocardial infarction, because these patients are at a higher risk than the general population.

Population-based Interventions

Two of the most widely used population based interventions that have an impact on a range of diseases are aimed at: (i) lifestyle change and (ii) tobacco use.

(i) Lifestyle change

The major risk factors for both CVD and diabetes are obesity, physical inactivity and unhealthy diets. Interventions that attempt to change lifestyles leading to these conditions are likely to have a significant impact on reducing both the mortality rate as well as the disease burden worldwide. Lifestyle interventions require the implementation of a range of co-ordinated programs to help individuals maintain a healthy weight, participate in daily exercise and consume a health diet.

A weight loss/weight maintenance program advocates a minimum of 150 minutes of physical activity similar in intensity to brisk walking. A healthy weight is maintained through less private car use and an increased use of non-motorised transport and walking. Transport policies can target prices through taxes and ensure adequate public transport. In Western Europe high petrol prices have discouraged automobile use compared to the United States, where the tax on gasoline is low.

A healthy diet program replaces saturated and trans fat with unsaturated fat; limits sodium intake and calories (particularly from sugar based beverages); and increases consumption of fruit and vegetables and whole grains.

The most significant instrument for implementing life style changes is education provided through schools, workplaces, media and health centres. This requires collaboration between government agencies, the health sector and these institutions.

Food policy that limits advertising of unhealthy foods, offers incentives to manufacturers to fortify foods with micronutrients and to replace unhealthy additives with healthier ones. Replacing trans fat content in foods is relatively inexpensive and effective.

Overall, the DCPP study estimates that replacing dietary trans fat from partial hydrogenation with polyunsaturated fat is likely to be extremely effective in populations in South Asia, where the intake of trans fat is high. If the replacement is done during manufacture at relatively low cost the cost effectiveness ratio of US$25 to $73 per DALY averted can be attained. This intervention would reduce CVD by 7 to 40 per cent depending on the region and also reduce type 2 diabetes. Trans fat consumption is

already low in China so replacing it with polyunsaturated fat would not avert as much disease as in South Asia, where the use of cooking fats with high trans fat content is high. This intervention requires no consumer education and the cost amounts to no more than US$0.50 per person per year.

Replacing saturated fat with monounsaturated fat in manufactured foods accompanied by a public education program is relatively expensive costing between US$1,865 and US$4,012 per DALY averted

Reducing salt in manufactured foods through a combination of legislation and education campaigns is also relatively expensive (US$1,325 to US$3,056 per DALY averted), but could be cost effective in populations with a high salt intake. Legislation that mandates reducing the salt content, accompanied by an educational campaign can reduce blood pressure and would cost US$6 per person per year.

(ii) Tobacco use

Tobacco use is a risk factor for six of the eight leading causes of deaths in the world. The DCP study indicates that in low and middle income countries smoking is also associated with respiratory illnesses such as asthma and TB.

Major interventions to reduce tobacco use have included:

- education;
- increasing taxation on tobacco products;
- advertising to warn of dangers or smoking, mandating warning labels on packaging, broadcasting antismoking messages in the media and comprehensive bans on the advertisement and promotion of tobacco products;
- banning tobacco in public places;
- prohibiting sale to young people;
- use of drugs that counter the effects of nicotine addiction and increasing their availability; and
- restrictions on the importation of tobacco products and programs aimed at encouraging farmers to stop growing tobacco.

DCP study indicates that increasing tobacco taxes by 10% generally decreases tobacco consumption by 4% in high-income countries and by about 8% in low- and middle-income countries. A 70% increase in the price of tobacco would prevent up to a quarter of all tobacco-related deaths among today's smokers.

A 33 per cent price increase yields a cost effectiveness ratio of US$3 to US$42 per DALY averted in low and middle income countries and US$85 to US$1773 per DALY averted in high income countries.

Nicotine replacement therapy (US$55 to US$751 per DALY averted) is relatively less cost effective, as are non-price interventions, including banning advertising, providing

health education information, and forbidding smoking in public places (US$54 to US$674 per DALY averted) in low income countries.

Table 17. Summary of population based interventions

Condition	Intervention	Cost-effectiveness (US$/DALY)
Asthma	Education	71,500
Co-rectal cancer	Fecal occult blood test	3,200 – 12,100*
Coronary artery disease	Legislation substituting 2% of trans fat with polyunsaturated fat at US$0.50 per adult	48
Diabetes	Life style intervention (type 2 prevention)	60- 100
Diabetes	Screening	4,280 – 6,910
Diabetes	Annual screening for microalbuminuria	2760- 4450
Diabetes, ischemic heart disease, and stroke	Legislation with public education to reduce salt content	1,937
Diabetes, ischemic heart disease, and stroke	Media campaign to reduce salt content	2,617
Haemophilus influenzae type B (Hib)	Vaccine	733
Hepatitis B	Vaccine	23,520
Hib, and hepatitis B, diphtheria, pertussis, and tetanus	Vaccine	296
HIV/AIDS	Voluntary counselling and testing	47
HIV/AIDS	Peer and education programs for high-risk groups	37
Indoor air pollution related illness	Kerosene	12-232**
Indoor air pollution related illness	Improved stove	306-605**
Influenza and pneumococcal disease	Vaccinations	180 - 220
Lung cancer	Early detection screening	20,000 – 100,000*
Pneumonia	Improved quality of care	132-5,000***
Tobacco addiction	Taxation causing 33% price increase	22
Tobacco addiction	Non-price interventions	353
Traffic Accidents	Increased speed penalties, enforcement, media campaigns, and speed bumps	2 1
Traffic Accidents	Enforcement of seatbelt laws, promotion of child restraints and random breath testing	2,449
Tuberculosis (endemic)	BCG vaccine	68
Tuberculosis, diphtheria, pertussis, tetanus, polio, measles	Traditional Expanded Program on Immunization (EPI) Scaling up of EPI	7

Notes: * per year of life saved.
** per healthy year.
*** per death saved.

Source: Jamison et al. (2006).

Table 17 provides a summary of selected population based interventions by disease and their cost effectiveness.

Personal Interventions

(i) Type 2 diabetes

Roughly 60 per cent of all cases of diabetes can directly be attributed to weight gain (Yach et al. 2006). Other risks include smoking, poor diet, smoking and too much alcohol. People in Asia develop diabetes at a lower degree of obesity and at younger ages, suffer longer with chronic diabetic complications and die sooner than in developed countries (Yoon et al. 2006). They have a strong genetic susceptibility to type 2 diabetes.

Life style interventions reported in Table 17 result in a 35 to 58 per cent reduction in incidence among people at high risk. The DCPP study indicates that overall such intervention costs $US60 to $US130 per QALY.

Table 18 below summarises the cost of interventions for type 2 diabetes and indicates that there are at least three interventions with costs of less than $1,000 per QALY. Administering metaformin is reported to result in a 25 to 31 per cent reduction in incidence among people at high risk at a cost of between $1,820 and $2,930.

The DCP study indicates that a variety of specific medications have been tested (metformin, acarbose, orlistat, troglitazone, antigiotensine-converting enzyme (ACE) inhibitors, statins, estrogens and prgestins) and have been found to lower diabetes incidence, but the expense, side effects and cumulative years of drug intervention are causes for concern.

Table 18. Cost of intervention, type 2 diabetes, US$

Smoking cessation	730 – 1,170
Annual eye examination	350 – 560
ACE inhibitor	510 – 830
Metoformin intervention	1,820 – 2,930
Cholesterol control	4,420 – 5,940
Intensive glycaemia control	2,000 – 3,230

Source: Jamison et al. (2006).

(ii) Cardiovascular diseases

The DCPP study estimates that the cost of treating acute myocardial infarction using aspiring and beta-blockers is less than US$25 per DALY averted (see Table 19). Including the use of thrombolytics such as streptokinase offers marginally greater effectiveness but is more expensive at US$630 to $730 per DALY averted as is the use of tissue plasminogen activator (US$16,000 per DALY averted).

The combination of beta-blocker atenolol with aspirin is highly cost-effective in preventing recurrence of a vascular event. Adding an ACE inhibitor such as enalapril

results in a cost effective ratio of US$660 to US$866 per DALY averted, a statin such as lovastatin results in US$1,700 to US$24,000 per DALY averted and coronary artery bypass graft is more than US$24,000 per DALY averted.

In regions were there is poor access to hospitals the combination of aspirin and beta-blockers is highly cost effective (US$386 to US$545 per DALY averted).

Table 19. Cost of intervention, congestive heart failure, ischemic heart disease and myocardial infarction, US$

ACE inhibitor & beta-blocker with diuretics	27-274
Aspirin, beta-blockers and ACE inhibitor	451-926
Statin, with aspirin, beta-blockers and ACE inhibitor	1,864-2,193
Aspirin and beta-blockers	13-15
Streptokinase, with aspirin and beta-blockers	671
Tissue plasminogen activator, with aspirin and beta-blocker	15, 869
Combination treatment with aspirin, beta-blocker thiazide, ACE inhibitor and statin	409

Source: Jamison et al. (2006).

The cost of treating acute ischemic stroke using aspirin is US$150 per DALY averted (see Table 20). In comparison, relatively in-effective interventions involve the use of a tissue plasminogen activator (US$1,300 per DALY averted) and anticoagulants such as heparin or warfarin (US$2,700 per DALY averted). Aspirin is the lowest cost option for secondary prevention of stroke (US$3.80 per single percentage point decrease in the risk of a second stroke within two years or US$70 per DALY averted). Combining the antiplatelet medication dipryidamole with aspirin is as cost-effective (US$93 per DALY averted). Carotid endarterectomy is expensive in comparison for secondary prevention at US$1,500 per DALY averted.

Table 20. Cost of intervention, stroke, US$

Aspirin	149
Heparin, recombinant tissue plasminogen activator	1,278-2,675
Aspirin and dipyridamole	70-93
Carotid endarterectomy	1,458
Polypill by absolute risk approach	773-3,483

Source: Jamison et al. (2006).

(iii) Chronic obstructive pulmonary disease (COPD)

The most important risk factors for COPD are:

- tobacco smoking;
- indoor air pollution (such as biomass fuel used for cooking and heating);
- outdoor air pollution; and
- occupational dusts and chemicals (vapors, irritants, and fumes).

Some of the population-based interventions for these factors are given in Table 17. Other population based interventions include: (i) BCG vaccine for areas where tuberculosis is

endemic has a ratio of US$68 per DALY; and (ii) Immunisation for TB, diphtheria, etc. has a ratio of US$7 per DALY (see Table 21).

The cost of personal interventions can differ dramatically between countries. Major personal interventions for COPD include inhaled medication (such as ipratroprium bromide or cortico-steriod such as fluticasone) which has a ratio of US$7800 to US$13,400 per QALY in high income countries. Intravenous treatment with A-1 antitrypsin therapy has a ratio of $14,400 to $215,000 per QALY in high income countries. Mechanical ventilation or oxygen therapy $15,000 to US$19,000 per YLS in high income countries. Bronchodilators for asthma patients has a ratio of US$10,600 to $13,900 per QALY in high income countries

Table 21. Cost of intervention, chronic obstructive pulmonary disease, US$

Inhaled medication	7,800-13,400
A-1 antitrypsin augmentation therapy	14,400-215,000
Mechanical ventilation or oxygen therapy	32,350-47,850

Source: Jamison et al. (2006).

(iv) Mental and neurological disorders

Some of the common neurological disorders include dementia, epilepsy, bipolar disorder, depression and panic disorder, multiple sclerosis, and Parkinson's disease. For many of these effective medications exist to control symptoms but there are not cures for some conditions such as Parkinson's disease or dementia..

The DCPP study found that personal interventions for depression and panic disorder are cost-effective at quite low levels for medication and medication plus psychosocial treatment. For schizophrenia and bipolar disorder treatments are typically more expensive (see Table 22).

Table 22. Cost of intervention, mental and neurological disorders, US$

Older antidepressants (TCA)	478-1,288
Newer antidepressant (SSRI)	1,003-1,771
Newer antidepressant (SSRI) plus psychosocial treatment	1,140-2,101
Lithium	1,587-5,295
Valproate	2,943-6,386
Older antipsychotic plus psychosocial treatment	1,743-4,847
Phenobarbital	25-261
Carbidopa and levodopa	1,311-2,254

Source: Jamison et al. (2006).

For epilepsy, administering phenobarbital helps averts seizures at a cost of US$25-261 per DALY averted. For Parkinson's disease the combination of levodopa and carbidopa cost US$1,311-2,254 per DALY averted.

Implications for this Study

In summary, there are treatments for most of the major causes of disease which are both cost-effective and if used could substantially reduce the burden of disease. Those interventions which cost less than US$1,000 per DALY include:

- Lifestyle changes including programs aimed a reducing trans fats in cooking, decreasing tobacco use, and providing immunisation against infectious diseases. These programs will reduce the incidence of diabetes, and cardiovascular disease among other conditions.

- The provision of medicines for treating diabetes, cardiovascular disease, depression, panic disorder, epilepsy and other diseases.

By themselves these interventions can lead to a significant reduction in the overall burden of mortality and morbidity. For a cost of between $1,000 and $2,000 other lifestyle programs can be introduced, while a greater range of medicines become available for reducing smoking, and treating diabetes, cardiovascular disease, depression and Parkinson's disease.

The standard of living in APEC developing economies as measured by income per capita is projected to increase markedly over the period to 2003. This increase will enable both governments and individuals to afford greater levels of expenditure per DALY, leading to enhanced access to existing and newer more effective medicines and medical technologies with consequent further reduction in the burden of disease.

For the purposed of costing the two programs of additional investment in health innovation assessed in this study, we use four alternative cases for the average cost per DALY, across a wide range of health programs of innovations to reduce the burden of disease. These average figures are US$1000, US$2500, US$5000 and US$7500, in 2005 prices. As health costs tend to rise faster than the overall level of prices, we also assume that these cost figures increase by 2% per annum from the 2005 to 2030.

6. A Model of Health Innovation in the APEC Developing Economies

To analyse the costs and benefits of increased investment in health innovation in APEC developing economies ('the region') over coming decades an aggregate model of health outcomes and of their economic and financial effects under various innovation paths was constructed. This work draws heavily on that of the World Health Organisation and the main elements of the model are outlined below.

Base Population Model

The starting point is the base population model. Beginning with the detailed population data for 2005, this module projects population by age and sex for the region in five year periods to 2030, for given age and sex specific fertility, mortality and migration rates. The fertility assumptions by age for individual economies are taken from the UN Population Projections (UN 2006), with fertility rates by age for the region created by combining the country rates using the base UN projection of female population in child-bearing age groups. The net migration assumptions are also drawn from the UN, and the age and sex specific mortality rates for different innovation scenarios are constructed as outlined below.

Three Chronic Disease Incidence Scenarios: Deaths and DALYs

The model is used to study health outcomes for three innovation scenarios, as represented by three sets of chronic disease mortality rates by age, sex and cause for the region. The first scenario (the 'constant mortality rates' scenario) uses the projected WHO mortality rates for 2005 held constant for each year to 2030 – these rates fall significantly over time related to the 2005 level. The second scenario (the 'ongoing innovation' scenario) uses the WHO projected mortality rates through to 2030. The third scenario (the 'enhanced innovation' scenario) assumes a uniform 1% cumulative reduction in chronic mortality rates in each year from 2010-2030. In each case the distribution of deaths by cause within a given age and sex group for a given year in the WHO base case projection is assumed to apply. In all three scenarios, the WHO assumptions for death rates from communicable diseases and from other causes are used unchanged.

Given these paths for fertility, mortality and net migration, the model generates a projection of population and deaths by age and sex for the region for five-year period out to 2030. The death projections are allocated by cause again using the distribution of deaths by cause within a given age and sex group for a given year in the WHO base case. Projections of disability adjusted life years lost (DALYs), and of the division of DALYs lost between years of life lost and years lived with a disability, are derived from these by a similar method, that is by applying the age, sex and cause specific ratio of DALYs lost to deaths, and of the age and sex specific years of life lost through death, to the mortality projections.

Treatment Costs

The next step is to estimate treatment costs for a given level and incidence of disease. Very little information is available for the APEC developing economies on the overall costs of treatment by disease, although there are some studies for individual countries and disease types. There are, however, detailed estimates of the cost of treatment per DALY for Australia and for some other developed economies. We use the Australian data, together with other information, to estimate the likely relative level of treatment costs per DALY by cause for the region in 2005. For that year total health spending by the economies in the region was US$734 billion, and the total number of DALYs was 348.7 million. These data, together with the estimated relative cost per DALY by cause, is used to produce estimates of cost per DALY by cause for the region in 2005.

As economies get richer, a greater proportion of disease is treated, and more sophisticated and costly methods of treatment are employed. Thus it is well known that there is a positive relationship between economic growth and health spending, and that the elasticity of health spending with respect to GDP is considerably higher than one (refs). It is therefore assumed that real treatment costs per DALY in the region will rise over time more than proportionately to GDP growth. Our base case uses average annual GDP growth for the region over 2005-30 of 6%, with an elasticity of 1.5. Clearly other assumptions can be employed here if required. On this basis the model estimates total treatment costs (taken here to equal total health expenditure) for the region to 2030 for the three health innovation scenarios.

Labour Force, Productivity and Growth

If individuals die earlier, their potential future contribution to GDP through being in the labour force is lost. If they continue to live with disease, and suffer some disability from that disease, they may withdraw prematurely from the labour force or they may continue to work with somewhat impaired productivity. Estimating these impacts on labour force and productivity, and hence on GDP, in the region is therefore an important task of the model.

From the population model we obtain projections of population by age and sex; from the ILO we obtain estimates of the labour force in the region by age and sex to 2005, and projections of detailed participation rates to 2030. Again we create age and sex base case participation rates to 2030 for the region as a whole from the ILO economy projections by weighting the individual economy figures by the ILO base case population projections. Applying these participation rates to our population estimates for the three scenarios leads to projections of the labour force.

There are a number of studies about how having a chronic disease affects labour force participation and productivity when in work, but most relate to developed countries and to specific diseases (Harris 2008; Goetzel et al. 2004; DeVol and Bedroussian 2007). Drawing on these studies, we proceed as follows. For a given age and sex group in a given year, the initial onset of non-fatal chronic disease is assumed to fall equally on

persons in the age group, whether or not they are in the labour force. Consistent with a number of studies, we assume that, for persons in the labour force, 40% of those with chronic disease withdraw, while 60% continue to work with impaired productivity on average. This impaired productivity involves both absences from work and reduced productivity while present. We use here estimates of these losses derived from the Milken Institute report (DeVol and Bedroussian 2007), which in turn drew heavily on Goetzel et al. (2004). These losses are expressed in the proportion of average GDP per employee lost for individuals working with a chronic disease, and vary across diseases, from 58% for cancer to 9% for asthma, as shown in Table 23.

Table 23. Productivity loss (increased absences and reduced on-the-job productivity), workers reporting a chronic disease, USA, 2003

	Number of employees reporting condition (million)	Proportion of productivity lost (share of GDP per employee, %)
Cancer	5.9	57.9
Asthma	13.8	8.5
Diabetes	5.9	22.3
Hypertension	27.2	12.9
Heart disease	9.5	13.9
Stroke	1.1	25.3
Emotional	7.7	27.9

Source: Estimates of the authors based on DeVol and Bedroussian (2007), which in turn draws heavily on Goetzel et al. (2004).

In applying these estimates here we treat the WHO central projections as the base case, even though the labour force impacts of chronic disease were not explicitly considered in those projections. That is, we measure the effects of different incidence of chronic disease in the 'no innovation' and the 'enhanced innovation' relative to 'ongoing innovation' scenario on labour supply and productivity relative to that scenario. The change in GDP in a given year, relative to the base case, is the sum of three factors: the loss of GDP from lower population, evaluated at average GDP per capita in that year; the loss from lower labour force, resulting from the share of the incremental number of persons with chronic disease that withdraw from the labour force; and the loss arising from lower productivity of those with chronic disease that remain in work.

Dynamic growth effects not included

It is also likely that increasing incidence of chronic disease in an economy or group of economies will have dynamic effects on growth. The perception and/or the reality of growing ill-health may lead to lower investment in both human capital and in physical capital, and flow-on effects to lower growth more generally. The Milken Institute study (DeVol and Bedroussian 2007) estimates these effects for the USA and finds that are likely to be substantial. While we recognise that they may well apply for the APEC developing economies also it has not been possible to include them in this study.

7. Returns to Investment in Health Innovation in the APEC Developing Economies

This section pulls together the various estimates discussed in earlier sections, and summarises our overall results.

The Costs of Health Innovation

There is an extensive literature on the cost of interventions that might reduce the burden of disease, and this effort has been co-ordinated in part through the Disease Control Priorities Project, which is supported by the World Bank, the World Health Organisation and the Gates Foundation (DCPP 2008). We draw on this literature here to prepare some estimates of the likely cost of innovation to achieve the goals of both the ongoing innovation and the enhanced innovation scenarios.

The cost of health innovation is mainly measured, in this literature, in terms of cost per DALY saved, and this approach is also adopted here. As reported below, we estimate the DALYs saved in the two innovation scenarios, relative to the constant mortality rates scenario, and hence can calculate the total cost of innovation if an estimate of the cost per DALY saved is available. The innovation cost literature is reviewed in Section 5 of this paper, and several things are clear. First, there is a wide range of potential innovations available to economies, at both the population and individual health levels. Second, there is wide variation in the cost of these innovations, some with a cost as low as US$100 per DALY and other ranging up to US$50,000 per DALY, although the majority cited are below US$3000-4000. Thirdly, most of these estimates are drawn from studies in the developed countries, and to the extent that local labour costs are involved the overall costs should be lower in developing countries.

Table 24. Cost of innovation, by scenario and for alternative cost per DALY assumptions, developing countries, 2010-20 (US$ billion and per cent of GDP)

	2010	2020	2030	2010	2020	2030
Costs (US$ per DALY)	**Ongoing innovation scenario**					
	Total cost (US$b 2005 prices)			Total cost (share of GDP, %)		
1000	26	53	79	0.14	0.16	0.14
2500	66	133	199	0.34	0.40	0.35
5000	132	266	397	0.68	0.79	0.70
7500	198	399	596	1.02	1.19	1.05
Costs (US$ per DALY)	**Enhanced innovation scenario**					
	Total cost (US$b 2005 prices)			Total cost (share of GDP, %)		
1000	26	73	118	0.14	0.22	0.21
2500	66	182	296	0.34	0.54	0.52
5000	132	365	592	0.68	1.09	1.04
7500	198	547	888	1.02	1.63	1.57

Source: Estimates of the authors.

It is necessary to draw on this detailed information to provide plausible levels of the average costs that might be incurred by APEC developing economies to reduce health

outcomes as provided in the scenarios. We have chosen to use a range of four possible cases for cost per DALY (US$1000, US$2500, US$5000 and US$7500). Section 5 concludes that there are a wide range of innovations available below US$1000 per DALY, and very many below US$2500. While a balanced portfolio of innovations will in any economy need to mix higher cost measures with the 'low hanging fruit', we believe that this range covers the realistic range of possibilities. It is also assumed that these cost figures increase by 2% per annum in real terms from 2005 to 2030.

Table 24 summarises our estimates of the cost of the two innovation scenarios, for a range of assumptions about the average cost per DALY across the whole intervention spectrum. For the enhanced innovation scenario the cost estimates for 2030 vary from 0.2% of GDP to 1.6% of GDP, with a most likely range of about 0.5-1.2% of GDP, or about US$300-600 billion (in 2005 dollars) by that time. Thus these are substantial investments in health innovation, but these figures must be placed in the context that total health spending in the APEC developing economies in 2005 was US$735 billion.

Selected Benefits from Increased Health Innovation

Individual benefit and reduced treatment costs from a lower incidence of disease

Every DALY saved is a benefit to the individual concerned, who enjoys the additional year of life without disability, and also to the community, in terms of a reduction in treatment costs or a gain from that individual's ability to contribute to economic and social affairs. There is an extensive literature on the value of a year of life. Several studies for the US have estimated this value of the order of US$150,000 (e.g. Murphy and Topel 2003; Nordhaus 2003), but there are other competing views and methods. It is beyond the scope of this project to address this issue for the APEC developing economies, so we take a very conservative valuation, that the value of a DALY is equal to average GDP per capita in the region in the year in question. Even on this conservative basis the value of DALYs saved in the two innovation scenarios is substantial – for the enhanced innovation scenarios about 4.2% of GDP in 2030 (Table 25, upper panel).

One important component of the benefit from greater investment in innovation, and the resulting lower incidence of chronic disease, is the reduced costs of treating chronic diseases. We use Australian data of the distribution of costs across diseases, together with other information, to estimate the likely relative level of treatment costs per DALY by cause for the region in 2005. For that year total health spending by the economies in the region was US$735 billion, and the total number of DALYs was 349 million. These data, together with the estimated relative cost per DALY by cause, are used to produce estimates of cost per DALY by cause for the region in 2005.

As economies get richer, a greater proportion of disease is treated, and more sophisticated and costly methods of treatment are employed. Thus there is a positive relationship between economic growth and health spending, with an elasticity of health spending with respect to GDP considerably higher than one. It is therefore assumed that real treatment costs per DALY in the region will rise over time more than proportionately to GDP growth. Table 25 reports treatment cost estimates for three elasticities (0.8, 1.0 and 1.2),

and the treatment cost estimates are sensitive to this assumption. On this basis the model uses the projected pattern of disease to estimate total treatment costs (taken here to equal total health expenditure) for the region to 2030 for the three health innovation scenarios.

Table 25. Benefits from higher innovation, 2010-2030; value of DALYs saved, reduced treatment costs and increase in GDP from labour force and productivity effects, two innovation scenarios

	2010	2020	2030	2010	2020	2030
	Value of DALYs saved, relative to constant mortality rates scenario					
	(US$b 2005 prices)			(share of GDP, %)		
Ongoing innovation	202	663	1614	1.04	1.98	2.85
Enhanced innovation	202	910	2403	1.04	2.71	4.24
	Reduction in treatment costs, relative to constant mortality rates scenario					
	(US$b 2005 prices)			(share of GDP, %)		
Elasticity 1.2						
Ongoing innovation	76	252	662	0.39	0.75	1.17
Enhanced innovation	76	343	972	0.39	1.02	1.72
Elasticity 1.0						
Ongoing innovation	61	182	436	0.31	0.54	0.77
Enhanced innovation	61	248	639	0.31	0.74	1.13
Elasticity 0.8						
Ongoing innovation	46	126	274	0.24	0.38	0.48
Enhanced innovation	46	172	403	0.24	0.51	0.71
	Increase in GDP, labour force and productivity effects					
	(US$b 2005 prices)			(share of GDP, %)		
Enhanced innovation	58	536	1530	0.33	1.57	2.68

Source: Estimates of the authors.

Estimates of treatment cost savings are reported in the middle panel of Table 25 for the three elasticity assumptions and for the two innovation scenarios. On the central elasticity scenario (1.0) savings in 2030 are estimated at US$ 436 billion (0.77% of GDP) for the ongoing innovation scenario and at US$639 billion (1.13% of GDP) for the enhanced innovation scenario. These savings rise over time, as the number of DALYs saved increases, and vary significantly with the elasticity assumption.

Increases in the labour force, productivity and GDP

If individuals die early, their potential future contribution to GDP through being in the labour force is lost. However, if they continue to live with disease, and suffer some disability from that disease, they may withdraw prematurely from the labour force or they may continue to work with somewhat impaired productivity. Estimating these impacts on labour force and productivity, and hence on GDP, in the region is therefore an important aspect of this study.

There are several components to the estimates summarised in the lower panel of Table 25. For given participation rates by age and sex, an increased population of working age means an increase in the labour force. In addition, if the incidence of disease within the

population is reduced, this leads to two effects: both greater workforce participation, and increased productivity while at work, arising from the lower incidence of disease. We also assume that better health in older age groups leads to increased participation by older workers, a phenomenon evident in a number of developed countries. Table 25 shows that in total these effects are substantial, with the combination of greater involvement in the workforce and greater productivity while at work leading to an increase in GDP of 2.7% by 2030 in the enhanced innovation scenario.

Dynamic growth and industry benefits

Two other benefits from increased investment in health innovation have been widely discussed. The first is that general expectations, arising out of such a program, of a healthier, longer-lived population (and for individuals of longer working lives) is likely to stimulate increased investment in physical and human capital, and hence contribute to more rapid economic growth. The recent Milken Institute study (DeVol and Bedroussian 2007) modelled this effect for the USA and found that it was highly significant. The second is the impact of much increased investment in health innovation in spurring innovation in an economy more generally, and integrating it more closely into global processes for knowledge based development. This is also likely to contribute to higher growth, but neither of these effects has been modelled in this study.

The Return to Increased Investment in Health Innovation

Leaving aside these two additional mechanisms, the costs and the economic and individual health benefits are summarised in Table 26 for the enhanced innovation scenario and for the central case of the critical assumptions (an average cost per DALY saved of US$2500 in 2005 prices and an elasticity of treatment costs per DALY with respect to GDP of unity). On this basis the estimated annual cost by 2030 of the enhanced innovation program is $296 billin, or 0.5% of estimated GDP by that time. The benefits in 2030 from the reduction in treatment costs is put at $639 billion or 1.1% of GDP, while the gains from labour force and productivity effects are estimated at $1530 billion, or 1.6% of GDP. Thus on these parameters estimates the economic benefits are more than seven times the estimated costs, with a benefit/cost ratio in 2030 of 7.3. As is evident from Table 26, the benefit/cost ratio rises over time, as the benefits of innovation lag the costs. The individual health benefits from enhanced innovation amount to about $2400 by 2030, or 4.2% of GDP, eight times the estimated cost of innovation. With all benefits included the benefit/cost ratio in 2030 is 15.4.

This estimate of the costs and benefits of much enhanced investment in health innovation is preliminary, and the estimates vary significantly with the assumptions made. But on the central cases summarised in Table 26, both the economic benefits and the individual health benefits are by 2030 more than seven times the estimated innovation costs. It is highly likely that the economic and social returns to the investments studied here are very high, and that this conclusion is not likely to change with reasonable variations in the assumptions.

Table 26. Overall benefits of increased innovation, enhanced innovation scenario relative to constant mortality rates scenario, 2010 to 2030, APEC developing economies

Levels of costs and benefits	2010	2020	2030	2010	2020	2030
	(US$b 2005 prices)			(share of GDP, %)		
Cost of Innovation	66	182	296	0.34	0.54	0.52
Benefits of Innovation						
Economic benefits						
Reduction in treatment costs[2]	61	248	639	0.31	0.74	1.13
Labour force and productivity	58	536	1530	0.33	1.57	2.68
Individual health benefits[3]	202	910	2403	1.04	2.71	4.24
Total benefits	321	1694	4572	1.69	5.02	8.05
Benefit/cost ratio						
Economic benefits						
Reduction in treatment costs[2]	0.9	1.4	2.2			
Labour force and productivity	0.9	2.9	5.2			
Individual health benefits[3]	3.1	5.0	8.1			
Total benefits	4.9	9.3	15.4			

Notes: [1]Estimated on the basis of an average cost per DALY saved of US$2500 in 2005 prices.
[2]Evaluated at a treatment cost elasticity with respect to GDP of unity.
[3]Estimated on the basis that the value of a DALY saved is equal to GDP per capita in the year in which the disease is averted.
Source: Estimates of the authors.

The work reported in this paper is in many ways preliminary, and needs to be explored and elaborated further in many dimensions. These include modelling of the situation in individual economies; defining more explicitly the most likely forms of health innovation required in particular economies, and hence the costs likely to be incurred and the benefits achieved; assessment of the impact of such investment on the financial position of governments; and detailed examination of the potential dynamic effects of much greater investment in health, in both overall economic and industry development terms. Such further studies could provide greatly improved information. Specific attention also needs to be given to the timing of costs and benefits, and hence to calculation of rates of return in addition to benefit/cost ratios. Nevertheless the results reported here do amount to a powerful case for the conclusion that the returns to greatly enhanced investment in health innovation in APEC developing countries would be very large indeed, and that such investment could play a significant part in a revised development strategy in many economies going ahead.

References

Australian Institute of Health and Welfare (AIHW) 2008, *The GRIM Books*, Canberra, available at: http://www.aihw.gov.au/mortality/data/grim_books.cfm

Asaria, P. et al. 2007, 'Chronic disease prevention: Health effects and financial costs of strategies to reduce salt intake and control tobacco use', *The Lancet*, vol. 370, pp. 2044-2053.

Begg, S. 2007, 'The Burden of Disease and Injury in Australia 2003', AIHW cat. no. PHE 82, Australian Institute of Health and Welfare, Canberra.

Chandra, V. et al. 2006, 'Neurological disorders', chap. 32, in D.T. Jamison et al. (eds), *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

CHNS 2008, *China Health and Nutrition Survey, Survey Design*, available at: http://www.cpc.unc.edu/projects/china/proj_desc/survey.html

Centre for Strategic Economic Studies (CSES) 2006, 'Sustainable Health Care Systems to Support Innovation', Framework Paper prepared for the Fourth Annual APEC Life Science Innovation Forum (LISF), Hoi An, Vietnam, 6-7 September.

CSES 2007, 'Developing an Integrated Approach to Emerging Health Challenges', Framework Paper prepared for the APEC Life Science Innovation Forum V, Adelaide, 19-20 April.

Cutler, D.M. 2004, *Your Money or Your Life*, Oxford University Press, Oxford.

Cutler, D.M. and Miller, G. 2005, 'The role of public health improvements in health advances: The twentieth-century United States', *Demography*, vol. 42, no 1, pp. 1-22.

Cutler, D.M., Deaton, A.S. and Lleras-Muney, A. 2006, 'The Determinants of Mortality', NBER Working Paper 11963, January, National Bureau of Economic Research, Cambridge, Mass.

DeVol, R. and Bedroussian, A. 2007, *An Unhealthy America: The Economic Burden of Chronic Disease*, Milken Institute, Santa Monica, Calif.

Disease Control Priorities Project (DCPP) 2008, *About DCPP*, available at: http://www.dcp2.org/main/Home.html.

Gaziano, T.A. et al. 2006, 'Cardiovascular disease', chap. 33, in D.T. Jamison et al. (eds), *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

Goetzel et al. 2004, 'Health, absence, disability and presenteeism cost estimates of certain physical and mental health conditions affecting U.S. employers', *Journal of Occupational and Environmental Medicine*, vol. 46.

Hall, R.E. and Jones, C.I. 2007, 'The value of life and the rise in health spending', *The Quarterly Journal of Economics*, vol. 122, no. 1, pp. 39-72.

Harris, A. 2008, 'Chronic disease and labour force participation in Australia: An endogenous multivariate probit analysis of clinical prevalence data', Centre for Health Economics, Monash University, Melbourne.

Hyman, S. et al. 2006, 'Mental disorders', in D.T. Jamison et al. (eds), *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

Jamison, D.T. et al. (eds) 2006, *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

Mathers, C. and Loncar, D. 2006, 'Projections of global mortality and burden of disease from 2002 to 2050', PLoS Medicine, vol. 3, no. 11, e442, available at: http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0030442

Mathers, C. and Loncar, D. 2005, 'Updated projections of global mortality and burden of disease, 2002-2030: Data sources, methods and results', Evidence and Information for Policy Working Paper, World Health Organizationm, Geneva.

Murphy, K.M. and Topel, R.H. 2003, 'The economic value of medical research', in K.M. Murphy and T.H. Topel (eds), *Measuring the Gains from Medical Research: An Economic Approach*, University of Chicago Press, Chicago.

Murray, C. 1996, 'Rethinking DALYs', in C. Murray and A. Lopez (eds), *The Global Burden of Disease*, World Health Organization, Geneva.

Murray, C. and Lopez, A. (eds) 1996, *The Global Burden of Disease*, World Health Organization, Geneva.

Murray, C. et al. 2003, 'Effectiveness and costs of interventions to lower systolic blood pressure and cholesterol: A global and regional analysis on reduction of cardiovascular-disease risk', *The Lancet*, vol. 361, pp. 717-725.

Nordhaus, W. 2003, 'The health of nations: The contribution of improved health to living standards', in K.M. Murphy and T.H. Topel (eds), *Measuring the Gains from Medical Research: An Economic Approach*, University of Chicago Press, Chicago.

Pharmaprojects 2008, 'Annual Review, Update Analysis', vol. 29, no. 1, pp. 1-6.

Popkin, B.M. 2008, 'Will China's nutrition transition overwhelm its health care system and slow economic growth?', *Health Affairs*, vol. 27, no. 4, pp. 1064-1076.

Popkin, B.M. et al. C. 2006, 'Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases', *Obesity Reviews*, vol. 7, pp. 271-293.

Rodgers, A. et al. 2006, 'The growing burden of risk from high blood pressure, cholesterol, and bodyweight', chap. 45, in D.T. Jamison et al. (eds), *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

Speizer, F.E. et al. 2006, 'Respiratory diseases of adults', in D.T. Jamison et al. (eds), *Disease Control Priorities in Developing Countries*, 2nd edn, World Bank and Oxford University Press, New York.

United Nations (UN) 2006, 'UN World Population Prospects: The 2006 Revision Population Database', New York, available at: http://esa.un.org/unpp/.

Ward, S. 2008, 'Demographic factors in the Chinese health-care market', *Nature Reviews Drug Discovery*, vol. 7, May, p. 383-384.

WHO 2008, 'Disability adjusted life years (DALY)', Geneva, available at: http://www.who.int/healthinfo/boddaly/en/index.html accessed 18 July 2008.

World Health Organisation (WHO) 2004, 'Burden of Disease statistics', available at: http://www.who.int/healthinfo/bod/en/index.html accessed 18 July 2008.

WHO 2005, *Preventing Chronic Diseases: A Vital Investment*, Geneva.

Wolfson, L.J. et al. 2008, 'Estimating the costs of achieving the WHO-UNICEF global immunization vision and strategy, 2006-2015', *Bulletin of the World Health Organization*, vol. 86, no. 1, pp. 27-39.

Yach, D., Stuckler, D. and Brownell, K.D. 2006, 'Epidemiologic and economic consequences of the global epidemics of obesity and diabetes', *Nature Medicine*, vol. 12, no. 1, pp. 62-66.

Yoon, K.-H. et al. 2006, 'Epidemic obesity and type 2 diabetes in Asia', *The Lancet*, vol. 368, no. 9548, pp. 1681-1688.

Zhao, W. et al. 2008, 'Economic burden of obesity-related chronic diseases in Mainland China', *Obesity Reviews*, vol. 9, sup. 1, pp. 62-67.

Zheng Xiao-ying et al. 2007, 'Future population and human capital in China', *Market and Demographic Analysis*, vol 13, no 1, pp. 1-11.