HEALTH EXPENDITURES, LONGEVITY AND GROWTH

by

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Abstract

This paper offers an integrated view of the relationships between health spending, medical innovation, health status, growth and welfare. Health spending triggers technological progress, which is a potential source of better outcomes in terms of longevity and quality of life, a direct source of growth for the bio-tech industries and an indirect source of growth through improved of human capital. The latter contributes to GDP per capita through two main channels: higher participation of the population in the labour force and higher labour productivity levels. In turn, income growth induces an increase in health expenditure, as richer countries tend to spend a higher share of their income on health. To analyse these interactions, the paper first focuses on demographic facts, disentangling the role of longevity and carrying out some 'thought experiments' on the indexation of active life on longevity. It then analyses the links between health care expenditures, technology and health status from a micro-level perspective. We investigate empirically the relation between GDP growth and health expenditures and develop a projection method to assess the size of total aggregate expenditures that could be channeled to the health sector up to 2050 for the US, Europe and Japan. We finally assess the potential impact of these health expenditures and better health status on potential growth and productivity.

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TABLE OF CONTENTS

Introduction

Ageing is expected to induce a drag on potential growth and make social security systems unsustainable in many developed countries. Such trends are unlikely to be fully compensated by economic factors, like higher capital intensity, migration or productivity. Inspired from the seminal work of Auerbach and Kotlikoff (1987), recent models have quantified the impact of the projected change in population structure, the subsequent a fall in labour force and different reform scenarios in pensions systems and labour markets (e.g. Ingenue (2001); Börsch-Supan *et al.* 2002, 2006). This type of literature was addressing the impact of the fall in fertility rates from post-World War II levels.

Less attention has been devoted to the issue of *longevity without incapacity* and how to benefit from it. Contrary to common views about ageing, healthy longevity should not be perceived as a negative shock. Rather, it is good news about individuals able to live and work longer provided they are not hampered by a premature retirement decision. Several studies (*e.g.* Duval, 2003; Börsch-Supan, *et al.*, 2005) have shown that the decision of early retirement is much less a matter of individual preferences towards leisure than the result of perverse incentives created by current institutional arrangements in pension systems and labour markets. Taking advantage of "healthy ageing" would critically depend on political support of mechanisms linking the duration of active lives to longevity gains (see Galasso, 2006). In this scenario the growth potential may improve, notably in European economies (see Oliveira Martins *et al.*, 2005).

In this context, several arguments contribute to the idea that health matters for growth and productivity. Better health positively impacts labour supply, notably through a longer life expectancy, and healthier individuals can reasonably be assumed to produce more per hour worked. According to human capital theory, a longer life span will also encourage people to acquire more education. Good health results in more educated and productive people. Healthier individuals (or the total population) are more willing to undertake investment, which in turn promotes growth. Finally, a substantial share of health spending being devoted to finance R&D, it contributes to innovation and growth.

This paper offers an integrated view of the relationships between health spending, medical innovation, health status, growth and welfare.[1] The different links are illustrated in the Diagram 1. Health spending is supposed to trigger technological progress. Technological progress is a potential source of better outcomes in terms of longevity and quality of life, a direct source of growth for the bio-tech industries and an indirect source of growth through an improvement of human capital. The latter contributes to GDP per capita through two main channels: higher participation of the population in the labour force and higher labour productivity levels. In turn, income growth induces an increase in health expenditure, as richer countries tend to spend a higher share of their income on health.

[Diagram 1. Links between Health spending, Technological progress, Longevity and the GDP

A question remains on the sustainability of health expenditure growth. As a share of GDP, total spending on health care[2] has risen steadily over the past thirty years. In particular, public spending grew by some 50% between 1970 and the early 1980s (Figure 1). Policy-makers are concerned that ongoing population ageing may exacerbate these trends. Most analyses, both at the micro and macro-level, have nevertheless shown that the impact of ageing *per se* on health care is small. In contrast, the role of preferences and technology are crucial. We provide empirical evidence that health expenditures tend to

1 . Data and empirical evidence covered here focus on three main developed regions: the US, EU (mostly EU-15) and Japan.

2 . For data availability reasons, total health spending displayed in the Figure includes both health and long-term care expenditures. Given the past low share of LTC in total spending (on average below 1% by 2005), this does not change the qualitative picture.

grow in line with aggregate income. On top of this income effect, the diffusion of new medical technology explains the growing share of health spending to GDP. Drawing from this analysis, we carry out several projection exercises showing a substantial increase in health expenditure shares by 2050.

Increased health spending is expected to positively influence aggregate productivity and growth, but evidence on this link is rather inconclusive in rich countries. We discuss the reasons for this puzzling result. We also analyse the growth potential related to health R&D and innovation activities.

[Figure 1. Evolution of Total, Public and Private OECD health spending]

To simplify the already complex interrelated factors, we decided not to include long-term care in the analysis presented here. Contrary to health care, long-term care services are rather basic in nature and their expenditure drivers are mainly related to demographic developments, in particular the growing share of very-old and frail individuals in total population. They will certainly contribute to public expenditure pressures over the next decades, but cannot enhance growth prospects. If anything, the development of low-productivity long-term care services could generate a drag on aggregate productivity growth.

Policy implications of the analysis are manifold. Pressures for public expenditure are higher for health than for pension systems. These challenges require an integrated and complementary policy package. Reforms in pension systems, health sector, labour, product and financial markets are deeply interrelated. While only some of these linkages are dealt with in the paper, to our knowledge, it is one of the first comprehensive attempts to cover these links. But much further research is needed.

The structure of the paper is as follows. The first section focuses on demographic facts, disentangling the role of longevity and carrying out some 'thought experiments' on the indexation of active life on longevity. Section 2 analyses the links between health care expenditures, technology and health status from a micro-level perspective. Section 3 investigates empirically the relation between GDP growth and health expenditures. Section 4 develops a projection method to assess the size of aggregate expenditures that could be channelled to the health sector. In section 5 we attempt to assess the impact of health expenditures and better health status on potential growth and productivity. The final section summarises and draws policy conclusions.

1. From Ageing to Longevity?

1.1 Transitory vs. permanent demographic shocks

Ageing trends are the result of two different and contrasted phenomena: the change from a high to a low fertility regime and the increase in longevity. The baby boom and subsequent bust are massive but *transitory* shocks. In contrast, the smooth but steady increase in longevity does look like a *permanent* shock (Oeppen and Vaupel, 2002; EC, 2003; Barbi, 2003). Supporting the hypothesis of a permanent shock, the frontier of longevity in different countries has increased almost linearly by 2.4 years per decade over the past century and a half (Figure 1.1). A similar trend was observed on average for the United States, Europe and Japan over the past 40 years (Table 1.1), though with a wide cross-country dispersion.

[Figure 1.1 Historical trends in female life expectancy, 1840-2000]
[Table 1.1 Increases in life expectancy for different age groups]

During the XXth century, increased longevity has resulted from uneven developments of mortality rates across age groups. The first half of century mainly experienced a reduction in child mortality. In the second half, the reductions in mortality were located in prime and old age groups. The role of health care was also different in the two periods (Vaupel, 2002; Yashin, 2003; Lichtenberg, 2003). The development of mass vaccination and antibiotics, together with improved hygiene and life style, help eradicating infectious diseases (tuberculosis, pneumonia, flu, etc.). The latter were the main cause of mortality in early XXth century, affecting in particular young children. But since then, the reductions in mortality have been associated with distinct factors, notably the treatment of cardiovascular diseases and cancer. The prevalence of these diseases is increasing in age and their treatment has triggered the development of medical innovation, as will be discussed below.

Against this background, most national population projections[3] embody a significant slowdown in longevity gains for the period 2005-2050 that is hard to justify given the current state of knowledge. On average for EU-15, the national projections assume gains in life expectancy longevity at birth of only 1.2 years per decade over the next fifty years (Table 1.2). This implies a significant deceleration of longevity. A stronger decline applies for Japan, whereas the projected slowdown is less marked in the United States (where longevity gains have also been lower).

[Table 1.2 Comparison of past with projected gains in life expectancy]

Accordingly, Oeppen and Vaupel (2002) argued that current population projections need to be adjusted for higher longevity gains. In addition, Cheung and Robine (2007) provided empirical evidence on a shift of the modal age of death in Japan, suggesting that currently there is no evidence that we are approaching an upper limit in human longevity. Olshansky *et al.* (2005) have put forward an opposite view. They noted that extrapolation of past trends cannot provide a good basis for projections, because the longevity gains are driven by improvements in environmental, economic and social factors that may not last in the future. In particular, widespread obesity trends in many developed countries would contribute to a deterioration of the health status of the population which *in fine* will reduce life expectancy. While remaining agnostic about future longevity trends, the consequences of different longevity scenarios will be tested in section 4.

1.2 The potential labour resources associated with longevity gains

The OECD economies have experienced during the past decades a relative abundance of labour resources. Due to the baby-boom, labour force has increased steadily since the early 1970s. But the situation will change radically over the next decades. Following the projections of Burniaux *et al.* (2003), at unchanged labour market and immigration conditions, the labour force could decline in the EU-15 by around 25 million workers by 2050 (or -14%) compared to the peak to be reached by 2010 (Figure 1.2). In Japan, the labour force has already started this decline and is projected to fall by 22 million workers (-36%) by 2050 compared with 1995. Only in the United States, labour force is projected to continue increasing, by around 37 million workers (+26%) between 2005 and 2050.

[Figure 1.2 Simulations of the effect of ageing and longevity on the labour force]

The decline in European labour force is mainly due to the strong reduction in the number of prime-age (aged 30-49) and young workers (aged 15-29), while the number of old workers (50-64) in Europe will increase by around 5% (Figure 1.2). In Japan, all age groups decline markedly. The sustained decline in total labour force could induce a substantial drag on potential growth, which could reach 1% in Japan and 0.8% per year in Germany (cf. Oliveira Martins *et al*, 2005). At unchanged conditions, it is unlikely that increased capital deepening and/or total factor productivity could fully compensate for this shock.

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3 . For a discussion on the underlying parameters of national demographic projections (2005-2050) see Oliveira Martins *et al.* (2005).

To investigate the contribution of longevity to counteract these worrying trends, we carried out two 'thought experiments'. First, we shifted the observed participation ratios[4] by age group over time in line with the average increase in life expectancy. In a second experiment, we shifted over time the old-age threshold (usually 65+) usually defining working age population (15-64 years) also in line with longevity gains.

It can be seen that some compensation can be found for the declining numbers of young and prime-age workers in the labour force. The gains are limited in Europe due to low participation in the labour force of older workers (Figure 1.2). When the same simulations are carried out for the working-age population, the gains are substantially larger, leading to a near stabilisation of the European labour force over the period 2005-2050 (Figure 1.3). Therefore the potential is not negligible.

[Figure 1.3 Simulations of the effect of ageing and longevity on the working-age population]

Using these counterfactual scenarios for labour force and working-age population, we also computed alternative scenarios for old-age dependency ratios, *i.e.* old-age people over working-age population, with the old-age threshold increasing in line with longevity. This 'longevity indexation' appears to be sufficient to stabilise, or even reverse, the upward trends in dependency ratios defined over the working-age population. The effect is stronger in the United States and EU-15 than in Japan, where the ageing process is particularly strong. In contrast, when considering the ratios over labour force projections, the effect of the longevity indexation is powerful in the United States and in Japan, but becomes much weaker for EU-15 (Figure 1.4). This is due to the much lower labour market participation ratios of older workers in Europe. The effect of indexation is therefore conditioned by the functioning of labour markets, indicating a strong complementarity between the two types of policies. Along the same lines, a recent paper by Lievre *et al.* (2007) computed an indicator of healthy working life expectancy and concluded that there is an untapped reservoir of healthy years that could be used to extend the length of the working life in Europe.

[Figure 1.4 Simulations of the impact of longevity indexation on dependency ratios]

These simple back-of-the-envelope calculations suggest that an appropriate management of longevity gains could be used to compensate for the ageing of populations in labour markets, as well as to old-age dependency ratios that are a key parameter for the sustainability of pension systems. The potential could be even larger if past longevity trends are maintained, contrary to what is generally assumed in population projections.

The critical condition for these longevity gains to materialise in longer working lives is a dynamic equilibrium between the increase in life expectancy and the number of years in good health (the so-called "healthy ageing" regime). Achieving this virtuous cycle, may require large investments in health care, which to be sustainable may require in turn a careful design of insurance mechanisms and use of technological progress. Understanding these mechanisms is the aim of the next section.

2. Ageing, Technological progress and Health expenditure growth

2.1 How can we explain the rise of health expenditures as a share of GDP?

A conventional explanation for the rising share of health spending in GDP, noted in the introduction, is that transfer programs, such as Medicare and Medicaid in the US or the comprehensive health insurance in Europe, by increasing coverage also boosted aggregate health spending. However, the latter does not

4 . Note that the baseline projections of Burniaux *et al.* (2003) assumed unchanged policies and thus the participation ratios of older workers were also assumed to remain constant over time.

explain why the demand for health care, as well as demand for comprehensive insurance, has increased so rapidly. Another explanation is related to the cost disease story (Baumol, 1967, 1993). Health care, like other services, uses labour intensively and may display low productivity growth. As a result, the relative price of health care tends to rise over time and, depending on preferences, this leads to a rising expenditure share. Along these lines, Triplett and Bosworth (2000) argued that labour productivity growth in the health sector was negative between 1987 and 1997. At the same time, the medical care component of the CPI has increased faster than the overall CPI. An alternative, and somewhat opposite explanation, is that the bulk of the expenditure increase is attributable to technological change (Newhouse, 1992). This explanation, which has received increasing attention in the literature (*e.g.* Fuchs, 1986; Okunade and Murthy, 2002; Cutler, 2004, Jones, 2004), will be the focus of our analysis.

In the course of the 1980s, governments started to react to these spending trends by putting in place a number of cost-containment policies (see Docteur and Oxley, 2003), resulting in a stabilisation of public health care expenditures in the OECD from mid-1980s to late 1990s. Concomitantly, private health spending accelerated. As public cost-containment policies acted mainly through macroeconomic mechanisms (*e.g.* wage moderation, price controls or post-postponement of investments), they could not be sustained forever.[5] Thus, after a long period of cost contention, since 2000 the share of public expenditures to GDP is increasing at a rate of over 3% per year for the OECD as a whole. In this context, it is crucial to identify the drivers of these expenditure trends, can they be related to demographic or to other factors?

2.2 The main drivers of health expenditure growth

The combined effects of ageing and the fact that health care expenditures increase with age are often referred to as a major determinant of the future health care expenditures. These two phenomena are illustrated for one country, France, in Figures 2.1 and 2.2 (wider cross-country evidence will be provided in section 4).

[Figure 2.1 Proportion of people aged 65 and over demographic effect, France]
[Figure 2.2 Individual health expenditure by age group (Euros), France]

Many projections of future health care expenditures simulate the impact of ageing simply by applying demographic previsions to a static expenditure profile by age. However, the profile of expenditures by age group changes over time. Using again French data (Figure 2.3), the only country for which this calculation was possible, a sizeable upward drift can be observed for each age group between 1992 and 2000. As we will see below, the drift is not due to a deterioration of patients' health status. This drift is rather related to changes over time in patients' behaviour, physicians' practices, as well as to the effect of technological progress. Therefore it is a *non-demographic* effect.

[Figure 2.3 France, health expenditures by age group (euros), 1992 and 2000]

Therefore, simply combining the data of Figures 2.1 and 2.2 to project health expenditure growth would miss the main part of the story. As we will see below, the upward drift of the expenditure profile displayed in Figure 2.3 is the main driver of expenditure growth. Ageing only plays a relatively minor role.

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5 . Indeed, it is difficult to contain wages and, at the same time, attract young and skilled workers in the health care sector. Controlling prices is not easy when technical progress is permanently creating new products and treatments. Equipments also need to be renovated, especially in presence of rapid technical progress.

2.2.1 The role of the proximity of death

Estimates on cross-sectional or panel data for OECD countries led to a very small or non significant influence of age on health expenditures, whereas GDP has a sizeable and highly significant impact (Getzen, 1992; Gerdtham *et al.*, 1992, 1998; Hitiris and Posnett, 1992); Leu 1986; O'Connell, 1996; OECD, 1987). A possible explanation was put forward by Zweifel *et al.* (1999), following Lubitz and Riley (1993) who pointed out that yearly payment per person for people dying within the year were 7.1 larger than for survivors (based on US *Medicare* beneficiaries in 1988). Accordingly, health expenditures appear to be increasing with age just because of the high health care costs in the proximity to death, together with the fact that the probability of dying increases with age. Once proximity to death is controlled for, age *per se* would not influence health expenditures. Zweifel *et al.* (1999) used micro-econometric estimates on Swiss data to support this finding. If it is the death proximity, instead of age, that influences expenditures, the increase longevity should then slowdown expenditure growth.

Subsequently, other papers investigated the respective influences of time to death and age on health expenditures (Seshamani and Gray, 2004a, 2004b; Stearns and Norton, 2004; Zweifel *et al.* (2004); Werblow *et al.*, 2007)). A very enlightening article written by Yang, Norton and Stearns (2003) makes it possible to understand the mechanisms at stake. The authors conduct a graphical analysis of person-month data for 25,994 *Medicare* beneficiaries. Figure 2.4 displays the individual health expenditure in relation to death proximity for three age groups (65 to 74, 75 to 84 and 85 and older). The curves for each age group are very close. Their main characteristic is the huge increase in health expenditures around four months before death, from $2,000 twelve months before death, to $8,000 in the last months. Figure 2.5 displays the average health expenditure by age, distinguishing between decedents (people dying in the year) from survivors. Large differences emerge between the two groups, supporting the role of proximity to death. Interestingly, however, we observe that the curve relative to survivors is increasing with age. Thus, time to death is not the only factor. For survivors, which account for the bulk of aggregate expenditures, health expenditures are increasing with age.

[Figure 2.4: Individual health expenditure ($) in relation to death proximity Medicare beneficiaries (USA)]

[Figure 2.5: Individual health expenditure ($) by age group decedents versus survivors, Medicare beneficiaries (USA)]

This empirical evidence suggests that: i) both age and time to death have an influence on health expenditures; and ii) health expenditure projections have to include time to death. These points are by now widely accepted. Using US projected life tables for 2020, Stearns and Norton (2004) show that omitting time to death leads to an overstatement of around 15 % for health expenditures. This downward correction is due to the fact that an increase in longevity is expected in the future.

2.2.2. The predominant impact of changes in medical practices

The discussions about the role of time to death focus on the interpretation of the profile of health expenditure by age (figure 2.2). They omit to consider the main driver of expenditure growth, i.e. the upward drift of the age-profile of health expenditure over time (figure 2.3). In other words, the derived predictions are implemented for a given level of technology, overlooking the role of changes in practices. Dormont, Grignon and Huber (2006) have proposed a micro-simulation method for analysing changes over time in the age profile that makes it possible to disentangle changes in morbidity on the one hand, and changes in practices on the other hand. Concerning morbidity, the authors consider a vector of chronic illnesses and disability indicators and allow for the changes over time in their prevalence by age. This enables to compute the resulting impact of all these changes on expenditures by age.

Changes in practices for a given morbidity level are captured by changes in the coefficients which measure the influence of morbidity on health care use. Changes in these coefficients show, for each given illness, whether health care expenditure is higher in 2000 than in 1992. These changes may be due to changes in patients' preferences, in physicians' behaviour and/or to technological progress (innovative procedures or drugs).

Dormont *et al.* (2006) use a representative sample of 3,441 and 5,003 French individuals, respectively in 1992 and 2000.[6] Their micro-simulation approach identifies the components of the drift observed between 1992 and 2000 in the age profile of health expenditures. To give an illustration, the observed drift in pharmaceutical expenditures is displayed in Figure 2.6. A large upward drift is observed for the age profile of individual expenditure between 1992 and 2000 (profile 1 and 4, respectively). The simulations show that this large upward drift is entirely due to changes in practices for a given level of morbidity (profile 1 to 2). For morbidity level they experienced in 1992, individuals have spent more in 2000 than they would had spent in 1990, irrespective of their age. In contrast, the changes in morbidity induce a downward drift (profile 2 to 3) for all age groups (except 70+). Put differently, changes in health conditions have retrospectively led to lower spending.

[Figure 2.6: Decomposition of the drift of the age profile of individual expenditures, France (micro-simulations), pharmaceutical expenditures, 1992-2000]

Applying the simulated profiles by Dormont *et al.* (2006) to the structure by age of the French population leads to an assessment of the relative effects of demographic change and expenditure profile drifts for the period 1992-2000 at the aggregate level. The results for pharmaceutical and total expenditures are provided in table 2.1. Pharmaceutical expenditure increased by around 67%, of which changes in practices explain 52 percentage points. The rise in health care expenditures due to changes in the age structure appears to be very small (4.6 percentage points). For total expenditures, the changes in practices explain 13 percentage points, compared with 3.4 percentage points due to changes in the age structure. Most importantly, the aggregate effect of changes in morbidity appears to be negative, reflecting the impact of health improvements of individuals for a given age between 1992 and 2000. Noteworthy, these health improvements cancel out the increase in costs related to pure ageing effects.

[Table 2.1 Explaining health expenditure growth, France]

What are the changes in practices made of? Identification can be drawn by contrasting the estimates obtained for physician consultations and pharmaceutical consumption and for participation behaviour versus conditional consumption. The results show that changes in practices are mainly induced by technological changes: for given age and morbidity, more treatments are provided, leading to higher costs and better outcomes. It is therefore crucial to examine thoroughly the dynamic of technological change in health care.

For France, there is microeconomic empirical evidence of a rather limited impact of ageing on health expenditure growth, in comparison with other drivers. One important issue is whether such a result could be generalized to other countries.

6 . The database used by Dormont *et al.* (2006) has the advantage of providing detailed information about morbidity and health expenditures at the micro level and for a rather long period. This makes it possible to: (i) provide empirical evidence of global health improvement; and, (ii) evaluate the savings due to changes in morbidity. Such databases are rare in other countries. The Survey of Health, Aging and Retirement in Europe (SHARE) collects the same kind of information, but only beginning in 2004. The second wave concerns 2006. In the future, this survey will provide precious information for several European countries. However, it is currently too early to use it for an evaluation of changes that occurred over time in morbidity and in medical practices.

2.3 Technological change and its impact on health status and spending

2.3.1 The pattern of innovation and product diffusion in health care

Health economists have usually identified technological change as the principal culprit for health expenditure growth. As pointed out by Gelijns & Rosenberg (1994), this appears to contradict conventional wisdom, where technological change is driving productivity gains.[7] They criticise this 'linear conceptualization' of medical progress, where "new ideas" of the biomedical scientists would go from laboratory to animal testing and then to bedside. Actually, the research leading to medical innovation does not necessarily take place in the biomedical sector: lasers, ultrasounds, magnetic resonance imaging, computer, nanotechnology have their origin in more general-purpose research and innovations. Moreover, development does not end with the adoption of an innovation. Adoption is generally the beginning of a long process of redesigning the innovation based on feedbacks from users. These incremental improvements after initial adoption play a crucial role in the development of pharmaceutical drugs and medical devices.

Medical technological change entails two basic mechanisms: i) the substitution of old treatments by new ones, this generally induces a gain in efficiency; and, ii) the extension of new treatments. The substitution effect leads to a gain in productivity and often lowers unit costs, in accordance with the standard view of the impact of technological progress. The rising costs in health care spending are mainly due to the treatment expansion effect, *i.e.* related to a potential demand for new goods and services.

Available statistics from the TECH network[8] on heart attack treatments enable to make this discussion more concrete. Heart attacks are both the most common cause of death in most developed countries and an area where many innovations have occurred over the past 15 years (see Box 1). This can be seen in the rising number of innovative procedures for heart attack treatments in the US and seven countries participating in TECH (Figures 2.7 and 2.8). Other indicators taken from the OECD Health database (Figures 2.9 to 2.11) also show the increasing use of new medical procedures, such as cataract surgery, hip replacement and knee replacement.

[Figure 2.7: Changes in the surgical treatment of heart attack USA, 1984-1998]
[Figure 2.8: Share of angioplasty procedures involving stents in heart attack admissions. Seven countries 1994-1998]
[Figure 2.9-2.11: Use of cataract surgery, hip and knee replacement in OECD countries]

Box 1. Medical innovations in Heart attack treatment

A heart attack is an acute event characterised by the occlusion of the arteries that supply blood to the heart. Together with drug therapy (aspirin, beta blockers, etc.), patients can receive various treatments such as thrombolytic drugs, cardiac catheterization, percutaneous transluminal coronary angioplasty and bypass surgery. Catheterization is a procedure used to view the blood flow to the heart to improve the diagnosis. Developed in the late 1970s, angioplasty appeared more recently than bypass surgery, which was developed in the late 1960s. It is an alternative, less invasive procedure for improving blood flow in a blocked

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7 . Quoting Gelijns and Rosenberg (1994): "*… Outside of medicine, technological change is identified as the primary driving force behind improved productivity and economic growth. One of the most decisive effects of technological change is that it makes it possible to produce a given volume of output with a smaller volume of inputs. Why, then, when considering medicine, is technological change deemed responsible for rising costs?*".

8 . The Technological Change in Health Care (TECH) Research network set up by Mark McClellan and Daniel Kessler has brought together investigators in clinical medicine, economics and epidemiology from sixteen countries to carry out international comparisons of technological change in the treatment of heart attack.

artery by inflating a balloon to create a channel through the blockage. This innovative procedure is less costly and more respectful of patients' quality of life than bypass surgery. Angioplasty can replace bypass surgery in some cases. However, the use of angioplasty is spreading above and beyond this type of substitution. Since the mid-1990s, it has increasingly been performed with the implantation of one or more stents (small mesh tubes that hold open the coronary artery) to improve outcomes.

Cutler and McClellan (1996) showed that growth in treatment costs for heart attack in the U.S results entirely from diffusion of innovative procedures, as prices paid for a given level of technology are fairly constant over time. In the US, by 1998, more than half of heart attack patients received catheterization and usually another procedure, instead of only 10 % of heart attack patients in 1984. The diffusion of angioplasty with stent also appears clearly in Figures 2.7 and 2.8.

Turning to other areas, the introduction of new medications such as selective serotonin reuptake inhibitors (SSRIs), including Prozac and similar medications changed completely the treatment of depression. In the mid-1980s, treatments with psychotherapy or tricyclic anti-depressors were the norm. Berndt *et al.* (2000), and Cutler and McClellan (2001) show that the introduction of SSRIs was followed by a demand boom in the US. In 1991, 30 % of depressed patients were treated with an SSRI; this proportion rises to nearly half by 1996. Berndt *et al.* (2000) show this substitution effect led to a gain in efficiency. The spending per incremental remission probability was reduced by about 20 %. Costs have been rising because of treatment expansion: diagnosis and treatments for depression doubled over the 1990s. The latter may have resulted from supply-induced demand encouraged by manufacturers of SSRIs providing incentives to doctors to watch for depression. However, the supply of these new products meets demand needs that were not previously satisfied. Indeed, many studies in the 1980s suggested that half of depressed persons were not appropriately diagnosed and treated.

For cataract, the substitution of newer for older technologies led to obvious gains in efficiency (Shapiro *et al.* (2001). There is no increase in the cost of a cataract operation between the late 1960s and the late 1990s, while health outcomes have increased: better visual quality and a reduction in complication rates. As operations are safer and more effective, there is a treatment expansion: a larger number of patients are operated (Figure 2.9), including those with less severe visual acuity problems.

Technological progress in health care is likely to have had an impact on the price of health care relative to other goods in the economy. Non-adjusted official medical price indices have generally increased more rapidly than prices in the rest of the economy. For example, in the US, medical care-CPI increased by 1.8 percentage points annually above the growth rate of the aggregate CPI between 1960 and 1999 (Cutler and McClellan, 2001). These indices can be criticized because they are poorly adjusted for quality changes and include as price change many factors that should be counted as quantity increases resulting from medical innovations. When they are adjusted for quality it is possible that true" price indexes have actually declined (see Box 2). Similarly, adjusting prices for the variety of products can lead to a decrease in the true relative price of health care goods (Box 2).

Box 2. Technical progress and quality/variety adjusted medical prices

A way to measure the benefit of health care is to focus on consumers' utility and consider price effects adjusted for quality. When consumer's marginal valuation of the good equals its costs, it is possible to link costs and value using a hedonic analysis (Griliches, 1971). As regards health care, the fact that patients are insured, together with the asymetry of information between patient and care providers, do not allow to assume that the marginal value of care equals its costs. One has to use direct evidence on the expected value of health improvement to assess the benefit of medical care. Accordingly, Cutler *et al.* (1998) build a Cost of Living (COL) Index to measure how much consumers would be willing to pay for changes in medical treatments and prices over time (Fisher and Shell, 1972). Applying this method to the price of heart attack treatments, they estimated the Cost of Living Index (COL) relative to the GDP deflator to have actually fallen by about 1 percent annually. This result was subsequently confirmed by Cutler and McClellan (2001) on heart attack, depression and cataract treatments. A policy implication of such results is that production growth in health care is likely to be understated by the current accounting approach.

Moreover, the “true” relative price of health care *vis-à-vis* other goods may decrease if new technologies increase the variety of products and if there is a demand for variety. Consider for example a model with a CES utility function: $U = \sum_i x_i^{(\sigma-1)/\sigma}$, where σ>1 is the elasticity of substitution among *n* products. Assuming price symmetry ($p_i = p \ , \ \forall i$), the true composite price index is equal to $P^* = n^{(1-\sigma)} \cdot p$. With two types of composite goods, say health (*H*) and all other goods (*O*), the true relative price would be: $P_H^* / P_O^* = (n_H / n_O)^{(1-\sigma)} \cdot (p_H / p_O)$. Thus, even if the usual price ratio (p_H / p_O) remains constant, the "true" relative price P_H^* / P_O^* would decrease when the pace of product creation in the health sector is faster than in the rest of the economy.

2.3.2 Impact of insurance systems and regulatory factors on technological progress

The incentives to produce innovation in the health sector are dominated by insurance systems and public provision. Weisbrod (1991) suggested that expanding insurance has provided an increased incentive of the R&D sector to develop new technologies, as new products tend to be always validated *ex-post* by the insurance system. Moreover, the orientation of technological progress is not neutral. Certain type of innovations will be favoured, depending on the design of the health insurance and on the payment systems implemented by the payers.

The cross national comparisons performed by TECH network, referred above, have shown that there are big differences in patterns of technological change across countries (McClellan and Kessler, 2002). The absolute differences in innovative procedure growth rates between rapid-growth countries (Australia, US, France, Israel) and slow-growth countries (Canada-Ontario, Finland) amount to a factor of two or more over a five-year period.

Many countries have a health care system characterized by a monopsonic third party payer, which can control the implementation of new technologies through effective budget ceilings. In countries having several third party payers, competition among them will tend to drive up technology adoption. Different providers' payment systems also matter: fee-for-services and per-case remuneration schemes are more likely to encourage a higher adoption of new technologies than fixed remuneration schemes (capitation, global budget). In some countries, hospitals have to apply separately for funds for large scale investments. In other, large investments are financed through the general remuneration of the hospitals. Direct control by a single payer through regulation of separate grants for large investments is likely to have a negative influence on the adoption rate of new technologies.

Bech *et al.* (2006) show that differences in technology use across countries and in their rates of adoption can be explained by these institutional factors. The main factors, which lead to lower utilization rates, appear to be the monopsonic payer and the funding of investments by specific grants. Baker and Brown (1999) suggest that managed care has slowed the rate of diffusion of new medical technologies. Dormont and Milcent (2006) show how a severe budget shortage induced by a global budget system makes it difficult for French public hospitals to finance the diffusion of angioplasty

Improving efficiency and eliminating waste are important goals for regulation. However, it is of crucial importance to keep in mind that some policies may retard technological progress. If the benefit induced by the new technologies is larger than their additional costs, such policies are not optimal.

2.3.2. The impact of health care on longevity and health

The most common indicator of health care outcomes is life expectancy at birth. As pointed above, the latter has increased steadily over the XXth century, by about 30 years in the US and in comparable countries. In recent years, EU-15 has performed better than the US in this respect (Figure 2.12), the latter displaying a persistent gap of around 1.5 years by 2004.

[Figure 2.12 Life expectancy at birth in the EU-15 and the US, 1990-2004]

Has life in good health (or the health status) also increased over time? Life expectancy fails to take into account morbidity differences. To address this shortcoming, an increasingly used measure is the health-adjusted life expectancy (HALE). The World Health Organisation (WHO) has computed gender-specific HALEs for all countries of the world: the results show a large variability of HALEs between countries, with still an advantage of the EU-15 vis-à-vis the US, at least two years for each gender. However, no data has been produced by the WHO to make it possible to compare HALE over time, and see how the evolution of HALE compares to that of life expectancy.

A European project, the European Health Expectancy Monitoring Unit (EHEMU), aimed at constructing comparable indicators on disability-free life expectancy (DFLE)[9] for European countries (Michel and Robine 2004). The results are mixed: while some countries have experienced an increase in lifetime lived free of disability, others have hardly shown any change over the period examined. More precisely, for a given age, mild and severe disability appears to have declined in several European countries, as well as in Japan. In some countries, the gains in DFLE are actually higher than the gains in life expectancy at birth (e.g. France, Germany, Japan).[10] In the US and the U.K., DFLE has increased but at a slower pace.

A study carried out by Robert Fogel (2003) on a large sample of 45,000 US veterans does not give support to the idea that increase in life expectancy led people to spend more years plagued by chronic illnesses. The average age of onset of various common chronic conditions (such as heart disease, arthritis, respiratory disease, etc.) increased by 10 years over an 80-year period, while life expectancy increased by 6.6 years. These results are in line with those of Freedman, Martin and Schoeni (2002) that the elderly are getting healthier in the US, as they are living longer.

Has health care played a role in reduced mortality and morbidity? Most studies point out several identification problems: many other factors than health care have influenced mortality, including behavioural changes, declines in pollution with the delivery of clean water and the removal of waste, increased education with advice about personal health practice, urbanization, etc. Nevertheless, there is evidence that better health care has improved health status.

Cutler, Deaton and Lleras-Muner (2006) showed that since the 1930s, mortality reductions have been driven by health care, first by vaccination and antibiotics, then by intensive care procedures. Murphy and Topel (2006) show that the gain in life expectancy is equal to about 9 years for men and women in the US between 1950 and 2000. They state that this gain in longevity is mainly due to the reduced mortality from heart disease and stroke (respectively, + 3.7 years and + 1 year for men, with comparable figures for women).

Hunink *et al.* (1997) showed that 43 % of the decline in coronary heart disease (CHD) observed between 1980 and 1990 resulted from improvements in acute treatment and that 29 % resulted from

9 . The difference between DFLE and HALE is that the former employs a dichotomous disability measure, while the latter uses a disability measure with different levels combined into a single value using utility weights specific for each level of disability. One advantage of the HALE method, as applied by WHO, is that it has been designed for use in a variety of countries with very different levels of data availability. However, the method relies on expert opinion for the development of the weights used for each condition.

10 . See Oliveira Martins *et al.* (2005), Table 2.4.

improvements in secondary prevention, *i.e.* medications to reduce blood pressure and cholesterol level. Cutler, Landrum and Stewart (2006) conclude that improved medical care for CHD explains up to 70 % of mortality reduction in the US over the period 1984 to 1999. For England and Wales, 42 % of the decrease in CHD mortality between 1981 and 2000 was found attributable to medical and surgical treatment (Unal *et al.,* 2004). Similar results were found for Scotland and the Netherlands (Capewell *et al*., 1999; Bots and Grobbee, 1996)).

Some results are also available concerning the impact of health care on reduced disability. Cutler, Landrum and Stewart (2006) show that improved medical care explains up to 50 % of the reduction in disability caused by cardiovascular disease in the US over the period 1984 to 1999. The increase in quality-adjusted life expectancy for these patients is around 3.7 years. Intensive procedures such as hip replacement and other surgeries rose particularly for people with muscular-skeletal problems between 1989 and 1999 in the US. Cutler (2003) shows that they led to a large decline in disability associated with those conditions during the same period.

This evidence suggests that investment and spending in health care have had a positive impact on the health status, supporting the "healthy ageing" regime experienced in US, Europe and Japan. But what is the likelihood for such a regime to be maintained in the future? Actually, three scenarios have been considered in the literature, illustrated in diagram 2.1. Scenario I corresponds to the "compression of morbidity" hypothesis, an optimistic theory suggested by Fries (1980). In that case there would be a reduction in morbidity and disability in the last ages of life. Life expectancy would be close to disease-free and disability-free life expectancy. At the other extreme, scenario II, corresponds to a pessimistic "expansion of morbidity" (Gruenberg, 1980), Kramer, 1980), where all gains in longevity translate into years in poor health. An intermediate hypothesis can be considered (Manton, 1982), such as scenario III, where the gains in longevity gains translate one-to-one into years in good health (or “healthy ageing”).

[Diagram 2.1: Three possible scenarios for future changes in morbidity at a given age]

To sum, there is a fair amount of empirical support for the view that health care (and/or expenditures) do matter for health outcomes. But the evidence is far more solid when looking at the effects of specific interventions or treatments, such CVD or depression treatments, when compared to studies that examine aggregate relationships.[11]

Based on the data reviewed here, there is certainly reason for hope that countries can achieve a healthy ageing regime, but this is by no way assured. Michel and Robine (2004) suggest that different patterns may evolve over time within the same country. In this model the aging population is based on a cyclical movement where, first, sicker people survive into old age and disability rises, then the number of years lived with disability decreases as new cohorts of healthier people enter old age but, finally, the number of years lived with disability rises again, when the average age of death rises so much that many people spend their last years at an advanced age burdened by multiple chronic illnesses and frailty. If this is the case then achieving healthy ageing seems possible but is not assured, and if achieved it may not be permanent

Looking ahead, a particular concern about the ability to maintain a healthy ageing regime arises from the extrapolation of recent trends in obesity, a challenge that is afflicting the US above all, yet many European countries are showing very similar, if delayed trends. Several studies in the US have documented a surprising increase in functional limitations among the middle-aged, caused by obesity, with obviously detrimental effects on late life functioning (Lakdawalla, Bhattacharya and Goldman 2001; Freedman, Martin and Schoeni 2004). This research suggests that at least in the US (where the compression of

11. For a survey on this area see Buck, Eastwood and Smith (1999).

morbidity thesis has so far received rather widespread empirical support, *e.g.* Fries, 2005) there is reason to expect a reversal of the hard-fought gains of functional decline. To the best of our knowledge no comparable findings exist for Europe, which is more a reflection of lack of suitable data than of the absence of the problem. But if the US results are any guide for what might happen in Europe, then the findings reinforce the importance of an active lifestyle and low-risk health habits such as avoiding obesity in maintaining functional independence into the advanced years.

2.4 Efficiency in health expenditures

The fact that health expenditures have induced gains in longevity and health does not mean that they are efficient. Efficiency refers to efficiency in care delivery, but also to the fact that the level of expenditures, as well as the process of technology adoption and diffusion should meet collective preferences.

2.4.1 The importance of assessing the value of gains in longevity

The results obtained by the *Future Elderly Model* show that it is not possible to draw relevant conclusions without evaluating the gains in longevity. The *Future Elderly Model* is a micro-simulation model set up by RAND authors to construct simulated health histories for US *Medicare* enrollees (Goldman *et al.*, 2005). Transition probabilities are estimated on a sample of about 100,000 *Medicare* beneficiaries observed between 1992 and 1999. With this framework, individual yearly probabilities of dying, health conditions or disability state can be estimated. In turn, these probabilities can be changed to simulate the impact of health improvements from new technologies. Ten selected technologies were selected and their impact on *Medicare* costs by 2030 is projected.

Table 2.2 summarises the results for three of these technologies: an intra-ventricular cardiovascular defibrillator, prevention of Alzheimer's disease and a (hypothetical) chemical Compound that extends life span. The three are cost-efficient in the sense that the cost of one year saved is lower or equals $ 100,000 (low bound for the one year of life, see next paragraph). Prevention of Alzheimer’s and the compound that extends life span have about the same annual cost, but the compound is much more efficient in terms of health outcomes. Accordingly, the compound is much more costly in the long run: +13.8 % (and 70.4 % in the case of morbidity expansion) instead of + 8 % for the Prevention of Alzheimer’s disease. Based on these results, Lubitz (2005) draws rather pessimistic conclusions on technological progress in health care: all technological advances add costs that overwhelm any savings from improved health; and, the impact of a new treatment on long term costs is directly connected to its efficiency in terms of number of years of saved life. These conclusions bring to light that there is a strong need to evaluate the welfare induced by a better health status.

[Table 2.2 Micro simulation results for three technologies by the Future Elderly Model]

2.4.2 The value of a statistical life

39 One way to assess the value of health is to measure the extent to which one is willing to trade off health for specific market activities for which a price exists. This is the principle of, so-called, willingness-to-pay studies. Namely, the “value of a statistical life” (hereafter, VSL), can be inferred from risk premiums in the job market: jobs that entail health risks, such as mining, pay more in the form of a risk premium. VSL can also be estimated by analysing market prices for products that reduce the likelihood of fatal injury. The VSL literature leads to estimates ranging from about two million dollars to nine million dollars (Viscusi and Aldy, 2003, Ashenfelter and Greenstone, 2004, Murphy and Topel, 2005). Reviewing the literature, Cutler (2004) considers that a low-bound of $ 100,000 per year of life saved could be adopted.

2.4.3 Using the value of a statistical life to evaluate the return on new technologies in health care

40 Assuming a VSL of $100,000 per year, Cutler and McClellan (2001) examine whether new treatments are worth additional costs. For heart attack, the gain in life expectancy is about one year, which corresponds, once the cost of living is deduced, to a present value of the benefit from technological change of about $70,000, while the increase in the cost of treatment is around $10,000 per year. They conclude that the return of technological change in heart attack treatments is high 1:7. For depression, the time spent in an ill-condition is reduced by height weeks with new treatments. This amounts to a benefit of about $6,000, around 6 times greater than the cost of treatment ($1,000). For cataract the result is even more impressive: the present value of benefit is equal to $95,000, to compare with a cost for the operation equal to about $3,000. These assessments are rather conservative, because they do not take into account the social gains arising from the fact that somebody who is cured is able to work and produce more. This remark may be less relevant for heart attack and cataract, which occur at very old ages. It is more relevant for depression, which increases the probability of early retirement (Conti *et al.* 2006).

Cutler *et al*. (2006) find that and increased spending on health care at birth resulted in an average cost of $19,900 per year of life gained (for the period 1960-2000). Assuming that 50% of improvements in longevity resulted from medical care (Bunker 2001, 1995; Bunker, Frazier and Mosteller 1994), Cutler *et al*. conclude that health care led to gains in welfare. A comparable study is proposed by Luce *et al* (2006). Using life-year values of $99,000 to 173,000, and conservatively considering only the health care-related improvements in survival over the past two decades, they find that one dollar health care spending in the US could generate from $1.55 to $1.94 in overall health gains.

Murphy and Topel (2006) provided undoubtedly the most striking result in this respect. Using individuals' willingness to pay, they found gains in life expectancy from 1970 to 2000 to have added to US wealth a gain of around 50 % of the annual GDP! Rising medical expenditures (reaching around 14% of GDP in 2000) would have absorbed only 36 % of the value of increased longevity. The authors distinguish between length and quality of life: life extension is valued because utility from goods and leisure is enjoyed longer, and improvement in the health status raises utility from given amounts of good and leisure. They show that the social value of improvements in health is an increasing function of the size of the population, the lifetime income, the existing level of health and of the proximity of the ages of the population to the age of most disease onset. These factors make it possible to predict that the valuation of health improvements will continue to rise in the future, as the population and incomes grow, especially because the baby-boom generation approaches the age of disease-related death. Finally, they show that improvements in life expectancy raise willingness to pay for further improvements in health by increasing the value of remaining life.

2.4.4 Efficiency in health care use and adoption of innovation

Bech *et al.* (2006, have provided empirical evidence that the organization of health insurance systems has an influence on the pace of adoption of technological innovations (see section 2.3.2). Obviously, design of health insurance, as well as payment systems, influence the efficiency in health care use. The lack of efficiency may correspond to underuse or overuse of health care and technology, in the sense that the level of consumption is below or above the level that would match preferences.[12] Prospective payment systems, such as global budget for hospitals, may hinder the use of costly innovations, while fee-for-services payments encourage more numerous and invasive procedures (there are examples relative to C-section for deliveries, other examples can be found in McKinsey, 1996). Even in the context of a prospective payment per DRG, McClellan (1997) has shown that the definition of the DRG can be closely linked to the implementation of a procedure, and thus create incentives for excessive use of procedures.

[12] Individual or collective preferences are at stake, depending on whether the basic insurance is public or private.

This is the case for angioplasty in the treatment of heart attack (Delattre *et al.* ,2002). Comparing the cost-effectiveness of revascularization (such as angioplasty) with more simple medical management in the population with a myocardial infarction, Rosen *et al.* (2007) show that the cost of revascularization is $55,100 per life-year gained, which much higher than the cost per life-year gained thanks to medical management, i.e. $ 15,900. These results suggest that revascularization is overprovided: there is room for improvement in efficiency.

To sum-up, we have learned key insights about the links between expenditures, health status and welfare:

- Technological progress, instead of ageing, is the main driver of health expenditure growth.
- Two mechanisms are involved in technological progress in health care, substitution and extension, where more goods are available and consumed. The growth in health expenditures is mostly explained by the extension effect.
- The diffusion of technologies has led to additional costs but also generated value in terms of longevity and better health, so that it contributes to welfare. Indeed, evaluating the gains in welfare induced by more longevity and health could lead to big numbers.

3. Is health care a luxury good?

Since Newhouse (1977) an extensive empirical literature has sought to assess whether health care is a luxury (income elasticity above one) or a necessity (elasticity below one). This is still an unsettled issue, which is unfortunate since many projection models rely on an assumption regarding this elasticity. An income elasticity greater than one implies that consumers' preferences drive health expenditure above income growth and could explain the increase in the share of health care in GDP. Getzen (2000) argues that empirical studies often failed to distinguish between sources of variation between groups and within groups: an individual within an insured group may have little reason or incentive to limit health expenditures, especially if the group is large and the individual's effect on the group is relatively insignificant, thus that individual's health care spending is insensitive to income. In contrast, the group's total expenditure on health care is limited by aggregate income. Therefore, total group spending will be more responsive to income than individual spending, and wider groups (countries) will be even more responsive. This stylised fact points out the importance of heterogeneity across groups of agents.

In general, the higher the level of aggregation, the higher the estimated income elasticity of health care spending. Studies at the individual level show that the majority of the variation in spending (50% to 90%) is associated with individual differences in health status, while income elasticities are small or even negative (Newhouse and Phelps, 1976; Manning et al., 1987; Sunshine and Dicker, 1987; Wagstaff et al., 1991; AHCPR, 1997). However, analysis of pre-1960 data where insurance is less prevalent and most payments are made out-of-pocket show much larger income elasticity (0.2 to 0.7). Similarly, consumption of dentistry, plastic surgery, counselling, eyeglasses and other types of care show income elasticities that are strongly positive and sometime substantially exceed one (Parker and Wong, 1997). In contrast, at the macro level, studies of national health expenditures consistently show income elasticities greater than one — or health care is a luxury good — with above 90% of cross-sectional and time-series variation explicable by difference in per capita income, and differences in health status having negligible effects (Abel-Smith, 1967; Kleiman, 1974; Newhouse, 1977; Maxwell, 1981; Leu, 1986; Culyer, 1988; Getzen, 1990; Gerdtham et al., 1992).

3.1 An econometric investigation

Against this background, we provide new evidence on the elasticity of demand for health by using different panel estimators and various explanatory variables. In particular, we propose new evidence on the elasticity of per capita public, private and total health care services. The model is essentially a reduced-form equation, with the choice of right-hand side variables influenced by the numerous contributions on the possible determinants of health care spending.[13] Newhouse (1972), for instance, assumed that per capita GDP is the main determinant of per capita health care expenditures:

$$HCE_{i,t} = \alpha_i + \beta GDP_{i,t} + u_{i,t} \quad (10)$$

Where $HCE_{i,t}$ stands for per capita health care expenditures, $GDP_{i,t}$ is per capita GDP, $u_{i,t}$ is an error term, $t = 1,\cdots,T$ (number of years) and $i = 1,\cdots,N$ (number of countries). However, other right hand side variables may be considered, as a trend to capture technology advances or health price discussed in the previous section. In this context, the risk for omitted variable bias can be high. Recent studies (Hall and Jones, 2007; Okunade and Murthy, 2002; Blomqvist and Carter, 1997) have stressed that the observed increasing health care expenditure as a share of GDP is likely due to other factors, such as insurance coverage, etc. Di Matteo and Di Matteo (1988) also argue that because health is labour intensive, its cost may increase as a function of average income, so that measured income elasticity is blurred by the price effect. Since the price elasticity is presumably negative, the income coefficient is likely to be biased downward. This conflicting evidence suggests testing the robustness of standard estimates using various explanatory variables. It could be also noted that a reduced-form model is also exposed to the well-known endogeneity bias.

Concerning econometric methods, different approaches have been used in the literature: (i) cross-section analysis, (ii) time series analysis and (iii) panel analysis. Two key issues are the degree of heterogeneity and the finite sample bias of standard time series estimates (especially as T is small). As panel data techniques are a standard method to deal with heterogeneity issues, this option was followed here.

We conducted a simple econometric test to illustrate how the estimates of the health spending income elasticity can be sensitive to different specifications. We consider three samples. The first sample (group 1) corresponds to an unbalanced panel of the 30 OECD countries for the period 1970-2002, where not all years are available for all countries. The second sample (group 2) corresponds to a nearly balanced panel of 19 OECD countries.[14] The last sample (group 3) comprises 17 OECD countries over the same time period.[15] For this latter group, it was also possible to gather some institutional variables characterising health systems. The data are derived from the OECD Health Data Base (2005a).

We also conducted separate regressions for per capita public, private, and total health care expenditures. For each independent variable, we consider a subset of the following explanatory variables:

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13. To explain the results of the macro elasticity of demand for (per capita) health care services with respect to (per capita) income, a first strand of explanations focuses on data. In this respect, one can quote the comparability of OECD data on health care expenditures, the definition of (per capita) GDP, the sampling period, and the transformation of variables (log-transformation, PPP-adjusted measure). See Hansen and King, 1996; Blomquist and Carter, 1997; Gerdtham et al. (1992).

14. Group 2 includes Australia, Austria, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, the United Kingdom, and the USA.

15. Group 3 excludes Luxembourg and the Netherlands from Group 2.

per capita GDP; a trend over the period 1970-2002 (common across OECD countries), as a loose proxy for role of long-term technological change; POPY, the share of young (0-14), POPP, middle-age (15-54) and, POPO old-age people (55-74) over the total population; the share of very old people (75+) serving as the reference group; and three dummies variables, which control respectively for the existence of gate-keeping and for the type of health care system (public or integrated).

In our investigation, four different specifications are tested. First, the pooled regression model (health and GDP variables are now in logs):

$$HCE_{i,t} = \alpha + \beta GDP_{i,t} + \gamma X_{i,t} + u_{i,t} \tag{11}$$

where $X_{i,t}$ is a set of regressors.

The one-way fixed effects model (in the individual dimension), where α_i denotes the i^{th} individual effect:

$$HCE_{i,t} = \alpha_i + \beta GDP_{i,t} + \gamma X_{i,t} + u_{i,t} \tag{12}$$

The two-way fixed effects models, where λ_t denotes the t^{th} temporal effect:

$$HCE_{i,t} = \alpha_i + \lambda_t + \beta GDP_{i,t} + \gamma X_{i,t} + u_{i,t} \tag{13}$$

Finally, the one-way error component model (in the individual dimension) where $\alpha_i \sim N(o, \sigma_\alpha^2)$:

$$HCE_{i,t} = \alpha + \beta GDP_{i,t} + \gamma X_{i,t} + v_{i,t}$$
$$v_{i,t} = \alpha_i + u_{i,t} \tag{14}$$

Table 3.1 to 3.3 report the results of the pooled OLS regressions. *P*-values are in brackets and standard errors have been determined using the White's correction or the Arellano's correction. Several points are worth commenting. Overall, results are robust across groups and across time period.[16] First, the income elasticity depends on the nature of health care spending. Income elasticity is in general below or close to one in the case of per capita private health expenditures whereas it exceeds one when considering per capita public or total health expenditures. Second, the inclusion of a common trend or time dummies over sub-periods leads to a decrease of the income elasticity, though it remains largely above one. Third, the population variables are often statistically significant at conventional levels, but their sign depend on the specification. They tend to be positive for public and total expenditures, while negative for private expenditures. This result could be due to the fact that public systems provide universal coverage to the elderly are thus are more affected by demographic factors.

[Table 3.1-3.3 Pooled OLS Regressions –Per capita health expenditures, public, private and total]

These results confirms earlier results, at least for per capita total health expenditures, in the sense that cross-sectional model estimates of the GDP elasticity of HCE are typically above unity (Gerdtham and

16. We also estimate the cross-section regressions over the period 1980-2002. Estimates are quite close to the pooled estimates. Results are not reported here but are available upon request.

Jonsson, 2000).[17] Nevertheless, cross-sectional models are fragile in small data sets and use an implicit assumption of homogeneity across countries. This leads to unrealistic assumptions such that the homogeneity of tastes, preferences and production functions across countries as well as the homogeneity of health systems, which could severely bias the estimates (Pesaran, Smith and Im, 1996).

In contrast, panel estimates offer a number of advantages over cross-sectional or time-series studies (see Baltagi, 2005). In particular, having multiple years of data for each country enables to include (time) country-specific fixed (or random) effects, thereby controlling for a wide range of time-invariant country characteristics, which may bias the estimate of income elasticity in cross-section (or time-series analysis). Table 3.4 to 3.6 reports estimates of the one-way fixed effects model in the individual dimension. Since the dummy variables (gate-keeping, public system and integrated system) are not time-varying, they cannot be estimated.[18]

[Table 3.4-3.6 One-way fixed-effect regressions –Per capita health expenditures, public, private and total]

Interestingly, the inclusion of a common time trend significantly reduces the income elasticity below one. If this common trend can be interpreted as technology advances, then it confirms the fact that neglecting the role of technology change tends to bias upward long-term income elasticity (Dreger and Reimers, 2005). At the same time, we assume here that cross-section effects are independent. This assumption may lead to spuriously interpret this common trend as technology progress in the sense that other factors may explain this term when accounting for cross-sectional dependence. For instance, this trend may also reflect the effect of relative prices. A second result is that the income elasticity further decreases when introducing the population variables. These variables have the expected sign in the case of per capita public and total health care expenditures. All in all, the third regression ([3]) displays the highest R^2 and the unexplained residual is negligible. When testing the pooled model against the one-way fixed effects model, the test statistic strongly supports the latter. Finally, the introduction of time dummies yields higher income elasticity and unexpected signs on population variables. Note also that they are often statistically insignificant.

To further assess the role of the time dimension, we ran two-way fixed effects regressions (Table 3.7). Except for few estimates of the per capita private health care expenditures regressions, we consistently find the income elasticity to be below one. Specification ([3]) is preferred by standard specification tests. However, there is no clear cut evidence between the one-way and two-way fixed effects models.[19]

[Table 3.7 Two-way fixed-effect regressions - Per capita health expenditures, public, private and total]

Finally, we also tested the one-way error component model in the individual variables for each type of per capita health care expenditure (Tables 3.8 to 3.10). The variance-covariance parameters are estimated using the Swamy-Arora method.[20] Results are fairly close to those of the one-way fixed effects model.[21]

17. A non-exhaustive list includes Cullis and West (1979), Leu (1986), Parkin et al. (1987), Culyer (1990), Gerdtham and Jonsson (1991a, b), Hitiris and Posnett (1992).

18. Using the method suggested by Canova (2007), we also regressed the individual effects on these variables. Results are generally not statistically significant.

19. Results are not reported here but are available upon request.

20. Results are robust to other methods.

21. The Hausman and Augmented-Hausman tests tend to favour the latter specification. Note that the use of one-way or two-way error component model could be questionable since OECD countries represent a closed population, i.e. the sample population is the same as the total population.

Overall, results confirms that the inclusion of a common trend significantly lower the income elasticity (below one).[22]

[Table 3.8-3.10 One-way error component model - Per capita health expenditures, public, private and total]

Some caveats are in order. First, we assume that variables are not integrated nor it exists a co-integration relationship. Second, we assume that there is cross-sectional independence. Third, income elasticity is obtained from a reduced-form equation in which potential important determinants are not taken into consideration due to missing or unreliable data. Moreover, we disregard the endogeneity problem of per capita GDP by choosing not to instrument the previous regressions (although the determination of non redundant and reliable instruments is a difficult task in the present setting). Fourth, we suppose that heterogeneity is modelled through individual or time effects, and random effects. Finally, the specifications retained here are static. Omitting dynamics may substantially bias our results. Additional tests for the existence of a co-integration relationship, cross-sectional dependence and convergence were also carried out, but to save space are not reported here.[23] They do not change qualitatively the results concerning the value of the income elasticity.

To summarise, our econometric estimates tend to favour the assumption of an income elasticity equal to or below one. This contradicts somewhat the critical assumption used by Hall and Jones (2007), as well as other studies, to derive their expenditure projections. Nonetheless, unitary income elasticity is not a low value in absolute terms. It implies that, *ceteris paribus*, health expenditures will grow in line with GDP per capita. In consequence, public health care budgets should not rely on economic growth to smooth or reduce expenditure pressures related to the health sector.

4. Long-term projections of aggregate health spending

How much resources could be devoted to health care spending and investment over the next decades? In trying to address this question, the different drivers of expenditure need to be disentangled. We have seen above that they can be broadly classified into *demographic* and *non-demographic* factors.

4.1 Demographic drivers of expenditure

Assessing demographic drivers requires the breakdown of health expenditures by age groups. These data are relatively scarce. For public expenditures, an average profile by age is available for the year 1999 (Figure 4.1).[24] As discussed above, the shape of these expenditure curves reflects the interaction between health care costs at the proximity to death and mortality rates. While mortality rates increase with age, the costs of health care near death (or 'costs of death') tend to be higher at young and prime age than for elderly people (Aprile, 2004). This explains why expenditures first increase with age, then peak and after decline at very old ages. The little spike in health expenditures at the beginning of the curve is just related to early infant mortality being higher than young and prime-age mortality.

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22. We also ran a one-way error component model in the time dimension as well as a two-way error component model, previous results are quite robust. Results are not reported here but are available upon request.

23. These results are available upon request. As a robustness check, we assume that the slope coefficients can be different across groups of countries. Empirical evidence stills tends to support the assumption of an income elasticity equal to or below 1.

24. For European countries, the data is based on the EU-AGIR Project; see Westerhout and Pellikaan (2005).

[Figure 4.1 Public health care expenditure by age groups]

For European countries, public expenditure profiles can capture well the profile of total expenditures. For the United States, where private expenditures play an important role, the available breakdown of public and private expenditures shows that the sharp increase in health expenditures at older ages is also only observed for public expenditures (Figure 4.2). Private expenditures tend to peak in the age group of 50-60 years old, but then decline afterwards.

[Figure 4.2 Public and private health care expenditure by age groups, US]

On the basis of these expenditure profiles and population estimates, the expenditures on those aged over 65 is around four times higher than on those under 65. The ratio rises to between six to nine times higher for the older groups (Productivity Commission, 2005a-b; OECD Health Database, 2005). As discussed in section 2, this fact is not a reason for expecting demographic pressures to be a major driver of the growth in health expenditures.[25] Indeed, one should take into consideration a dynamic and positive link between health status and longevity gains, reflecting a "healthy ageing" process. This is likely to lower the average cost per individual in older age groups, all the more so as major health costs tend to come at the end of life.

For the purpose of projecting health expenditures we need then to disentangle the expenditures survivors and non-survivors. The expenditures for the *non-survivors* can be estimated by multiplying the health costs near to death by the number of deaths per age group. Here the proxy for the 'costs of death' is the health expenditure per capita for the group 95+, assuming that after this age all health costs are death-related. This amount was then multiplied by a factor, equal to 4 for an individual between 0 to 59 years old[26] and declining linearly to 1 afterwards, to reflect the decline of the 'costs of death' with age.

The expenditure curve for *survivors* is simply derived by subtracting the death-related costs just described from the total expenditure curves, when available (18 OECD countries). Given the uncertainties surrounding these data, it seemed preferable to estimate an average expenditure curve for survivors and then calibrate this curve for each country. In this way, the projections are less sensitive to initial conditions and to country-specific data idiosyncrasies. This average expenditure curve for *survivors* was estimated econometrically in a panel of 18 OECD countries by 20 age groups, using a spline function and country fixed-effects, as follows:

$$\left.\frac{\text{Health Exp.}}{\text{Population}}\right|_{age\ group} = -137.8 \cdot age + 9.94 \cdot age^2 - 0.29 \cdot age^3 + 0.004 \cdot age^4 - 0.00002 \cdot age^5 + 1222.6$$

where *age* is the central point in each age bracket (*e.g.*, 2, 7, 12,…, 97). All the estimated coefficients are significant.

Under the hypothesis that health costs are mostly death-related, the projected increase in life expectancy must be accompanied by an equivalent gain in the numbers of years spent in good health.

25. The effect of ageing on health expenditures per capita has also been weak in the past, see Culyer (1990), Gerdtham *et al.,* (1992), Hitiris and Posnett (1992), Zweifel *et al.* (1999), Richardson and Roberston (1999), Moise and Jacobzone (2003) and Jönsson and Eckerlund (2003).

26. This proportion is based on Aprile (2006) and some evidence gathered by the EC-Ageing Working group (EC-EPC, 2005). The results are not very sensitive to the alternative assumptions, because mortality rates are rather low for young and prime-age people.

Otherwise, an increasing share of the population living in “bad health” would emerge and health care costs would then cease to be mainly driven by the costs of death, as initially assumed (*q.e.d.*).

In such a scenario, the expenditure curve for *survivors* is allowed to shift rightwards in line with longevity gains, progressively postponing the age-related increases in expenditure.[27] This development tends to reduce costs compared with a situation in which life expectancy would not increase. The baseline projections presented in this paper follow this "healthy ageing" scenario, but the sensitivity of the results to alternative assumptions is also tested below.

As regards *non-survivors*, two different effects are at play. On the one hand, the number of deaths is set to rise due to the *transitory* effect of the post-war baby-boom. On the other hand, if mortality falls over time, due to a *permanent* increase in longevity, fewer will be at the very end of life in each given year, mitigating health care costs.[28] The total effect on public health care expenditures will depend on the relative size of these effects.

4.2 Non-demographic drivers of expenditure

As discussed in the previous section, a reasonable approach seems to assume an income elasticity equal to one and, subsequently, to test the sensitivity of the projections to this assumption. Assuming unitary income elasticity, Oliveira Martins and de la Maisonneuve (2006) estimated the average residual growth for OECD countries at around 1 % per year for the 1990s. The central expenditure projections assume this average residual growth. There are at least two reasons for common assumption in the context of long-run projections. First, in countries where cost-containment policies have resulted in a low or negative residual (*e.g.,* Austria, Denmark, Ireland, Italy, Sweden) there could be a trend reversal, e.g. because new personnel has to be attracted or run-down facilities renewed. Second, in countries where the residual growth was very high (*e.g.,* Portugal, United States) it may seem likely that cost-containment policies will be implemented in the future. These effects would lead to a certain cross-country convergence of the expenditure residual over time.

4.3 A projection model for health care expenditures

Defining *HE*, *Y* and *N* as real health care expenditures, real income and population, respectively; and, ε the income elasticity of health expenditures and *NDF* the other non-demographic factors, the growth of health expenditures can be decomposed as follows:

$$\Delta\log\left(\frac{HE}{N}\right) = \Delta\log(\mathit{Adjusted\ age\,factor}) + \varepsilon\cdot\Delta\log\left(\frac{Y}{N}\right) + \Delta\log(NDF) \qquad (15)$$

or expressed in share of expenditure to GDP:

$$\Delta\log\left(\frac{HE}{Y}\right) = \Delta\log(\mathit{Adjusted\ age\,factor}) + (\varepsilon-1)\cdot\Delta\log\left(\frac{Y}{N}\right) + \Delta\log(NDF) \qquad (16)$$

27. In contrast, in “pure demographic” projections (see Dang *et al.,* 2001), the expenditure curves would not shift rightwards with longevity, reflecting the implicit assumption of unchanged health status at any given age. When the cost curves stay put in presence of longevity gains, the share of life lived in ‘bad health’ increases when life expectancy increases. This corresponds to the “expansion of morbidity” scenario referred to in section 2.

28. See for example Fuchs (1984), Zweifel *et al.* (1999), Jacobzone (2003) and Gray (2004).

Intuitively, the mechanical effect of population ageing on expenditures can be seen as moving up along the expenditure curve, assuming that the age profile of expenditures remains constant over time. This demographic effect is adjusted for the 'healthy ageing' by shifting the expenditure curve rightwards, implying that older people still cost more than the young, but at progressively older ages. Finally, the cost curve shifts upwards due to non-demographic drivers (income and other non-demographic effects).

In order to make the projections less sensitive to the starting year and allow for some convergence of expenditures to GDP across countries,[29] the total logarithmic growth rates derived from equation (16) for each country are applied to the OECD cross-country average expenditure share to GDP in 2005 (a sort of "representative" country). The changes in expenditure shares calculated from this common base are then added to the country-specific shares in 2005 to obtain the projected ratios of expenditure to GDP (see Annex II).

Additional exogenous assumptions underlying the projections are listed in Box 3 (more details are also provided in Annex II).

Box 3. Exogenous variables and assumptions underlying the projections

The projections require a set of exogenous data, as follows:

(1) Population projections (*N*). The population projections were gathered by the OECD Directorate on Employment, Labour and Social Affairs, directly from national sources.

(2) Labour force projections (*L/N*) rely on Burniaux *et al.*(2003). These projections are constructed in the basis of a, so-called, cohort approach. They correspond to a baseline scenario, i.e. the impact of current policies is assumed to influence labour participation over the next decades, but no additional assumptions are made concerning future policy changes.

(3) Labour productivity (*Y/L*) growth is assumed to converge linearly from the initial rate (1995-2003) to 1.75% per year by 2030 in all countries, except former transition countries and Mexico where it converges only by 2050.

The projected GDP per capita is directly derived from the above exogenous variables (*Y/N = Y/L x L/N*). This simple framework is not supposed to capture in the best way productivity differentials across countries, but to isolate, as far as possible, the effect of ageing and other demographic factors on the projections. Further details can be found in Oliveira Martins and de la Maisonneuve (2006).

29. Without this specification, spending patterns of countries with equivalent expenditure drivers would diverge in terms of share of expenditure to GDP merely due to different initial expenditure to GDP ratios. Such a divergent scenario is not very appealing in the context of long-term projections. This issue has been explored in a few empirical papers. Hitiris (1997) examines total health expenditures convergence for a group of 10 European countries and finds no evidence of convergence. Narayan (2007) examines the catch-up hypothesis, especially whether or not per capita total health expenditures of the Canada, Japan, Switzerland, Spain, and the United Kingdom converge to those of the US over the period 1960-2000. He uses univariate and panel LM unit roort tests that allow potentially for structural breaks and provides evidence of relative convergence when incorporating one or two structural breaks (see also Barros, 1998; Okunade and Karakus, 2001). However, the unit root approach of convergence has been criticized on the ground that non-stationary processes can meet the definition of convergence (Nahar and Inder, 2002; Bentzen, 2005). We also investigated the convergence hypothesis for per capita public, private, and total health care expenditures using the recent approaches developed by Nahar and Inder (2002) and Phillips and Sul (2007). The results, available upon request, support the hypothesis of convergence of GDP and total health expenditures per capita. Health expenditures as a share of GDP also converge across countries.

4.4 Expenditure projections for the US, EU-15 and Japan

The framework described above was used to project expenditures over the period 2005-2050. The demographic effects can be decomposed into the health care spending for survivors, the adjustment for "healthy ageing" and the death-related costs (panel A Figure 4.3). Pure demographic effects can be quite large for some countries, but they tend to be compensated by a better health status, as longevity increases. The death-related costs account only for a small fraction of the increase in expenditures as a share of GDP (to around 7% of total health care spending in the OECD by 2050).[30] The net effect of demographics on health care expenditures ranges from virtually zero in Sweden to nearly 1.5 percentage points of GDP for Slovakia. This can be mapped to differences in evolving old-age dependency ratios (Panel B of Figure 4.3). Admittedly, the "healthy ageing" assumption, albeit in line with observed patterns of morbidity regimes in the US and European countries, can be viewed as relatively optimistic.

[Figure 4.3 Demographic effects on public health care expenditure]

We carried out several simulations. In the scenario I it is assumed that, on top of the demographic effects, the expenditure residual grows at 1% per year over the projection period and the income elasticity is equal to 1. In such a scenario, the US expenditure share would reach 19% of GDP by 2050, or around a 5 percentage points increase compared with 2005. A similar increase is obtained for EU-15 and 6 percentage points for Japan (Table 4.1). In nearly all countries, health care expenditures would then exceed 10% of GDP by the end of the projection period.

[Table 4.1 Projection for Total health care expenditures, scenario I]

In scenario II, we kept the same assumptions of scenario I but the income elasticity was set to 1.5, as some studies have projected expenditures assuming income elasticities well above one. Average expenditures will more than double with a projected increase of above 9 percentage points of GDP (Table 4.2). The income effect accounts for around 4 percentage points of GDP in the US and EU-15. The expenditure share would reach 23% in the US, and around 16% of GDP and Europe and Japan by 2050.

[Table 4.2 Projection for Total health care expenditures, scenario II]

In scenario III, we kept the same assumptions as in same scenario I but the residual was set to 2% growth per year. This scenario is rather mechanical, as the sustained growth of the expenditure residual just compounds over time without limit. It illustrates, however, the type of assumptions that are required to generate the very high shares of health care to GDP put forward in some studies (such as Hall and Jones, 2007). On average, expenditures will more than double with a projected increase of above 12 percentage points of GDP (Table 4.3). The US expenditure share would reach 26% of GDP by 2050, and around 20% both in the EU-15 and Japan.

[Table 4.3 Projection for Total health care expenditures, scenario III]

Finally, in a voluntarily "cost-containment" scenario, the residual expenditure growth is assumed to grow at 1% per year, but converging to zero by 2050. This hypothesis could be justified on the grounds that health care expenditures to GDP could not continue to grow at such constant rate, without limit.[31] But this 'transversality condition' may appear controversial in view of past experience. Under perfect health market conditions, a continuing increase in the share of income going to health care spending could reflect

30 . See Oliveira Martins and de la Maisonneuve (2006).

31. Similar transversality conditions have also been imposed in other projection exercises. For example, Englert (2004) assumes that income elasticity ultimately converges to one.

individual preferences, as discussed in section 2. But the health care market is not perfect and governments are footing most of the bill. Thus, rapid growth of the share of health care spending in income would have to be compensated by reductions in other public spending items, which may be difficult to achieve, and/or increased health care charges for individuals. Such cost sharing has already been introduced in most countries. This implicitly means that policies could progressively rein in the expenditure residual, *e.g.* by ensuring that future technology improvements are mainly used in a cost-saving way. This may imply some trade-offs. Reining in the impact of technological progress on health care demand without foregoing the benefits it provides to patients could be a challenging task.

The income elasticity was kept at 1, which would imply that public health care expenditure and income would evolve in parallel over the long-run. In order to be coherent with a lower residual growth over the projection period, it was assumed that lower technology improvements lead to an "expansion of morbidity", implying that expenditure curves do not shift rightwards over time in line with longevity gains.

Under this scenario, public health care expenditures would still increase on average by nearly 4 percentage points between 2005 and 2050, from 7.8% to above 11% of GDP (cf. Table 4.4). Moreover, larger increases by 2050 are found in countries in Central and Eastern European countries, which are experiencing a rapid demographic change. In the US, the share of expenditure to GDP would be contained at around 18%.

Table 4.4 Projection for Total health care expenditures, scenario IV]

This projection illustrates how uncertainties concerning the parameters may drive different expenditure scenarios. Nonetheless, even in the mildest projections, the expected increase in the resources directed to health care are substantial.

4.5 Can the optimal share of health care spending in GDP be estimated?

At this point the question is what could be the optimal level of health expenditures? Hall and Jones (2007) proposed a model where the key parameter is the curvature of the marginal utility of consumption (γ). If γ is high, the marginal utility of consumption of non-health goods declines quickly and the optimal share health spending rises rapidly, this growth reflecting a value of life that grows faster than income (a simple static version of this model is spelled out in Box 4).

Box 4. The model of Hall and Jones (2007)

Denote by x the individual's health status, which is assumed to be equal to its life expectancy. The mortality rate of the individual is thus equal to $1/x$. y is the individual's income; c consumption, which is supposed to be stationary over the life cycle and h health expenditures. Expected lifetime utility for the representative individual is then defined by:

$$U(c,x)=\int_0^\infty e^{-(1/x)t}u(c)dt = x\,u(c) \qquad (1)$$

The income can be spent either on consumption or health:

$$c+h=y \qquad (2)$$

A health production function defines the value of health for a given level of expenditures h:

$$x=f(h) \qquad (3)$$

The optimal allocation of resources maximizes the expected lifetime utility (1) subject to the budget constraint (2) and the health production function (3). The problem of the individual becomes:

$$\underset{c,h}{Max}\, f(h)\, u(c) \qquad \text{s.t.} \qquad c + h = y$$

The first-order conditions for this problem imply that the marginal benefit of saving a life equals the marginal cost of saving a life. Let $L(c,x) = U(c,x) / u'(x)$ denote the value of life in units of output. The optimal allocation of resources verifies:

$$L(c,x) = \frac{x^2}{f'(h)} \qquad (4)$$

The share of income devoted to health expenditures is denoted by $s = h/y$. The elasticity of the health production function with respect to health expenditures is denoted by η_h and the elasticity of the utility function with respect to consumption by η_c. From condition (4), one can derive that the optimal share of income devoted to health care (i.e. the share that maximises social welfare) verifies condition (5):

$$s = \eta_h = \frac{L(c,x)/x}{y} \qquad (5)$$

The production elasticity is likely to fall as spending rises. Therefore, from condition (5) it can be seen that the optimal share of income devoted to health care s increases if the value of one year of life $L(c,x)/x$ rises faster than income. This condition can also be expressed as follows :

$$\frac{s}{1-s} = \frac{\eta_h}{\eta_c} \qquad (6)$$

This shows that a rising share of income devoted to health care is optimal if η_c is decreasing more rapidly than η_h. The thrust of the argument behind this result is that satiation occurs more rapidly with non-health rather than with health consumption.

Does the rising share of health expenditures observed in all developed countries fit collective preferences? In other words, are preferences likely to meet condition (6)? Let us assume a standard utility function:

$$u(c) = b + \frac{c^{1-\gamma}}{1-\gamma} \qquad (7)$$

Empirical literature suggests that $\gamma = 2$, or at least that $\gamma > 1$. These values imply that the marginal utility of consumption declines quickly, which is a condition for the value of life to grow rapidly. From (7), one can derive the expression of the value of one year of life:

$$\frac{L(c,x)}{x} = b\, c^{\gamma} - \frac{c}{\gamma - 1} \qquad (8)$$

With $\gamma > 1$, the value of one year of life will grow faster than consumption and income. This implies that the optimal health share s should rise over time.

To see how technology interacts with preferences, Hall and Jones (2007) consider a health production function, *f(h)* (equation (3), Box 4), of the following form:

$$x = (zh)^{\theta} \qquad (9)$$

Where the technological progress is denoted by *z*. Hall and Jones (2007) set up a full dynamic model that allows for age-specific mortality, age-specific elasticities of the health production function (θ_a, for a given age a), as well as growth in total resources and productivity growth in the health sector. The health production function identifies three different causes in the decline in age-specific mortality: technological progress in health care, resource allocation (*i.e.* the share of income devoted to health spending), and others causes (pollution, education, trends in risky behaviors such as smoking, etc.). Depending on assumptions relative to the pace of technological progress, Hall and Jones find that technological progress and increased health spending account each for around 1/3 of the decline in age specific mortality.

The marginal cost of saving a life can be derived from the health production function (Table 4.5). Hall and Jones obtain a baseline value of about \$1.9 million for an individual aged 40-44. The literature leads to estimates of VSL which range from about two million dollars to nine million dollars (Viscusi and Aldy, 2003). If VSL is equal to the bottom of the range provided by the literature, i.e. \$2 million, health expenditure is at the efficient level for this age group. With higher VSL health spending would still be too low.

[Table 4.5 Estimated marginal cost of saving a life]

The optimal share of health spending depends on various assumptions regarding preferences and the value of life. Hall and Jones (2007) use a benchmark of $\gamma = 2$, but simulations are also performed for $\gamma = 2.5$, 1.5 and 1.01. Income per person is assumed to grow at an average (historical) rate of 2.3% per year. The simulations suggest that a rising share of the spending devoted to health care is a robust feature of the optimum, as long as γ is not too small, which is equivalent to say that health is a superior good (Figure 4.4). Only at the extreme case where $\gamma = 1.01$, the marginal utility of consumption falls more slowly than the diminishing returns in the production of health, implying that the optimal health share declines over time (cf. equation (6) Box 4).

[Figure 4.4: The increase in the optimal share of spending devoted to health care]

To complete the picture, Figure 4.5 shows how the optimal share of health spending depends on assumptions regarding the value of life and the pace of technological progress. The assumption relative to VSL influences positively the optimal level of health share. Conversely, the higher the productivity gains in the health production function the lower the optimal level of the health share in GDP. Overall, the optimal health spending is invariably high from 23% percent in the case where γ=1.01 to 45%. These results suggest that historical and future increases in the health spending share may be desirable from a welfare-enhancing point of view.

[Figure 4.5: The optimal share of spending devoted to health care]

Nevertheless, the crux of the Hall and Jones' argument for a rising share of the health consumption in GDP is the fact that the marginal utility of consumption of non-health goods falls relative to that of health as income rises. In other words, as satiation occurs more rapidly in non-health consumption than in health, the latter can be viewed as a superior good (or its income elasticity is greater than one). The empirical investigation presented in section 3 suggests that this hypothesis tends to be rejected by the data, which casts some doubts on the foundations of the Hall and Jones' results. Moreover, as we show in the Annex I, their result also depends critically on the specific form of the utility function, notably the presence of the constant term (cf. equation (7) in Box 4). While the share of health expenditures in GDP is set to rise in the future, determining their optimal level remains therefore an open question.

As a final note, the Hall and Jones' approach says nothing about how a higher level could be financed and whether it could be financed at all, given whatever political economy constraints may exist. Under current institutions, the level of spending implied by their approach seems hardly imaginable, implying that new forms of health care funding may need to be found. The question to be answered now is how these expenditure developments could influence economic growth.

5. The impact of health on productivity and growth

There are reasons to believe that health matters for growth, both through labour participation and productivity. First, health may impact labour supply. A good health status increases the time available both for work and leisure. Moreover, health also influences the decision to supply labour through its impact on wages, preferences and expected life horizon—the net effect depending on substitution and income effect. Second, healthier individuals could reasonably be assumed to produce more per hour worked, thus increasing productivity. Third, according to human capital theory, better health contributes to more educated people and thus more productive people. An increasing life expectancy will also encourage people to acquire more education. Fourth, the state of health of an individual (or the total population) is likely to impact not only upon the level of income but also the distribution of this income between savings and consumption and hence the willingness to undertake investment, which in turn promotes growth. Fifth, R&D in health, which represents a substantial share of total R&D, may contribute as an engine of innovation and growth.

5.1 Health, human capital and growth: general results

Since the seminal work of Becker (1964),[32] there is a sound theoretical and empirical basis to the argument that human capital matters for economic growth, but until recently, human capital has been mostly narrowly defined as education. At the same time, the idea of health representing—next to education—an important component of human capital was introduced most prominently by Grossman (1972), but has been acknowledged more widely. Grossman (1972) distinguishes between health as consumption good and health as a capital good. As a consumption good, health enters directly into the utility function of the individual, since one enjoys being healthy. As a capital good, health reduces the number of days spent ill, and therefore increases the number of days available for both market and non-market activities. Health is not only demanded but also produced by individuals. They inherit an initial stock of health that depreciates with time, but they can invest to maintain and increase this stock. The production of health also requires the use of time by individuals away from market and non-market activities. These two ideas have been introduced in growth models where the growth rate of total factor productivity can be endogenised.

Van Zon and Muysken (2001) analyze the trade-off between health and human capital accumulation in the endogenous growth framework of Lucas (1988). Health influences inter-temporal decision-making in three different ways. First, health generates positive utility of its own, through the average health level in the economy. The average effect also affects longevity.[33] Second, the provision of health care services directly competes with those of labour services allocated to the production and human capital sector. In other words, more health services lead to less human capital accumulation. Finally, health serves as a pre-request to the provision of human capital services. In this respect, health enters both in the utility and the production function. In particular, the generation of health services is defined by decreasing returns (Forster, 1989; Ehrlich and Chuma, 1990; Grossman, 1972) whereas human capital accumulation is modelled using constant returns to scale (the well-known knife-edge condition on the human capital accumulation dynamics). In this context, the social planner chooses the fractions that are respectively spent on human capital accumulation and health services production. This choice impacts on the average health level, and thus on the human capital accumulation, the production of the final good and the utility function. Two polar cases can be distinguished from this model. If the impact of the average health level on longevity is an externality, health becomes a pure complement to growth, *i.e.* any reallocation of labour

32. In the original formulation of his theory, Becker (1964) pointed to health as one component of the stock of human capital, but then focused in his early empirical work exclusively on education.

33. Longevity being proportional to the average health level of the population.

from the health sector towards the human capital sector leads to a decline in growth. In contrast, if the impact of the average health level on longevity is internalised (as in their model), then increases in the demand for health services, as for instance caused by an ageing population, will adversely affect growth.

Other elements relating longevity, human capital and growth have been considered in the theoretical literature. Indeed, the expansion of life expectancy allows for higher returns to be obtained over a longer period of time and thus create incentives to invest more in education (Kalemli-Ozcan *et al.*, 2000; De la Croix and Licandro, 1999). In contrast, a reduction of life expectancy leads to higher competition for resources between the consumption and health needs of the elderly and the investment on education of the young population (Zhang *et al.*, 2003). In particular, Zhang *et al.* (2001) show that the effect of a life expectancy extension on long-run economic growth will depend on the utility parameters and the social security system. For instance, with a pay-as-you-go social security system, an increase in longevity will accelerate of parent's value on the welfare of their children and not the number of their children.

5.2 Does health contribute to growth in rich countries?

Confirming the above theoretical arguments, on a worldwide level, better health, typically measured by life expectancy, appears as a significant determinant of a country's subsequent economic growth, in some cases contributing even more than education (see Sala-i-Martin, Doppelhofer and Miller, 2004, Hongbin, Zhang and Zhang, 2007; López-Casanovas, Rivera and Currais, 2005).[34]

But the effect of health and longevity on growth is not so clear cut for developed countries. If non-active people are getting older and older through an increase of life expectancy, this will not expand the labour force nor the returns on investment in education or training. However, longevity also affects agents' willingness to substitute consumption over the life-cycle. Individuals with a higher life expectancy tend to be more patient and thus have higher levels of savings. *Ceteris paribus*, this should yield higher growth (Reinhart, 1999). Overall, life expectancy will affect growth via three different links: the saving decision, the labour market participation, and the competition for resources between the different activities. Therefore, there is no consensus about whether an increase of life horizon has a positive or a negative effect on growth, or simply does not affect it at all.

It could be noted that empirical studies often rely on poor proxies of health. The contribution of health is measured by life-expectancy, total health care expenditures, child mortality, or the mortality of some specific diseases. These explanatory variables often fail to capture the plausible pathways through which health may enhance growth through its effects on labour market participation, worker productivity, investment in R&D and human capital, savings and population age structure (Bloom and Canning, 2000; Bloom and Canning, and Sevilla, 2003; Easterlin, 1999).

In addition, the fact that the relation between health (or its proxies) and growth is weaker for developed countries could be due to a non-linear relationship, positive at low levels of development and insignificant or negative at higher levels. Bhargava *et al.* (2001) use adult survival rates (*i.e.*, the inverse of adult mortality rates) between ages 15 and 60 as a health proxy in order to assess the effect of health on economic growth in a worldwide panel data set for the period 1965 to 1990. Using an interaction term

34. It could be noted that disentangling the role of health in the context of standard growth regressions faces several general econometric challenges that have been highlighted in the literature (Pritchett, 2006; Rodrick, 2005; Sala-i-Martin, Doppelhofer, and Miller, 2004). In this context, recent papers have developed alternative approaches, for instance a macroeconomic production function model of growth (Bloom and Canning, 2005).

between the health proxy and per capita income, they detected a threshold income level beyond which adult survival rates have negligible or even negative effects on growth rates.

Using data from more than 50 developing and developed countries, Jamison *et al.* (2004), find that increases in physical capital stock dominate (accounting for 67% of total growth) but both educational improvements (14%) and health improvements (11%) make up for an important share, too. Most importantly, investment in health presents diminishing returns, consistent with the results reported by Bhargava (2001). These results require some qualifications. First, given lack morbidity or disability data, only mortality rates are used as a proxy for overall health conditions. However, it is plausible that changes in morbidity may also be significant for income growth while they are only partially correlated with mortality decline and they might lag mortality decline. Second, health improvements above the age of 60 (the threshold used in Bhargava *et al.*, 2001) may have an impact on retirement decision and may further improve even if the adult survival rate have already reached high levels.

Focusing on high-income countries, Knowles and Owen (1995) incorporated a proxy for health in the Mankiw, Romer and Weil's (MRW) empirical growth model. They examine a cross section of 84 countries for the period 1960 to 1985, using OLS estimates.[35] Their results suggest a stronger, more robust, relationship between *per capita* income and life expectancy, than between income and educational human capital. For a sub-sample of 22 high income countries, no statistically significant impact of life expectancy was found.

Rivera and Currais (1999a, 1999b, 2003) examine the impact of health in a cross-section of 24 high-income countries using an augmented Mankiw-Romer-Weil model.[36] In contrast to Knowles and Owen (1995), they use health expenditures as a proxy for health status, arguing that mortality rates represent a very limited indicator of the output of health care systems. Indeed, medical care is not exclusively or primarily aimed at influencing directly the probability of dying. In the absence of reliable time series data capturing both mortality and morbidity, the choice of health expenditures can not be entirely dismissed. Both OLS and 2SLS estimates are carried out (using several instruments, such as alcohol consumption, rate of population over 65 years old, beds in-patient care per 1,000 population, etc). Results suggest a fairly robust positive impact of health (expenditures) on income. Following a similar approach, Gyimah-Brempong and Wilson (2004) and Beraldo *et al.* (2005) also found fairly, robust, statistical significant positive contribution of health expenditures on growth. The endogeneity of health expenditures to GDP per capita could nevertheless be a serious drawback in this type of studies.

Along these lines, recent contributions have focused more narrowly on the links between government health spending and growth. Agenor (2005) concentrates on the potential trade-off between health and other public services, such as education, security, and infrastructure services. The optimal allocation of government spending is determined in an endogenous growth model where public expenditure is an input in the production of final goods as well as health services. In his model health is treated as labour-augmenting and not as a separate factor of production. In particular, the amount of effective labour services provided by a worker is assumed to be proportional to his average health level. At the same time, health services enter in the household's utility function and thus affect directly the welfare. The specification of Agenor (2005) is close to the model proposed by Barro (1990), and thus do not display any transitional dynamics (reduced-AK model) when the flow of health services is considered. An increase of public spending on infrastructure increases growth both through an increase in infrastructure services to

35. The authors argue that (non-reported) 2SLS estimates gave qualitatively similar results. The 2SLS estimates use lagged values of potentially endogenous regressors - a strategy they acknowledge to be the natural choice in time series regressions but not in cross-country regressions.

36. These regressions are conducted over the years 1960-1990 in Rivera and Currais (1999a, 1999b), and for 1960-2000 in their 2003 article.

production and to health services. But it also reduces the resources allocated to health and hence leads to lower productivity and growth. The net effect is ambiguous and depends on the calibration of the parameters of the economy. When both the production and utility function depend on the stock of public capital in health, no general results can be derived.

In contrast, Aisa and Pueyo (2005, 2006) analyze the impact of government spending in a model of endogenous longevity. Aisa and Pueyo (2005) endogenise life expectancy by allowing the probability of survival to depend on health care public expenditures. Moreover, the accumulation of the health status depends on public health care expenditures as a percentage of income (Rivera and Currais, 1999).[37] Their model also follows Barro (1990). The production of final goods is obtained by combining private capital, labour and productive public services. Both public expenditures, which represent a constant fraction of GDP, are financed through taxes. Therefore, there is a trade-off between the amount of productive public services allocated to the production of final goods and the amount of health expenditures, which leads to a higher health status and thus increases the survival probability. Their theoretical results show that a higher life expectancy leads to a higher savings rate and to an expansion of the labour force (the labour participation effect). Depending on the parameters, these effects may enhance growth. But Aisa and Pueyo (2005) acknowledge that this effect is likely to be less clear cut in OECD countries, where efforts to increase life expectancy may have a negative effect on long-run growth. By modelling a non-monotonic effect of government spending on economic growth, Aisa and Pueyo (2006) obtain similar results. Public expenditures have two opposite effects. On the one hand, they reduce the impatience of consumers by lengthening life, which promotes saving and growth. On the other hand, resources devoted to health are at the expense of other factors, especially the accumulation of physical capital, which reduce growth. All in all, the effect of public expenditures is mixed.

Surrounding this analysis, an important question is whether health care expenditures contribute to health outcomes. Echoing some of the results obtained at the micro or individual level presented in section 2, results appear particularly mixed when examining the relationship at the aggregate level. Earlier commentators have argued that the role of healthcare was rather small and may even have been detrimental (Illich 1976, McKeown 1979). In fact, the impact of "curative medical measures" may reasonably be assumed to have had little effect on mortality decline prior to the mid-20th century (Colgrove 2002). Since then, however, the scope and quality of healthcare have changed almost beyond recognition, but the debate about the relative role of health care continues.

Explaining the mixed results obtained so far, Suhrcke and Urban (2006) argued that there is very little variation in life expectancy among rich countries (much in contrast to the wide variation among poor countries). They also share the view that the link between health expenditures and health outcomes is far too poorly understood for the former to serve as a proxy of the latter. For this reason, they use a health proxy that at least displays significantly greater variation among rich countries and is particularly characteristic of the health challenges that these countries are facing: the cardiovascular disease (CVD) mortality among the working age population. Starting from a worldwide sample of countries (acknowledging data problems on CVD data for low and middle income countries), they find that that the effect of working-age CVD mortality rates on growth was dependent on the level of initial per-person GDP. They therefore split the sample into (broadly defined) low- and middle-income countries, on the one hand, and high-income countries (26), on the other hand. Results were remarkably robust across different specifications and methods. In their preferred estimate, a 1% increase in the CVD mortality rate was found to decrease the growth rate of per-person income in the subsequent five years by about 0.1% in the high-income country sample.[38] While 0.1% is a small amount in growth terms, it is sizeable in absolute money

37. They also assume a constant depreciation rate as in standard accumulation equations.

38. The result is based on a panel of five-year intervals between 1960 and 2000, and includes a set of standard controls (including initial income, openness, secondary schooling, etc.). The authors used a dynamic panel

terms when accumulated over many years. As an aside, the authors did not find a significant influence of CVD mortality on growth in the low- and middle-income country sample.

Weil (2005) uses three microeconomic indicators of health: average height of adult men, the adult survival rate for men and age of menarche for women. His preferred estimate leads to the conclusion that eliminating health differences among countries would reduce the variance of (log) per capita GDP by 9.9%. But this effect tends to be smaller than what is derived from cross-country regressions. Bloom and Canning (2005) compared the size of the microeconomic estimates of effect of health on wages with the macroeconomic estimates of the effect of health on worker productivity using a calibrated macroeconomic production function model. However, their database derived from the Penn World Tables also includes non-OECD countries, thus making difficult a comparison.

Most importantly, the positive impact of improved health on economic growth has been in many countries prevented by a fixed and too low retirement age. Once institutional incentives for early retirement are lifted and the effective retirement age increases, through labour market participation of the elderly, the health status could have a more important role on growth.

5.3 Mechanical impact of ageing and individual productivity

A reason why the impact of health on growth may not appear as strong as it could be expected in the future is related to the question of productivity *level* vs. *growth* effects. Indeed, while health could be seen as a labour-augmenting factor increasing the level of individual productivity, its effect could not be sufficient to generate a growth enhancing mechanism. To see this point, we follow here a numerical simulation on the impact of ageing on productivity carried out by Oliveira Martins *et al*. (2005). They postulated different scenarios for the relation age between age and productivity, as displayed in Figure 5.1. It is commonly assumed that individual productivity follows a (quadratic) inverted U-shaped age profile (*e.g.* Miles, 1999). However, in a more optimistic age-productivity profile, productivity could stabilise after a certain age up to retirement (cf. Aubert and Crépon, 2003). The impact of health care in this context could be envisaged as inducing, for example, a stabilisation in the health status at older ages that would prevent productivity to fall. The question is how much this would make a difference for aggregate productivity?

[Figure 5.1 Different age-productivity profiles]

The impact of each hypothetical individual age-productivity profile on aggregate productivity can be derived by applying them to population projections 2005-2050 used in this paper. Oliveira Martins *et al.* (2005) made this calculation for the US, Japan, Germany and France. Comparing the most optimistic scenario, assuming a flat productivity profile for old-age workers, with the more pessimistic one, where productivity declines steadily, shows a level difference; however, the order of magnitude of the change is small (+/-2.5%) and this level effect would stabilise relatively rapidly (Figure 5.2). Therefore it would hardly induce a significant growth effect. Nonetheless, a better health could still help maintaining individual productivity levels, which combined with reforms that would create incentives and conditions for extending working lives, would still have a significant macroeconomic impact through labour force participation, as illustrated by the simulations presented in section 2 above.

[Figure 5.2 Mechanical impact of ageing on productivity levels]

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growth regression framework, taking into account potential endogeneity problems from reverse causality or omitted variables, which might determine both CVD mortality and growth simultaneously.

5.4 R&D, innovation and market structure in the health sector: Europe vs. the US

An important channel through which the health sector could influence growth is the R&D activities. Sanso and Aisa (2006) propose a model in which health is an engine of growth. More specifically, the biological deterioration rate—"the rate at which the effectiveness of health goods in maintaining a given level of health decreases as individual growth older"—is a key a parameter to determine the steady-state growth rate. In this respect, Sanso and Aisa (2006) develop a dynamic general equilibrium model in which they integrate the accumulation of human capital, innovation in medical technology, health and longevity. In this framework, when agents decide on their "quantity" of life, the need to offset the biological deterioration rate encourages medical research, and thus growth, which permits in turn to finance medical research and health care expenditures.

In this perspective, the situation in the US contrasts with Europe. We will focus here on the pharmaceutical sector (for a description and analysis of the medical devices sector, see Pammolli *et al.* 2005). The US is increasingly outperforming Europe (and Japan) as the main player in medical innovation when looking at standard measures of R&D inputs (measured for instance by R&D expenditures) and outputs (measured for instance by patents and patent citations). The comparatively stronger emphasis in Europe on cost containment through its Social Security price and reimbursement regulations goes a long way in explaining these differences. This is what has arguably led to slower implementation of cost-enhancing technology in Europe. In the US, with very limited incentives for agents to consider the costs of treatment, there has accordingly been very limited incentive to invest in cost-reducing R&D. The EU health sector has therefore been in the position to take advantage of the development of new technologies elsewhere - chiefly the US - as it has been able to introduce them slowly, after the expensive early stages of implementation. While this has certainly contributed to lower average costs (at the expense of delay in implementation), it is hard to say what the effect on overall productivity in the EU has been. In evaluating the comparative performance of the different systems it is also important to take into account the trade-offs involved, for instance in terms of its effect on access to health care, which has become much skewed in the US case.

Before entering into the description of innovation outcomes of the pharmaceutical sector it is helpful to develop an idea of some basic characteristics of the market, and how they differ between the EU, the US and Japan. Overall, the pharmaceutical industry is a significant but nevertheless comparatively small sector of the economy. At the same time it displays a high level of productivity and is an exceptionally R&D intensive sector. The US market is not only the biggest but it has also been the fastest growing recently. In recent years the US pharmaceutical market, measured by sales at ex-factory prices, has grown faster than European markets (Table 5.1). The US market is currently twice as large as the EU-15 aggregate, and accounts for approximately 50% of the world market for pharmaceuticals (up from 31.2% in 1995). Europe held a 30% share of the global pharmaceutical market in 2003, while Japan's share in 2003 was nearly 12%. China, Brazil and India - not shown here - are growing fast, gaining shares in the international market (EC 2006).

[Table 5.1 The size of the Pharmaceutical markets (million Euros)]

5.4.1 A comparison of medical innovation input and output

Research and Development (R&D) is particularly important in the pharmaceutical industry. Despite data limitations and methodological problems, there have been some attempts to measure pharmaceutical R&D expenditures (*e.g.*, Figure 5.3). The data shows an increase in R&D expenditures at least in Europe and the US, with the US overtaking Europe in recent years.

[Figure 5.3 Pharmaceutical R&D expenditure in Europe, the US and Japan (€ million, current prices and exchange rates)]

Although R&D expenditures have generally increased globally, the innovative output has declined over the past decades. This becomes for instance visible in the number of new chemical entities placed on the world market (Figure 5.4), indicating a decline in all three countries/regions. The Figure also shows that while the European pharmaceutical industry has for many years been the world's leading inventor of new medicines, over the past decade, the United States has become the dominant player, including R&D where Europe is under-represented in some crucial research fields such as biotechnology. Between 1960 and 1965, European companies invented 65% of new chemical entities (NCEs) placed on the world market. Forty years later their share had fallen to 34%. The latest data available (period 2001-2005) show the predominance of the United States which has now become the leading inventor of new molecules in the world.

[Figure 5.4 New chemical or biological entities]

The most widely used indicators in the empirical literature for the measurement of technological change are patents and of patent citations. Patents are a unique source of information about innovative activities, particularly in the pharmaceutical industry, where they play a prominent role in protecting returns from R&D. Table 5.2 represent all pharmaceutical and biotechnological patents granted from 1974 to 2003 by the United States Patent and Trademark Office (USPTO) to inventors and institutions located in the US, Japan, and the EU.

[Table 5.2 Shares of USPTO-granted pharmaceutical patents by countries on the nationality of the assignee and location of inventor]

Data indicate that the US is the main locus of innovative activities, and that its lead has grown over time. Table 5.2 shows that the majority of patents in biotechnology and pharmaceuticals are held by inventors located in the US. The number of pharmaceutical patents held by US-based inventors increased by 7 percentage points between 1984-1993 and 1994-2003. The increase is even more striking if we weight each patent by its importance, as approximated by the number of citations it receives (see Table 5.3).

[Table 5.3 Shares of patent citations of USPTO-granted pharmaceutical patents by countries based on the nationality of the assignee and location of the inventor]

Interestingly, the share of EU inventors is higher than the share of EU institutional assignees. The opposite is true for the US, even if the imbalance is gradually disappearing. In other words, there are more European inventors involved into research assigned to US organizations and performing their research in the US than vice-versa, although the globalisation of R&D activities is gradually eroding this disparity.[39]

The US dominance appears even stronger when we consider patent citations data. In fact, Table 5.4 suggests that on average patents assigned to US institutions have a much greater impact on future innovative activity. US biopharmaceutical patents received 5.56 citations on average between 1994 and 2003, far more than European (2.92) and Japanese (2.07) ones. Furthermore, the largest share (almost half)

39. It is important to note that in recent years, the number of patents in pharmaceuticals and biotechnology granted by the Chinese patent office has increased. The same applies to US patents granted to Chinese inventors. These increases indicate a process of accumulation of scientific and technological capabilities. India's recent performance in biopharmaceutical innovation, as reflected in patents granted, is similar to that of China. If these trends persist, China and India will strengthen their positions, becoming attractive and competitive destinations of foreign direct outward investment by multinational corporations (EC 2006).

of the European and Japanese citations go to US patents, although this finding must be interpreted with caution, since we are considering data on patents granted by the USPTO. Nevertheless, the trends in pattern of citations of the EU citing US and JP citing US reveal an increasing importance of US research for inventors located in Europe and Japan.

[Table 5.4: Patent citations]

5.4.2 Market structure characteristics explaining differences in innovative performance

There are significant differences in market structures between Europe and the US that are likely to affect incentives for R&D. Price differences between the US and EU-15 are accounted for entirely by differences in prices for branded drugs. In fact, prices of generic drugs in the US are substantially aligned with prices in the EU-15. In a few countries, such as Germany, generic prices are even higher than in the US. Price at entry for branded drugs is 43.4% higher in the US than average price in the market. The corresponding price gap in the EU-15 is 28.2%, and in Japan just 3.9%. US generic products, by contrast, are priced at 60.3% of the average prices in the market.

These price differentials between the US and Europe reflect radical differences in the extent of market regulation. Prices for branded drugs in countries with free or semi-regulated prices - such as the US and, to a lesser extent, UK and Germany - are higher than in countries where more direct forms of price regulation are in place, such as Italy and France. At the same time, the relatively unregulated markets tend to experience fierce price competition after patent expiry, since higher prices of branded drugs represent a strong incentive for generic entry and price competition à la Bertrand (Pammolli *et al.*, 2002; Magazzini *et al.* 2004). Generic penetration in terms of volume is much higher in the USA (33.7% of the market in 2004) and UK (31%) than in the average EU-15 (13.8%) and Japan (2.6%). The possibility to command substantially higher market prices for new and branded drugs can act as a powerful incentive for R&D and capital investments that can explain, to a certain extent at least, the different trends characterising the EU and US pharmaceutical industries.

Overall, the US market is more concentrated than all the most important EU markets (Germany, France, Italy and Spain, but not the UK), as well as Japan, China and India. On average, the three leading products in each of 100 different therapeutic categories account for 85.6% of total market share in the US, as compared with a total market share of 76.5% in the EU-25. It is clear that European markets are much more fragmented than the US market. The US market is as concentrated as the European one in terms of volume, while it is the most concentrated in terms of sales. To a large extent, the high concentration of the US market is due to the "premium price" that best-in-class products can command. Indeed, the relative price of the market leader in the US is 44% higher than the market average price - more than in Europe (22%) and Japan (15%).

Higher concentration in the US market does not imply less competition, however. On the contrary, firm turnover in the US is almost double that of the EU-15 and EU-25. The "premium price" for new innovative drugs tends to induce higher levels of industrial concentration in the US. The lower turnover of EU markets translates into a higher persistency and a lower contestability of the leading products. The US average persistency of the leading product is slightly less than 6 years, while in the EU it is almost 10 years and in Japan more than 15 years

The US market has also the highest product turnover. The US rate is 59.5% higher than EU-15, and 38.8% higher than Japan. The most striking difference is found in product exit rate, which is on average 77.2% higher in the US than in the EU-15, and 40.7 higher than in Japan. Product entry rates are 51.3% higher in the US than in the EU-15, and 38.8% higher than in Japan. Therefore, the process of creative destruction is much more intense in the US market than in European or Japanese markets.

All in all, the US pharmaceutical market seems highly contestable; product turnover is much more frequent than in the EU and Japan; and competition from generic producers is substantial. US market behaviour is consistent with that of a market characterized by Schumpeterian competition, where innovators can gain temporary quasi-monopoly profits, which in turn spur innovation efforts by competitors that quickly leads to more innovative products and a high turnover of market shares. Dynamic competition is less evident in the EU as a whole, and especially in certain continental European countries. As documented extensively in Gambardella, Orsenigo and Pammolli (2000), there is too little market-based competition in some of the European countries, resulting in a less-efficient industry, as reflected in productivity indicators and market performance.

6. Summary and policy discussion

Since human capital is the main driver of productivity and growth in knowledge-based economies, health should also matter for economic outcomes. In the context of rapid population ageing, the contribution of health for human capital and hence for growth potential could therefore be expected to become increasingly important. This paper tackled this issue by offering an integrated view of the relationships between, health spending, medical innovation, health status, growth and welfare.

We started with the observation that longevity has increased steadily in developed countries. Providing labour market and pension reforms offer the right environment, we showed that these longevity gains could be used to smooth the negative effects of baby-boom bust on labour force, notably in Europe. A key condition, however, is the existence of a virtuous cycle between longevity and health status (so-called "healthy ageing"). Despite the uncertainties on whether healthy ageing could continue in the future, improved health status can be (and has been) achieved to a significant extent through improved health care. The evidence reviewed here, suggests that the value attributed to the resulting reduction in mortality and/or morbidity, at least for specific interventions or treatments, most often exceed the costs and thus has been a worthwhile investment.

But health care is costly and developed societies are spending an increasing share of their income in health services and products, with already strained public budgets paying most of the bill. This rising expenditure trend has little relation to demography, but it is rather driven by consumers' preferences for longer lives and the diffusion of technological progress. We provided empirical evidence that health expenditures tend to grow in line with incomes (unitary income elasticity); on the top of this income effect, it is the change in medical practices that explains most of the drift of health expenditures per capita.

The structure of health insurance, as well as the regulation of health care supply might also encourage some costly innovations with a small benefit in terms of social welfare. Prevention policies should also be considered in this regard. The paper focused on curative treatments, adopting a somewhat narrow perspective of “health investment”. The potential for (especially primary) prevention – through the health care system or beyond – to improve health and thereby perhaps even to alleviate the future health expenditures burden is still a matter of some debate (Fries, Koop, Sokolov *et al.* 1998; Harvey 1998). While more work to clarify the potential health and fiscal benefits from prevention is clearly warranted, the value of non-clinical prevention may even become more important in the future, given the already big and rising challenge of obesity affecting essentially all rich countries (and not only).

Policies have to define the limit between the package of health care services which are covered through a mandatory health insurance (public or private and regulated through a managed competition scheme), and the other services which will be covered by a private voluntary insurance. In each country, a fine tuning should allow to take into account social preferences relative to the pace of technological progress, equity in access to innovations and tax burden.

Given the various determinants of health expenditures, we carried out several projection exercises leading to the conclusion that the expected increase in the resources directed to health care by 2050 is substantial (ranging from 4 percentage points in a conservative scenario to above 12 percentage points of GDP). The question then arose on what could be the likely impact of these developments on economic growth, and what could be the impact, if longevity was "better managed"? In particular, would there be a role for investing in health to act as a driver of the European catching up with the US in terms of GDP per capita?

Despite convincing theoretical arguments, the empirical evidence reviewed in this paper on the impact of health and health spending on economic growth in rich countries is rather mixed. Probably, the positive impact of improved health on the economy has been hindered by a fixed and too low retirement age. Once institutional incentives for early retirement are lifted and the effective retirement age increases, through labour market participation of the elderly, the health status could have a more important role on growth. It may seem a bit paradoxical that Europe is doing better than the US in terms of life expectancy, but is falling to capitalise on these additional human resources by having early retirement and long inactive lives. Simple numerical simulations support the view that the labour market participation effect is likely to be more important than a hypothetical increase in the individual level of productivity associated with a better health status.

Finally, given the role of preferences and the demographic transition, the global market for health services and products is huge. Satisfying this demand offers a potential for growth, but the EU is lagging behind the US in terms of health-related R&D and innovation. This is partly due to differences in regulation and market structure, which would require appropriate product market reforms. In this context, ageing countries could take advantage of longevity and develop goods and services targeted to the older segments of the population. This would build new dynamic comparative advantages, reinforced by fast technical progress in biotech sectors. Overall, health policies are connected and are often complementary with other areas (e.g. public budgets, labour market, pensions, etc.), so reforms need to be broad-based.

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ANNEX I: SPECIFICATION OF THE UTILITY FUNCTION AND THE INCOME ELASTICITY

In this Annex we show the relation between the specification of the utility function used in Hall and Jones (2007) and the value of the income elasticity. Assume that a social planner chooses consumption and health spending to maximize the utility of the individual, *e.g.* the optimal allocation solves the following program,

$$max_{c,h} f(h)u(c) \text{ s.t. } c+h=y$$

where

$$u(c)=b+\frac{c^{1-\gamma}}{1-\gamma}$$
$$f(h)=A_a h^{\theta_a}.$$

This programme is similar to the Hall and Jones' model (see Box 4 in the main text). Under standard regularity conditions, the first-order conditions are given by:

$$f(h)u'(c)-\lambda=0 \quad (1)$$
$$f'(h)u(c)-\lambda=0 \quad (2)$$
$$c+h=y. \quad (3)$$

Using (1) and (2), we have:

$$\frac{f(h)}{f'(h)}=\frac{u(c)}{u'(c)}$$

or

$$\frac{h}{c}=\frac{\eta_h}{\eta_c}$$

where $\eta_h = h\frac{f'(h)}{f(h)}$ and $\eta_c = c\frac{u'(c)}{u(c)}$.

Solving the first-order conditions we one obtain:

$$h=\theta_a\left(\frac{b+\frac{c^{1-\gamma}}{1-\gamma}}{c^{-\gamma}}\right)$$

which implies from equation (3) :

$$c+\theta_a\left(\frac{b+\frac{c^{1-\gamma}}{1-\gamma}}{c^{-\gamma}}\right)=y.$$

It is straightforward to see that:

$$\frac{dc}{dy}=\frac{1}{(1-\gamma)\left(1+\frac{\theta_a}{1-\gamma}\right)+\gamma\frac{y}{c}}$$

$$\eta^*_{y/c} = \frac{1}{(1-\gamma)\left(1+\frac{\theta_a}{1-\gamma}\right)(1-s^*)+\gamma}$$

Where $s^*=h/y$ is the optimal share of health spending in GDP. Some algebraic manipulations yield the income elasticity of the health demand:

$$\eta^*_{y/h} = \frac{\theta_a\left(b\gamma\left(c^*\right)^{1-\gamma}+\frac{1}{1-\gamma}\right)\left(\frac{1-s^*}{s^*}\right)}{\left(1-\gamma\right)\left(1+\frac{\theta_a}{1-\gamma}\right)\left(1-s^*\right)+\gamma}.$$

The income elasticity depends on b, γ, and θ_a (since s^* depends on η_h and η_c, which in turn depends on the parameters of u and f). In particular, it could be larger or lesser than one, depending on the values of the parameters and the optimal consumption allocation. However, in the particular case where *b=0*, we have $s^* = h/y = 1/(1+\eta_c/\eta_h) = 1/(1+(1-\gamma)/\theta_a)$ and the income elasticity is equal to one. In other words, the fact that the optimal share of health spending is rising with GDP depends critically on a strictly positive *b* parameter. Hall and Jones acknowledge the critical importance of this condition for their results, without establishing the formal relationship between the form of the utility function and the income elasticity.

ANNEX II: DATA SOURCES AND METHODS OF HEALTH EXPENDITURE PROJECTIONS[40]

Estimating death-related costs

The primary data for 18 OECD countries are drawn from the AGIR data set (Westerhout and Pellikaan, 2005, based on EC-EPC, 2001) for EU-15 countries and from national sources for Australia, Canada and United States.

The cost of death for the oldest group (95+) is assumed to be the lowest and was proxied by their observed health expenditure per person when available. For France, Germany, Italy, United Kingdom, Spain, Netherlands and Australia for which the expenditure for the oldest group were not available, the cost of people aged 75-79 was taken as a proxy. In fact, when available, expenditure at age 95+ is roughly equal to the level of expenditure at age 75-79. For the countries where no cost expenditures were available, the cost of death for the oldest group was estimated by taking 3 times the average health expenditure per capita.

The costs of death for other age groups are then derived by multiplying this estimate by an adjustment factor equal to four between ages 0-4 to 55-59, gradually decreasing to 1 afterwards. Multiplying these costs of death by the estimated number of deaths by age group (using mortality data) gives the death-related cost (DRC) curve.

Calibration of the expenditure curves on the OECD Health database

The cost curves derived for the year 2000 were first calibrated in order to fit with levels of 2005, the starting point of the projections. The total health and long-term care expenditures for 2005 being not yet available in the OECD Health Data (2005a), an estimate was made by applying the observed growth rate in expenditures 2000-2003 (or 2002, depending on the countries) for the whole period 2000-2005. A second step was to split the total spending into health and long-term care. The details of this split are provided below and involved an estimate of the shares of long-term care expenditures using OECD (2005b).

The costs of death by age group for 2005 were derived by applying the same growth rate as the total health expenditures between 2000 and 2005. The total death-related costs in 2005 were computed as the product of the cost of death by the projected number of deaths by age group in that year. The total survivor expenditures were then derived by subtracting the total death-related costs from the total health spending. Using this information, the survivor cost curve was calibrated proportionally for each age group.

Projecting the demographic effects under a "healthy ageing" scenario

Shifting the survivor cost curve according to longevity gains involves two steps:

(1) The survivor expenditure curve by five-year age groups is interpolated in order to derive a profile by individual age. In this way, the cost curve can be shifted smoothly over time in line with life expectancy gains.

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40 This Annex draws from Oliveira Martins and de la Maisonneuve (2006).

(2) An "effective age" is calculated by subtracting the increase in life expectancy at birth according to national projections from current age. For example, a 70-year old person in Germany is projected to have an effective age of 67 by 2025 and 64 by 2050.

The starting point of the projections

The projected changes in spending expressed in percentage of GDP were calculated from a common base applied to all OECD countries. This base was taken as the OECD average of expenditure in 2005. These changes were added to the initial level of expenditures in each country. This approach makes the projected changes (expressed in percent of GDP) less dependent from the base year levels and also allows for a certain catch-up of expenditure ratios across countries. More precisely, the variation of the share of expenditure to GDP in country *j* between, say, 2005 and 2050, is calculated as:

$$\Delta\left(\left.\frac{Expenditure}{GDP}\right|_{\substack{country\,j\\2050-2005}}\right)=\exp\left[\Delta\log\left(Drivers\right)\Big|_{\substack{country\ j\\2050-2005}}+\log\left(\left.\frac{Expenditure}{GDP}\right|_{\substack{average\,OECD\\year=2005}}\right)\right]-\left(\left.\frac{Expenditure}{GDP}\right|_{\substack{OECD\ average\\year=2005}}\right)$$

TABLES & FIGURES

Diagram 1. Links between Health spending, Technological progress, Longevity and the GDP

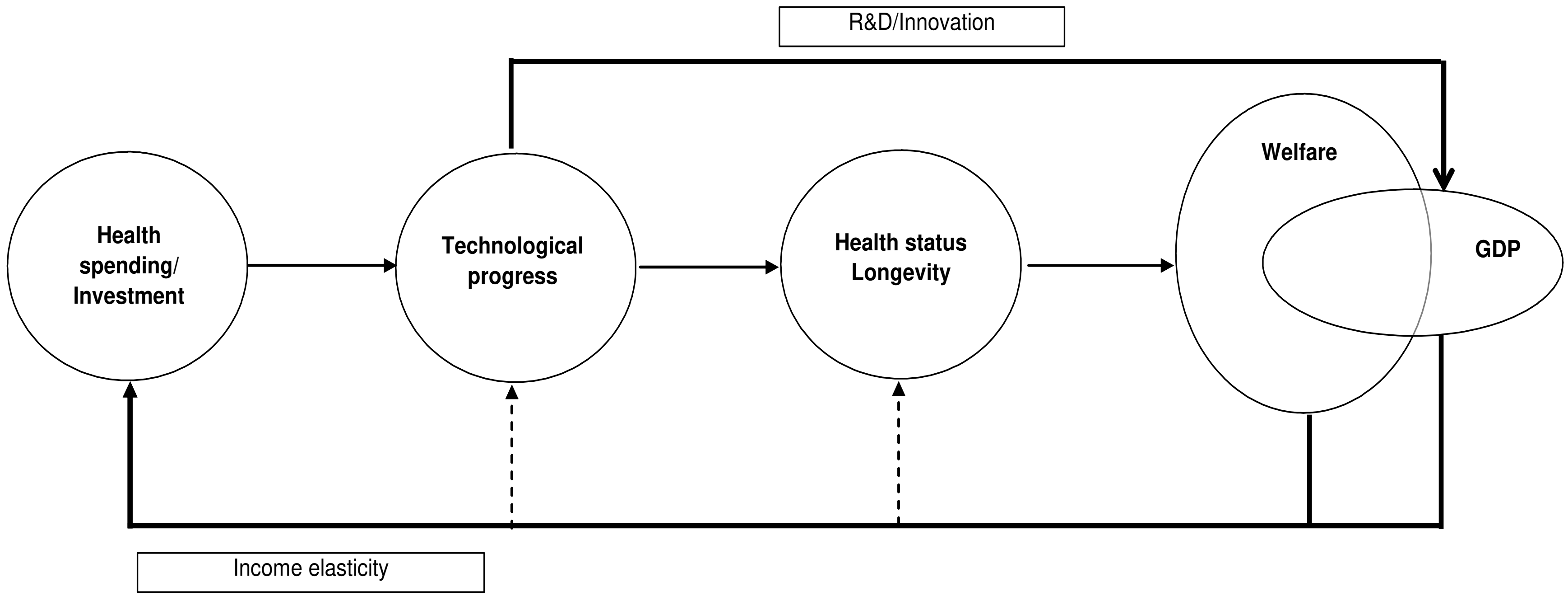
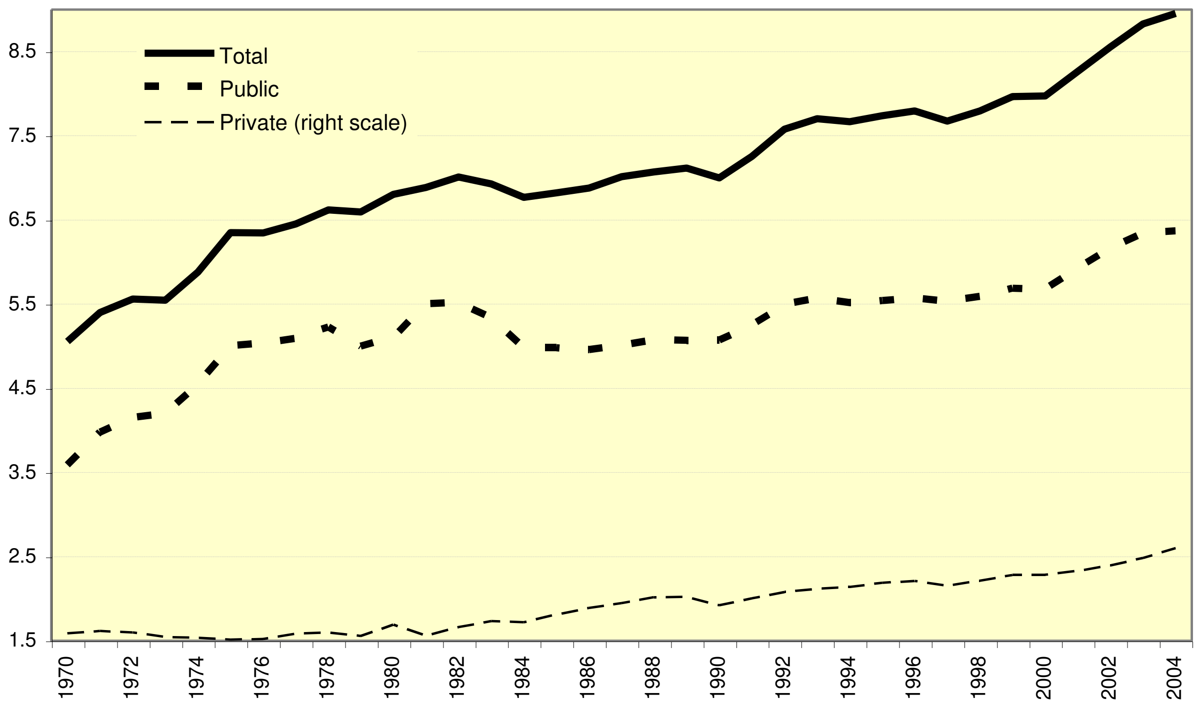
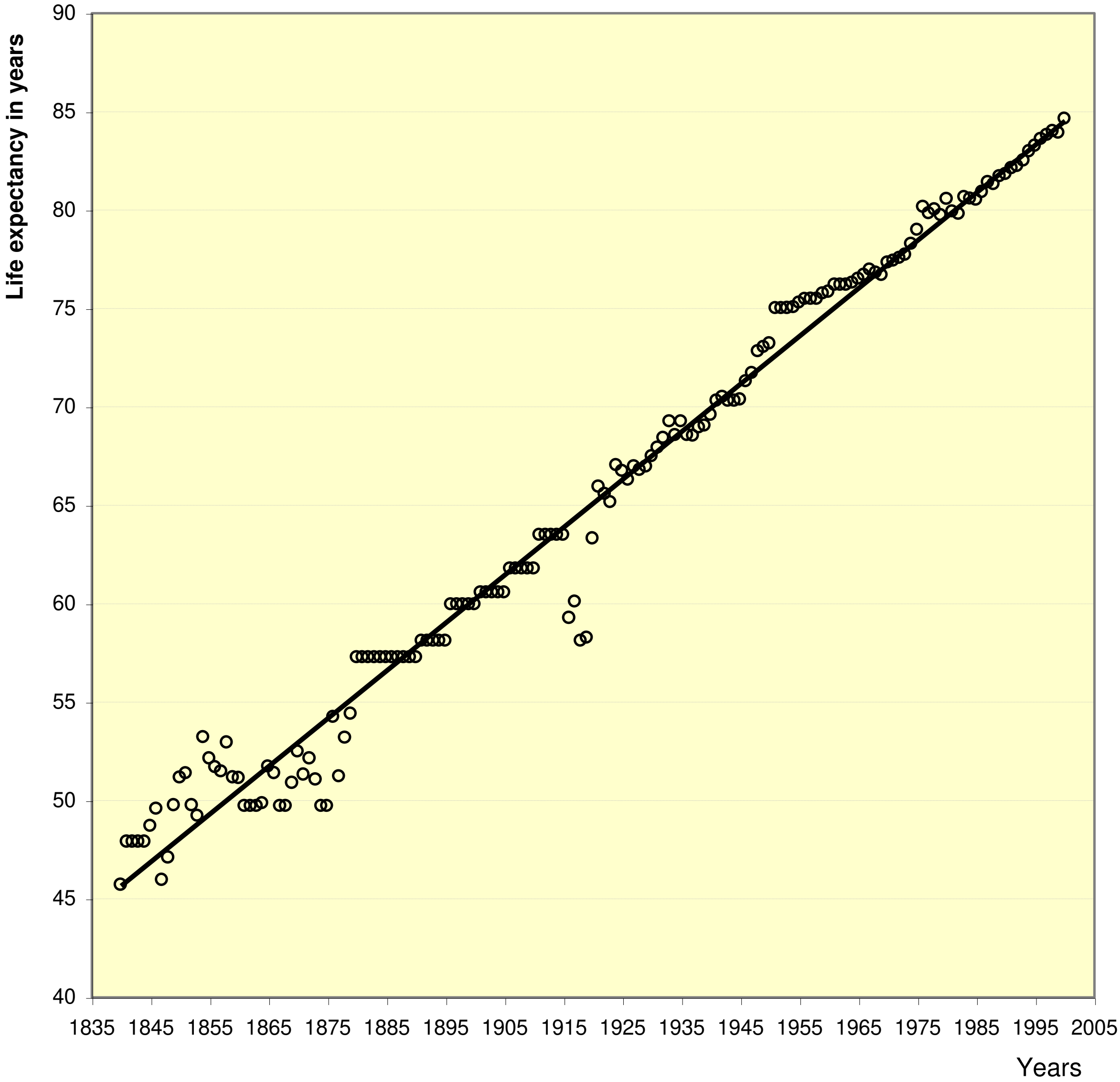


Figure 1. Evolution of Total, Public and Private OECD health spending (in % of GDP)



1. Unweighted average of available OECD countries. Including long-term care expenditure.
Source : OECD Health Database (2006).

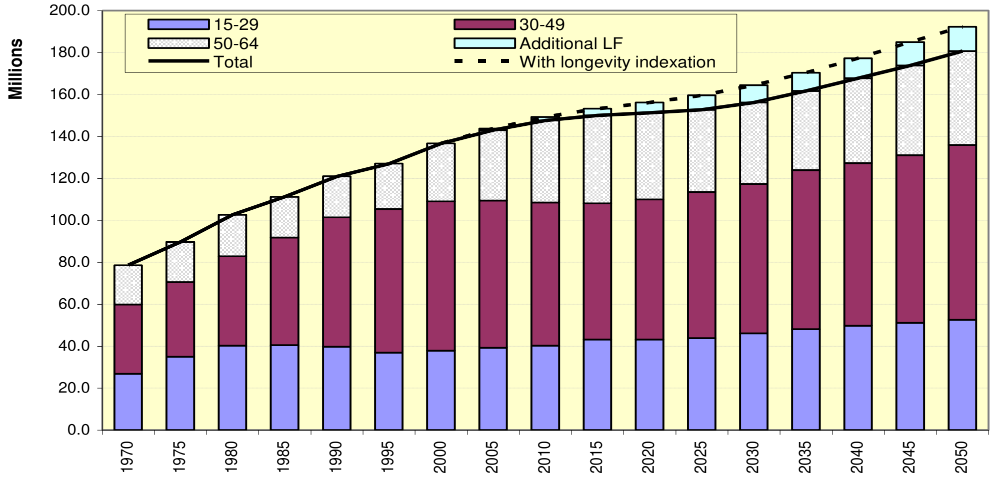
Figure 1.1 Historical trends in female life expectancy, 1840-2000 [1]



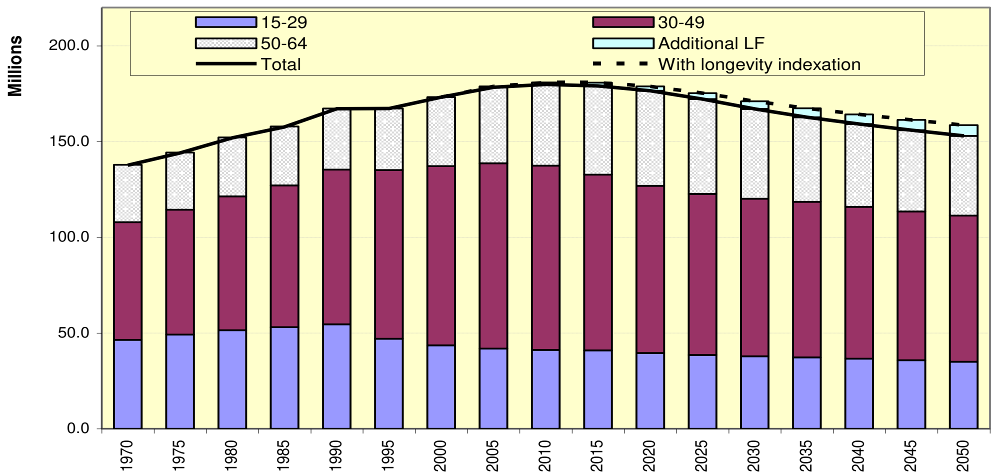
1. Country with the highest life expectancy. The linear trend: slope=2.43 and R^2=0.98.
Source: Oeppen and Vaupel (2002).

Figure1.2 Simulations of the effect of ageing and longevity on the labour force[1]

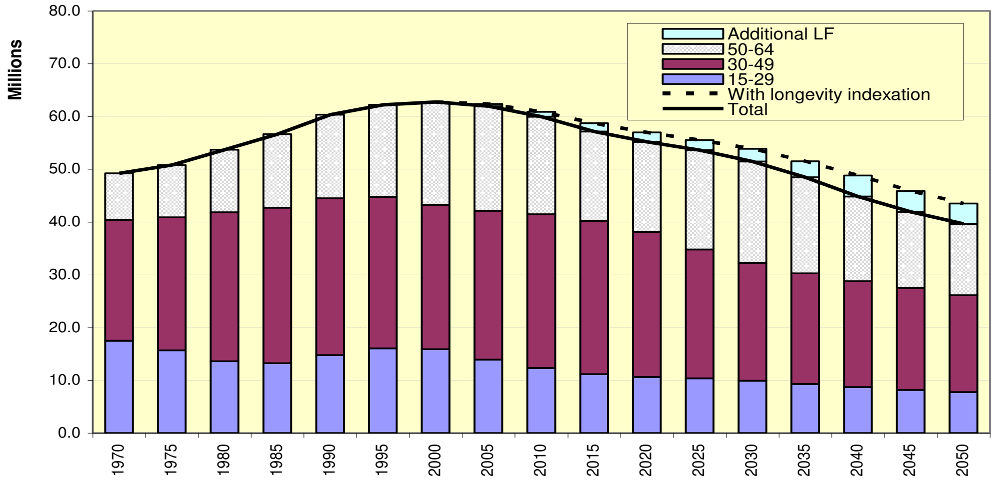
United States



EU-15



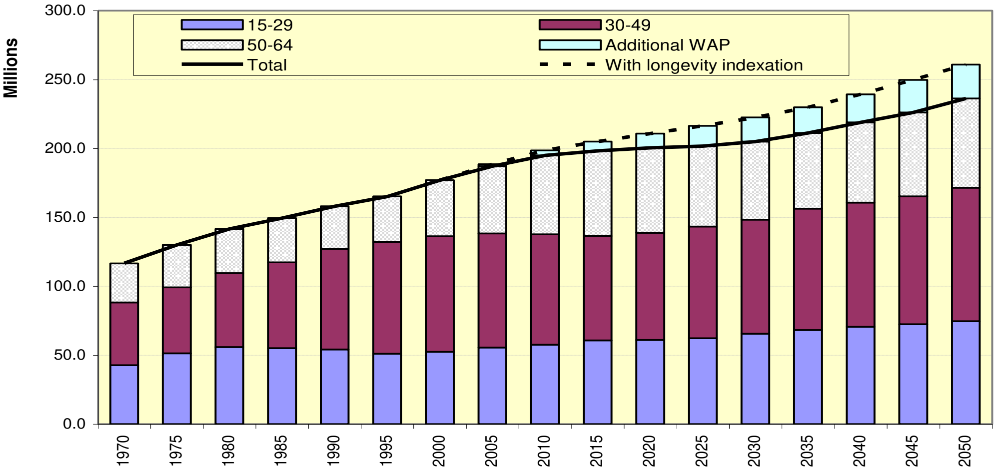
Japan



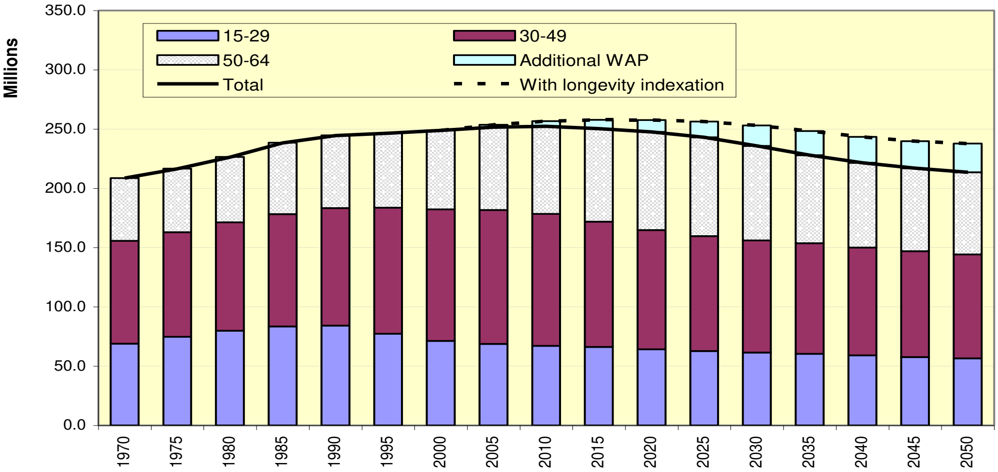
(1) The labour force projections are derived from te baseline scenario of Burniaux et al. (2003). The longevity indexation method is described in Oliveira Martins et al. (2005).

Figure 1.3 Simulations of the effect of ageing and longevity on the working-age population

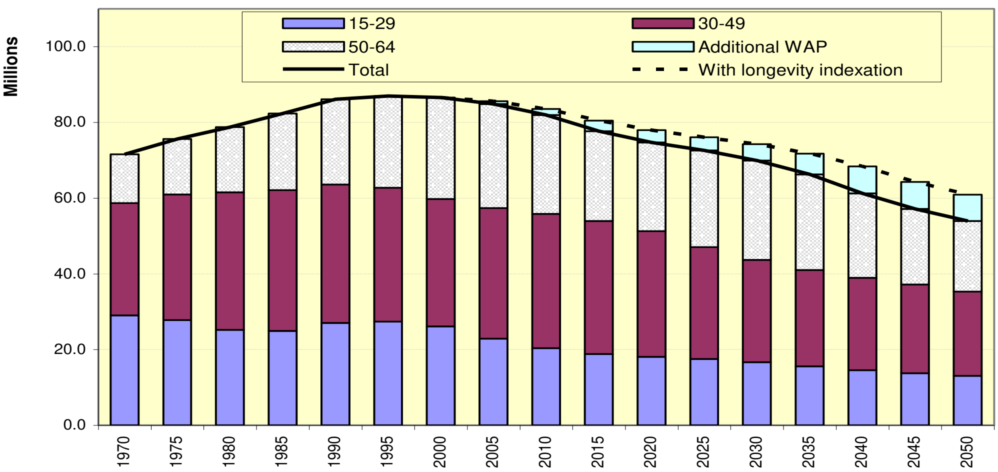
United States



EU-15

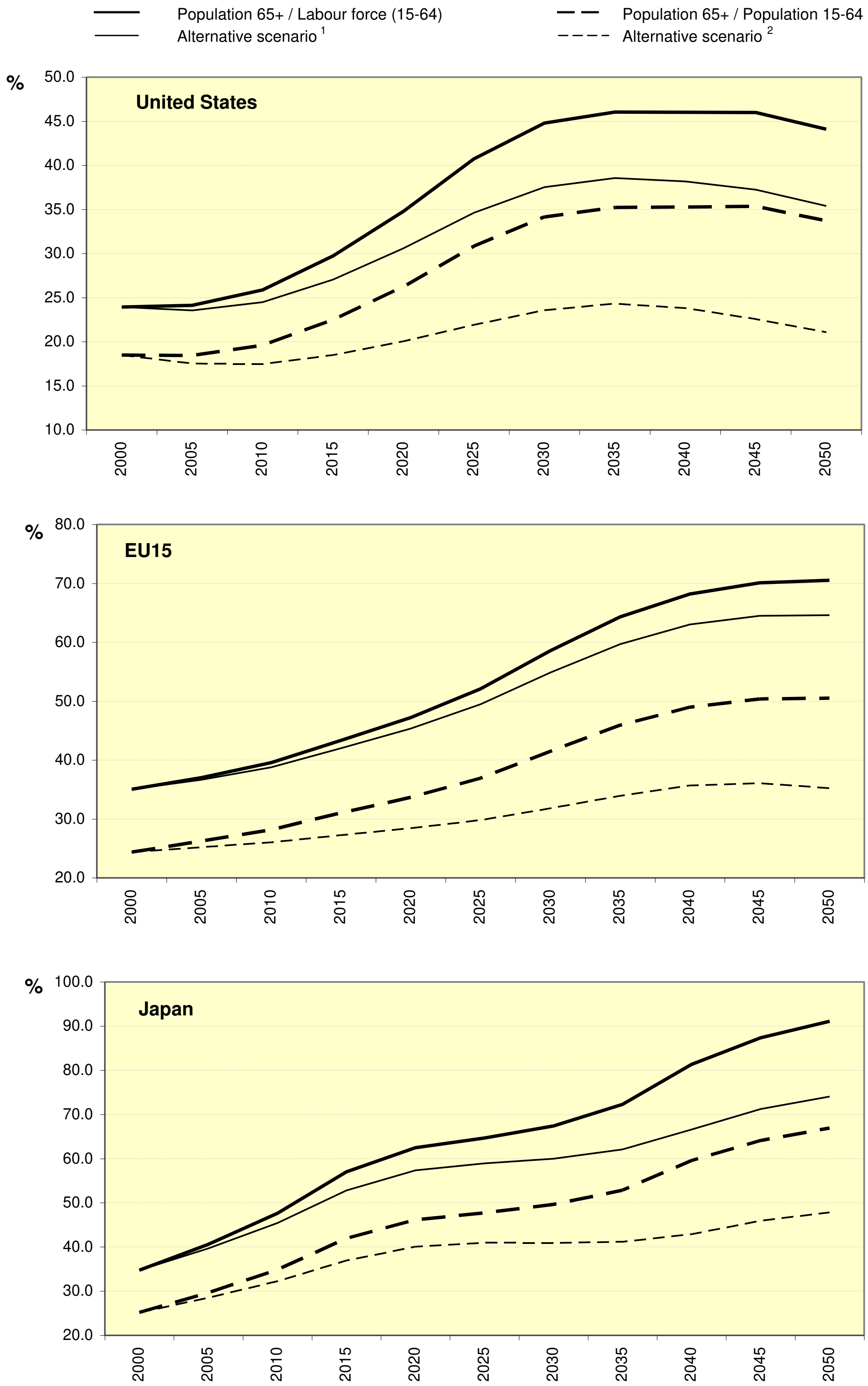


Japan



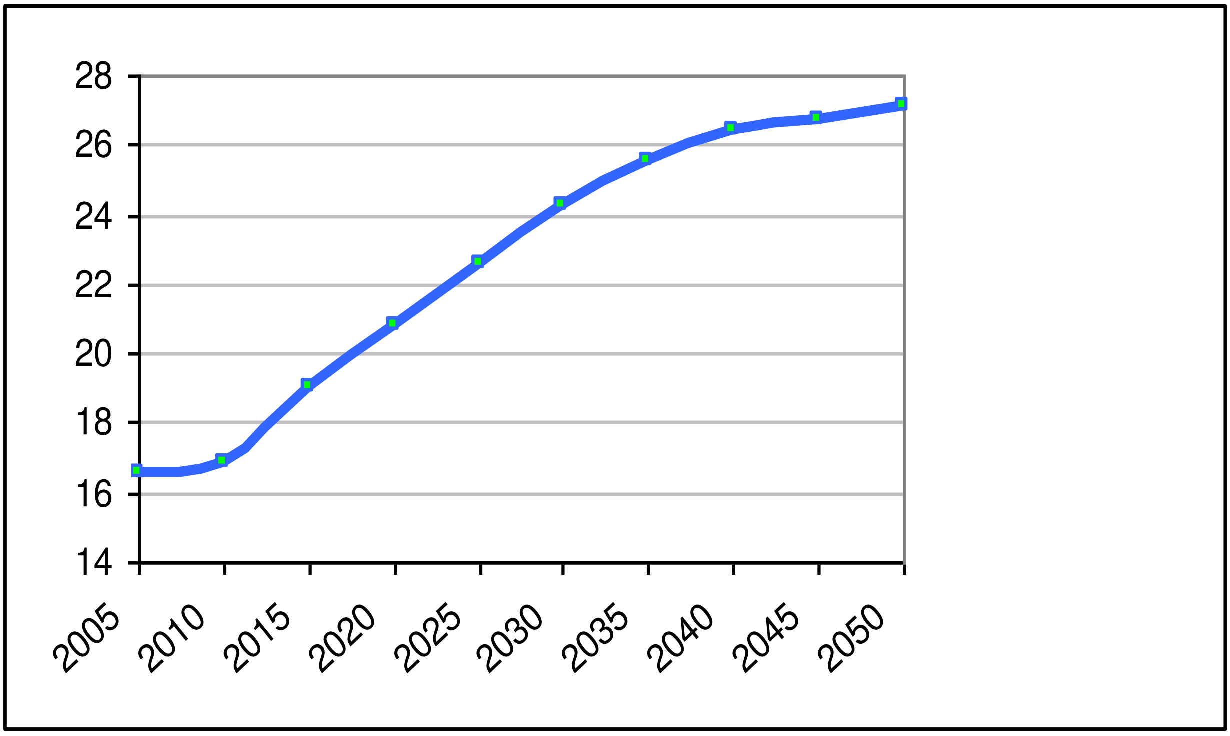
(1) The labour force projections are derived from te baseline scenario of Burniaux et al. (2003). The longevity indexation method is described in Oliveira Martins et al. (2005).

Figure 1.4 Simulations of longevity indexation on dependency ratios



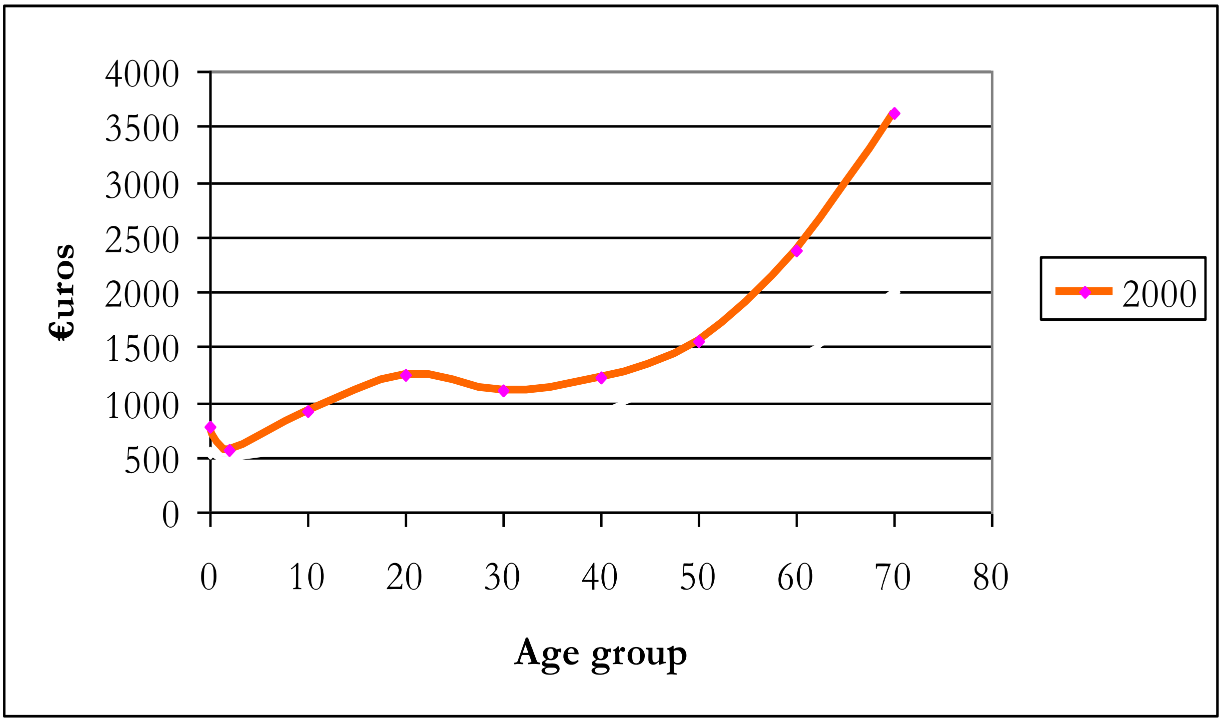
1. Population in retirement / Labour force, indexed on longevity.
2. Population in retirement / Working age population, indexed on longevity.

Figure 2.1 Proportion of people aged 65 and over (demographic effect), France



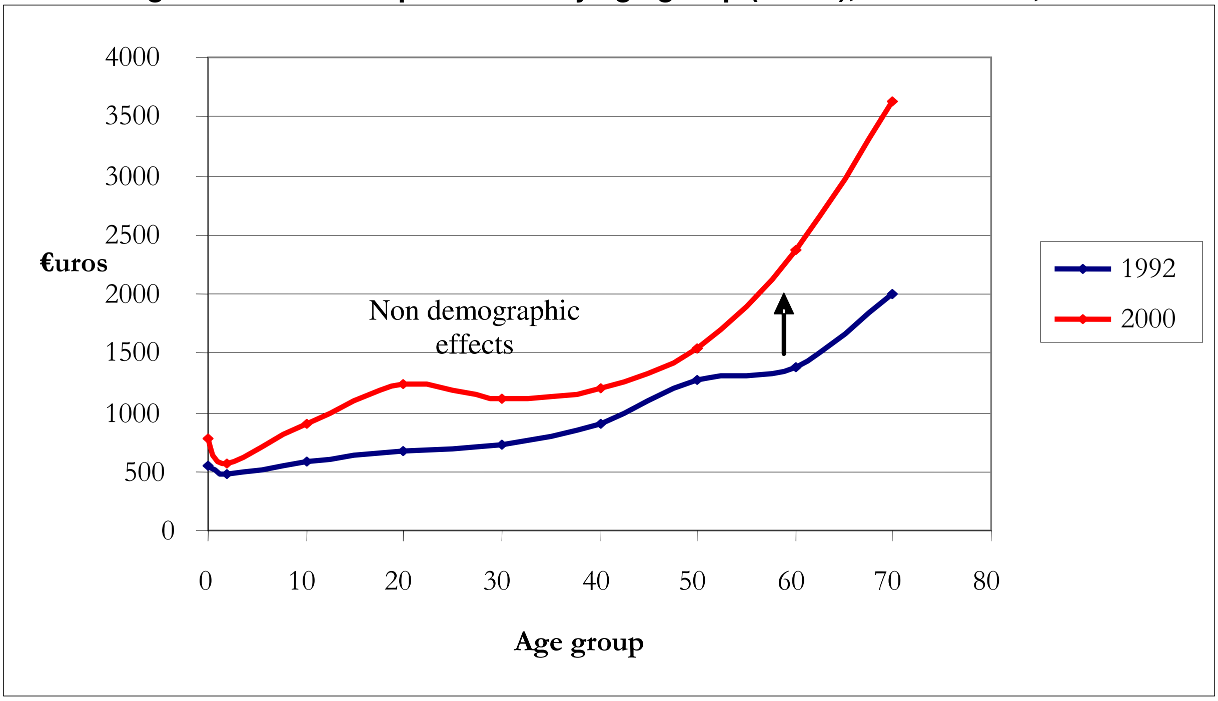
Source: OECD

Figure 2.2 Individual health expenditure by age group (Euros), France



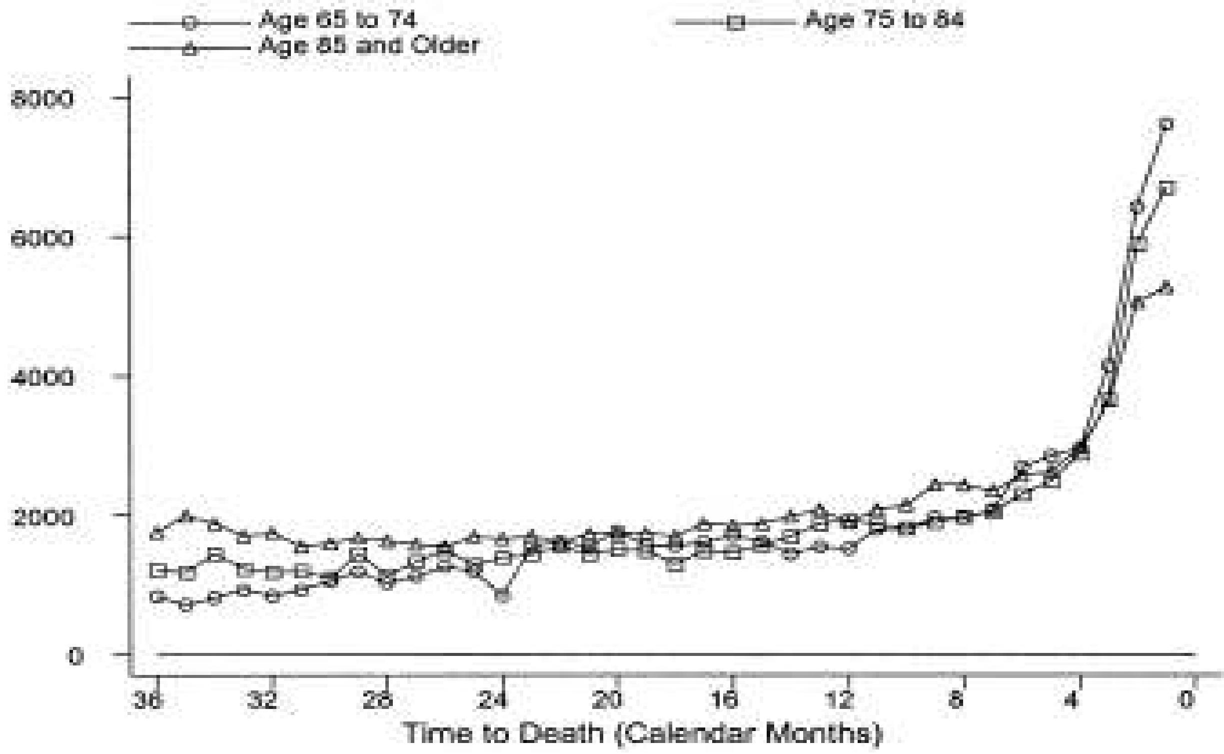
Source: Dormont, Grignon & Huber (2006)

Figure 2.3 Health expenditures by age group (euros), 1992 & 2000, France



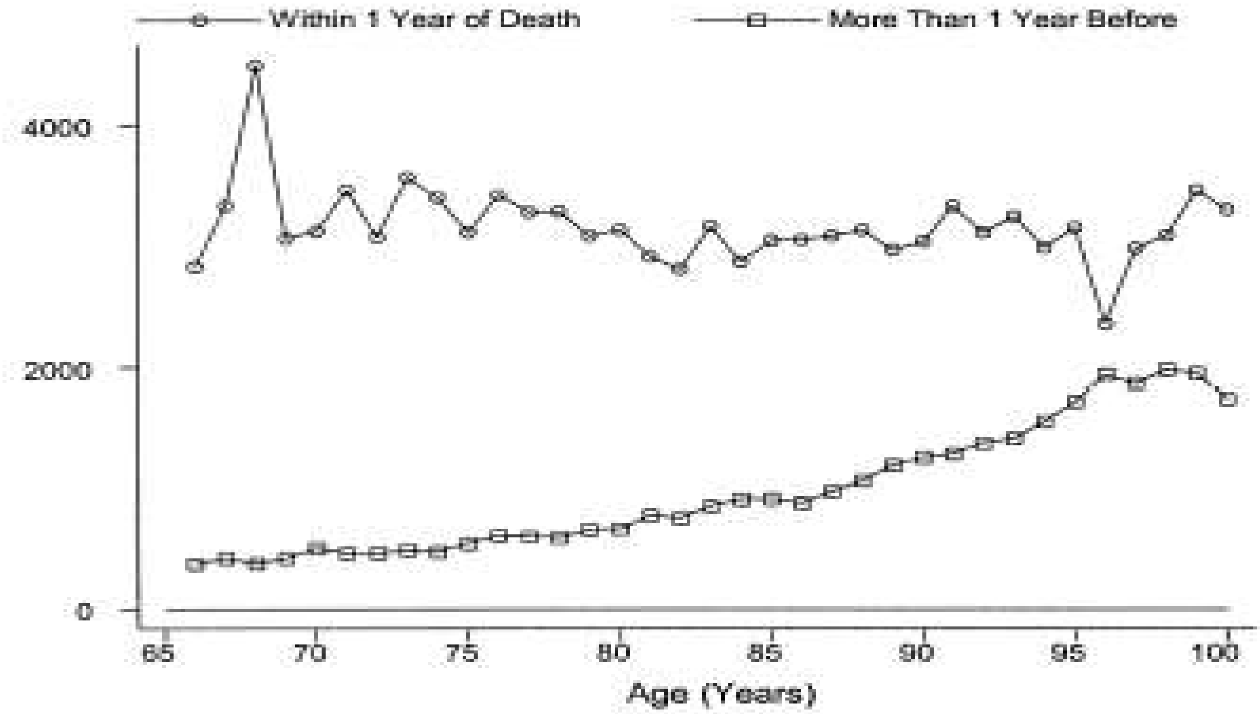
Source: Dormont, Grignon & Huber (2006)

Figure 2.4: Individual health expenditure ($) in relation to death proximity Medicare beneficiaries (USA)



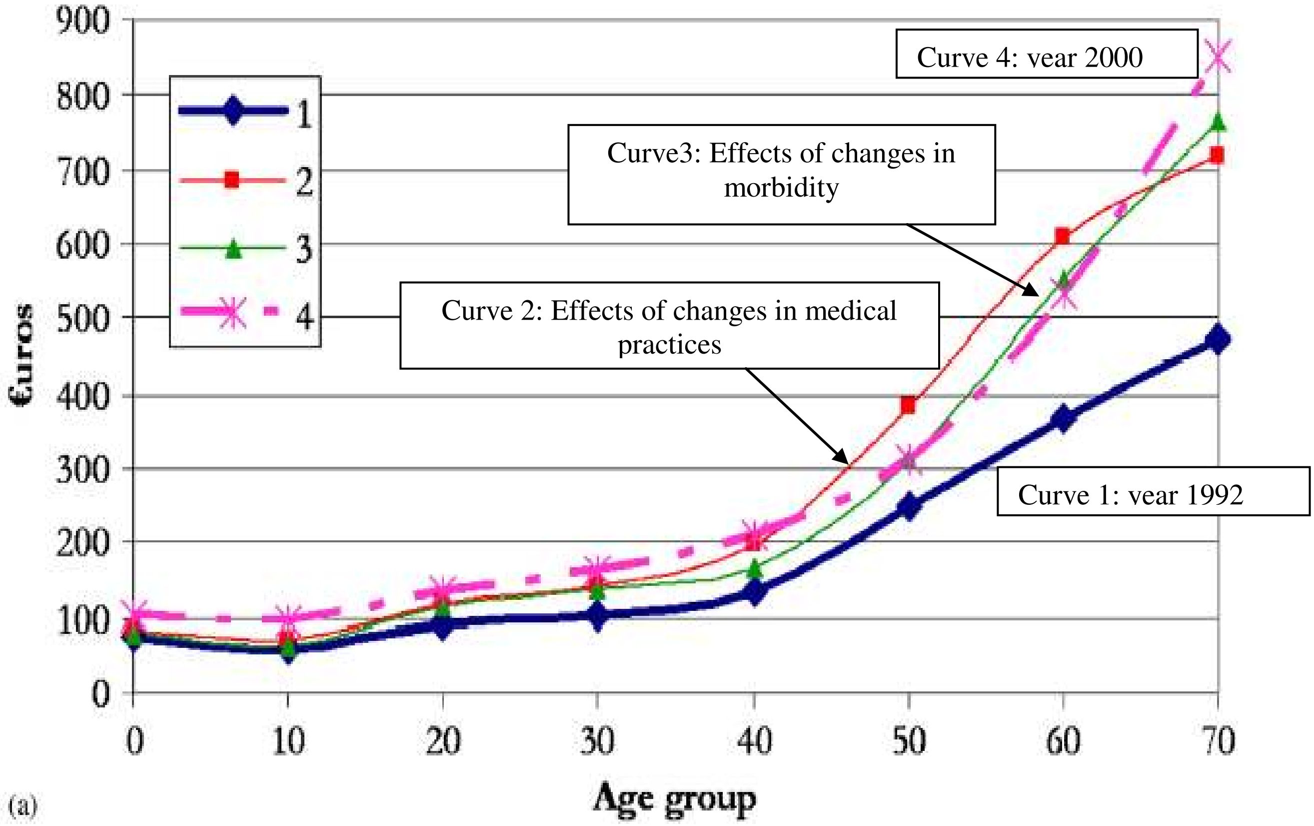
Source: Yang *et al.* (2003)

Figure 2.5: Individual health expenditure ($) by age group decedents versus survivors Medicare beneficiaries (USA)



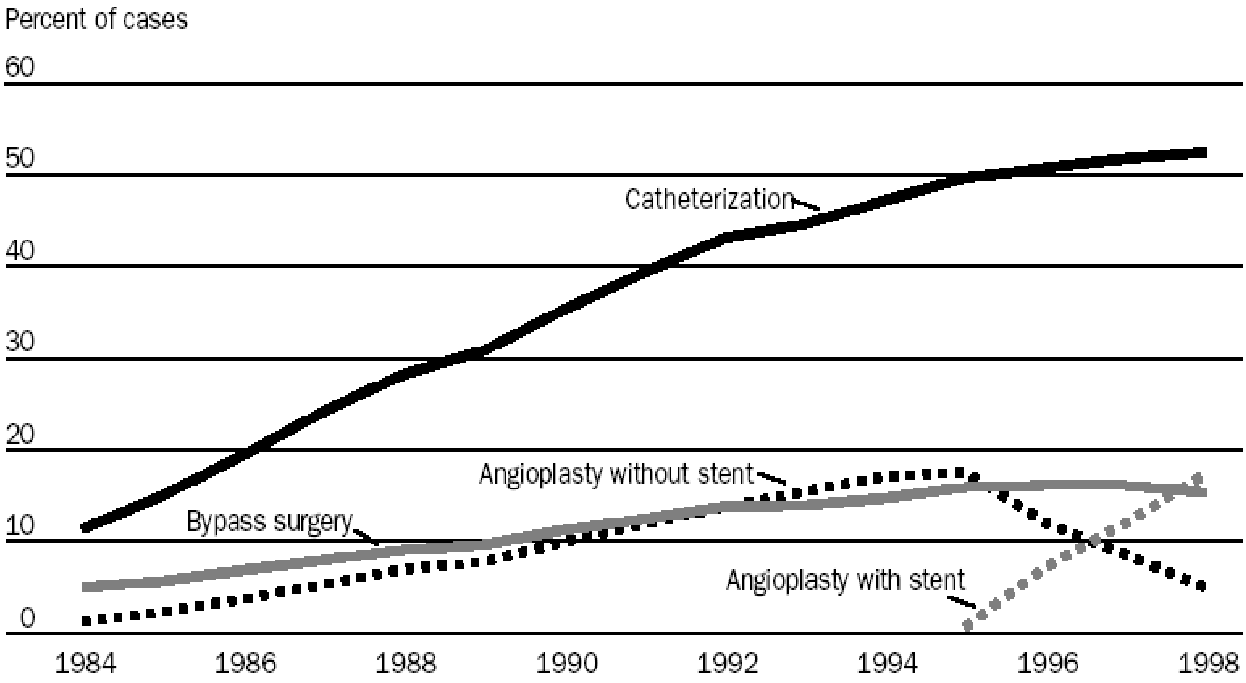
Source: Yang *et al.* (2003)

Figure 2.6: Decomposition of the drift of the age profile of individual Pharmaceutical expenditures, France (micro-simulations), 1992-2000



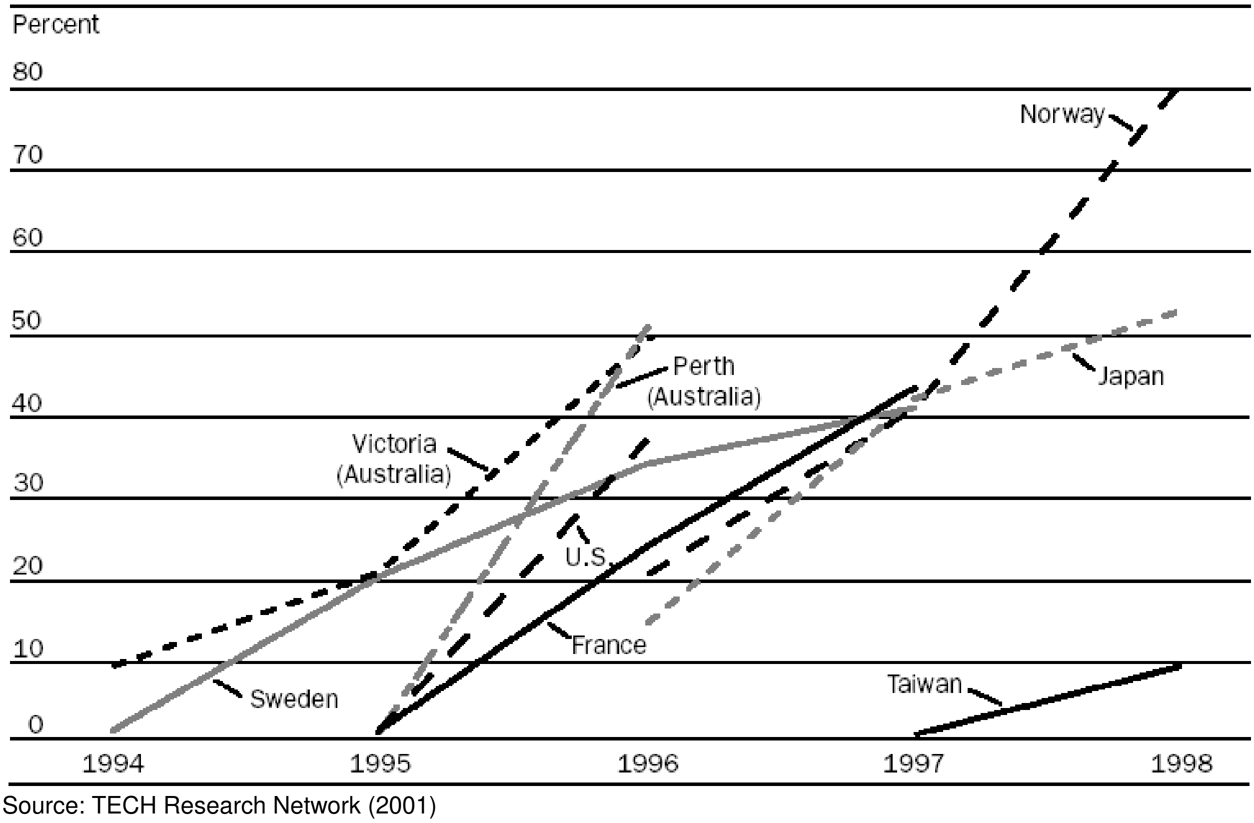
Source: Dormont, Grignon & Huber (2006)

Figure 2.7: Changes in the surgical treatment of heart attack USA, 1984-1998



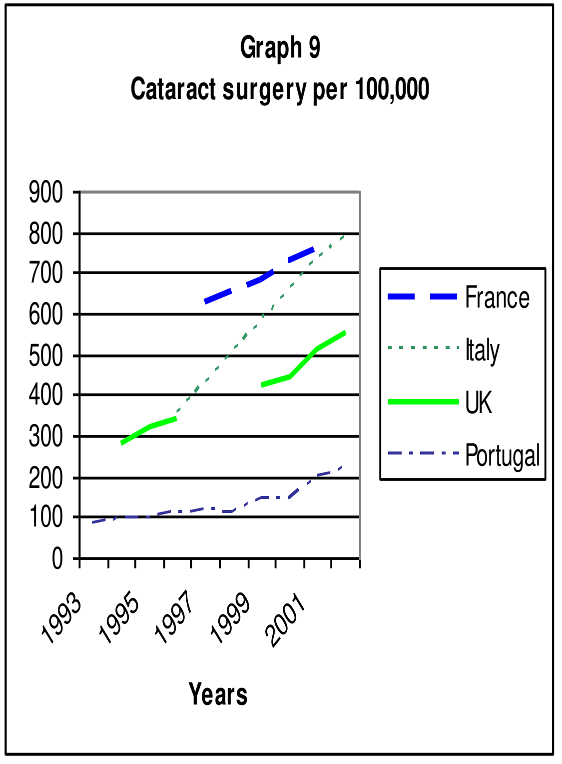
Source: Cutler & McClellan (2001)

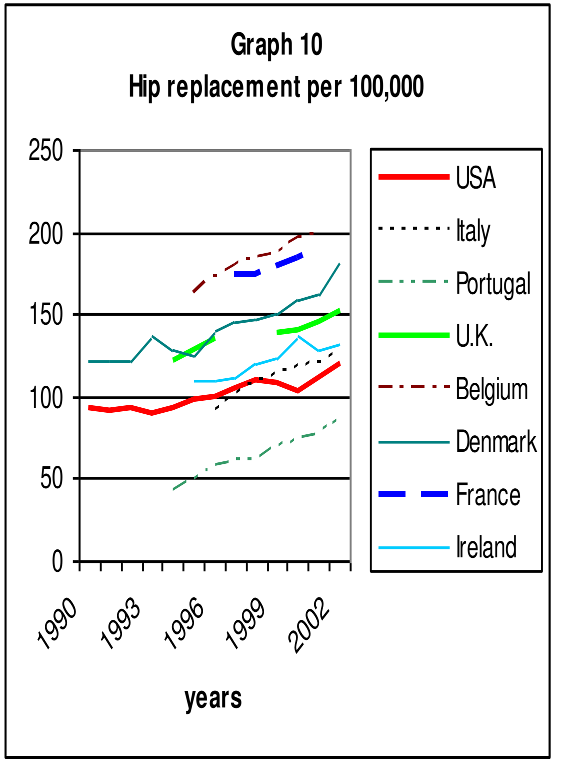
Figure 2.8: Share of angioplasty procedures involving stents in heart attack admissions Selected countries 1994-1998

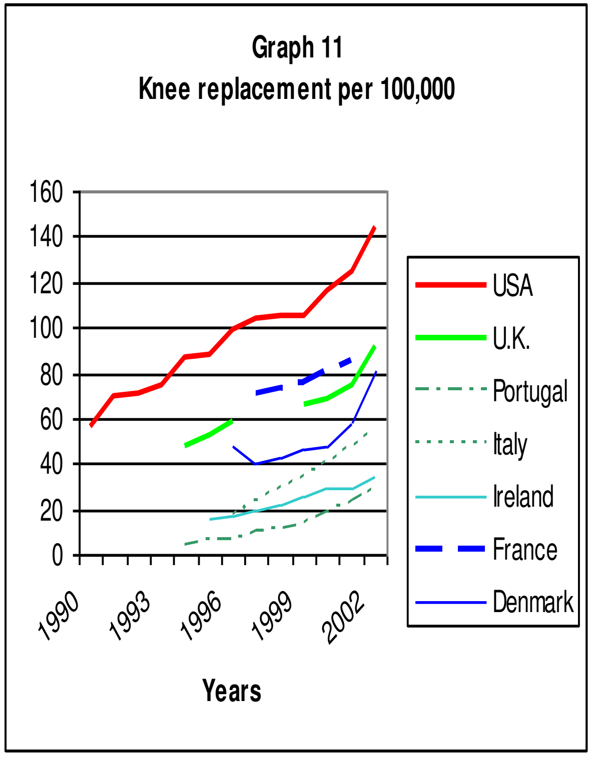


Source: TECH Research Network (2001)

Figures 2.9-2.11: Use of cataract surgery, hip and knee replacement in OECD countries

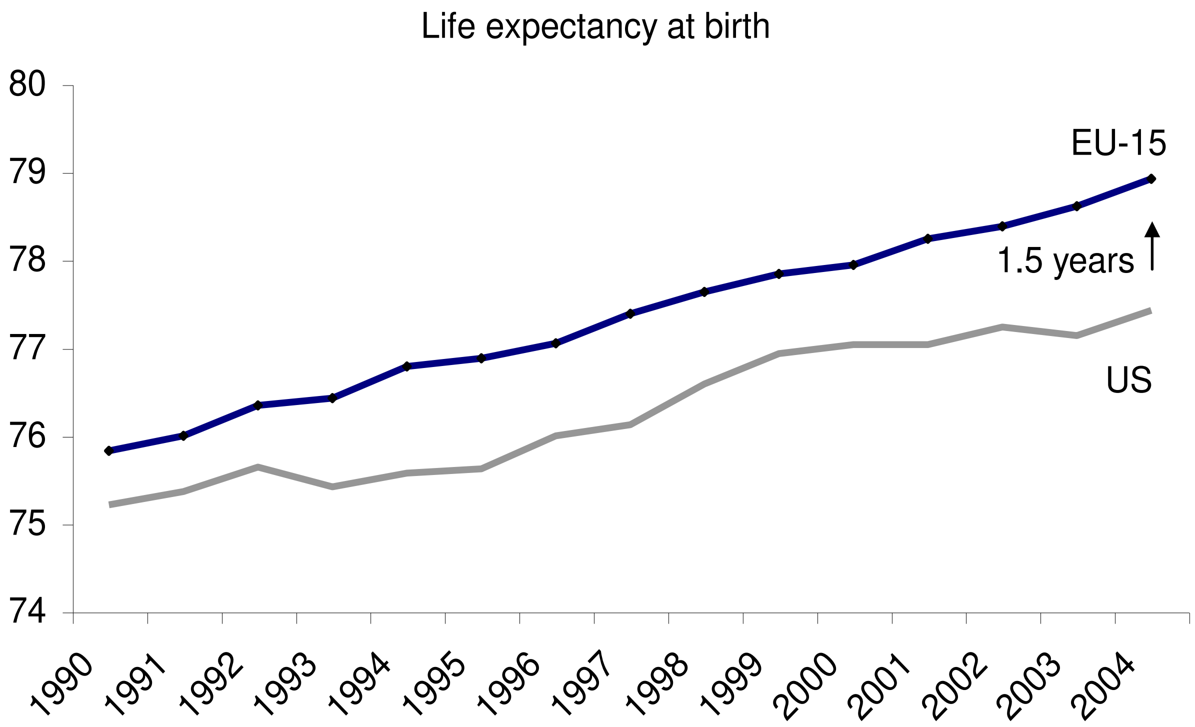






Source: OECD Health Data (2004)

Figure 2.12: Life expectancy at birth in the EU-15 and the US, 1990-2004



Source: World Bank (2006)

Diagram 2.1: Three possible scenarios for future changes in morbidity at a given age

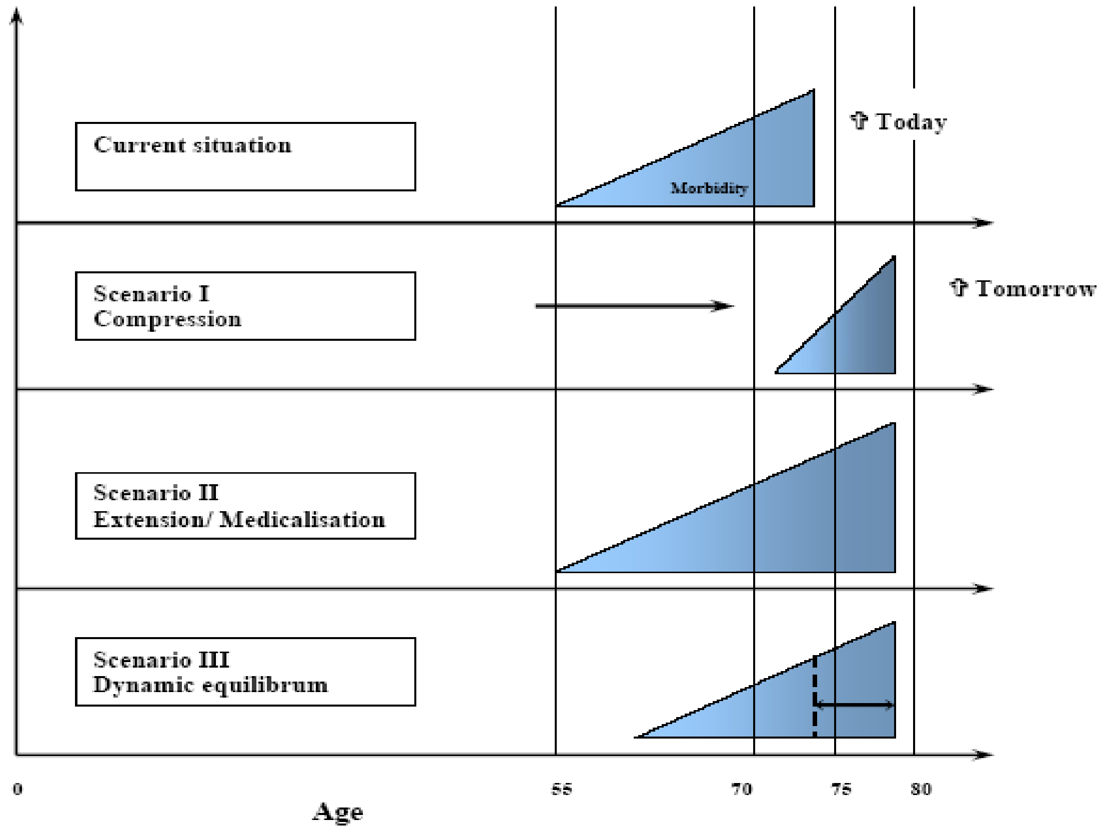
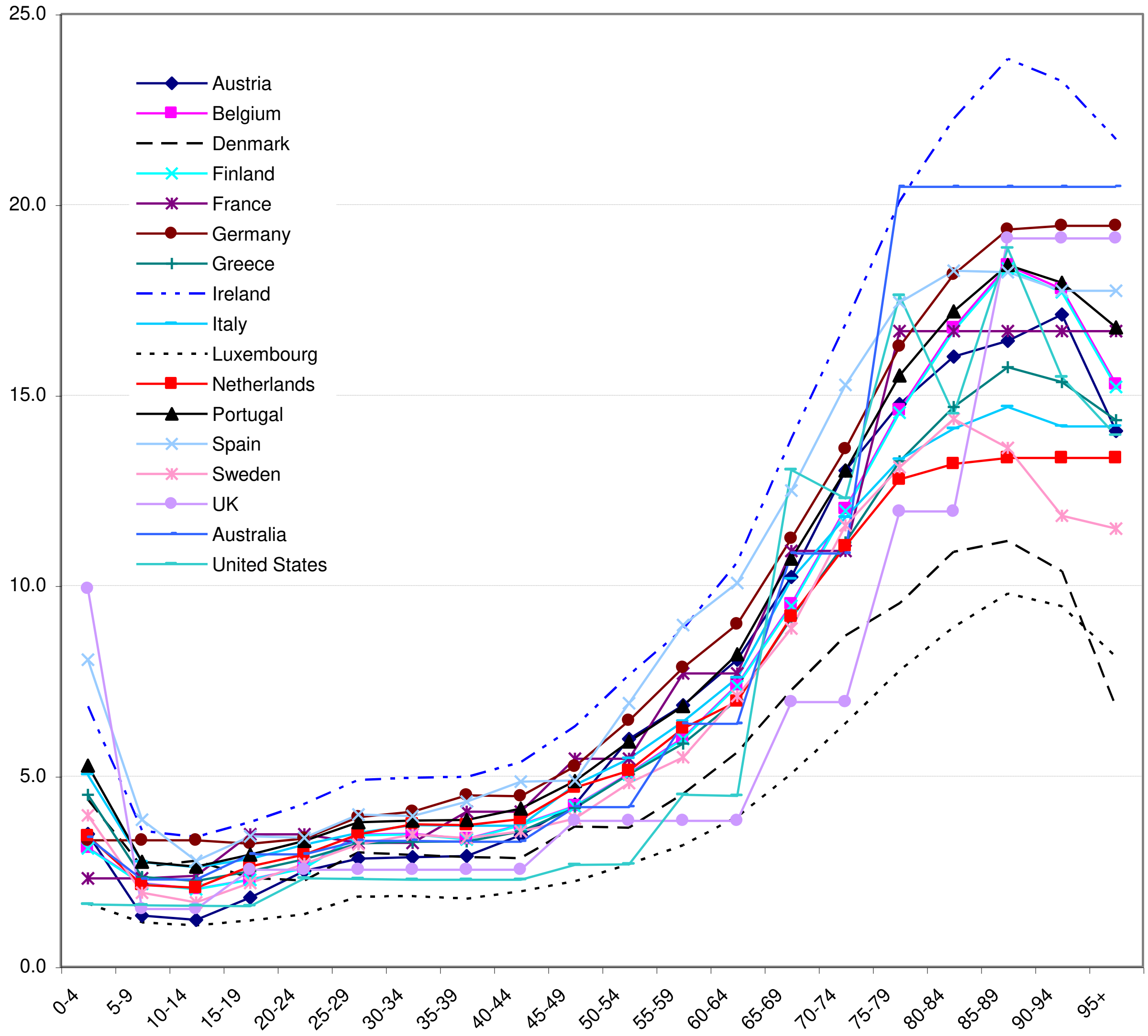


Figure 4.1 Public Health care expenditures by age Groups[1], 1999

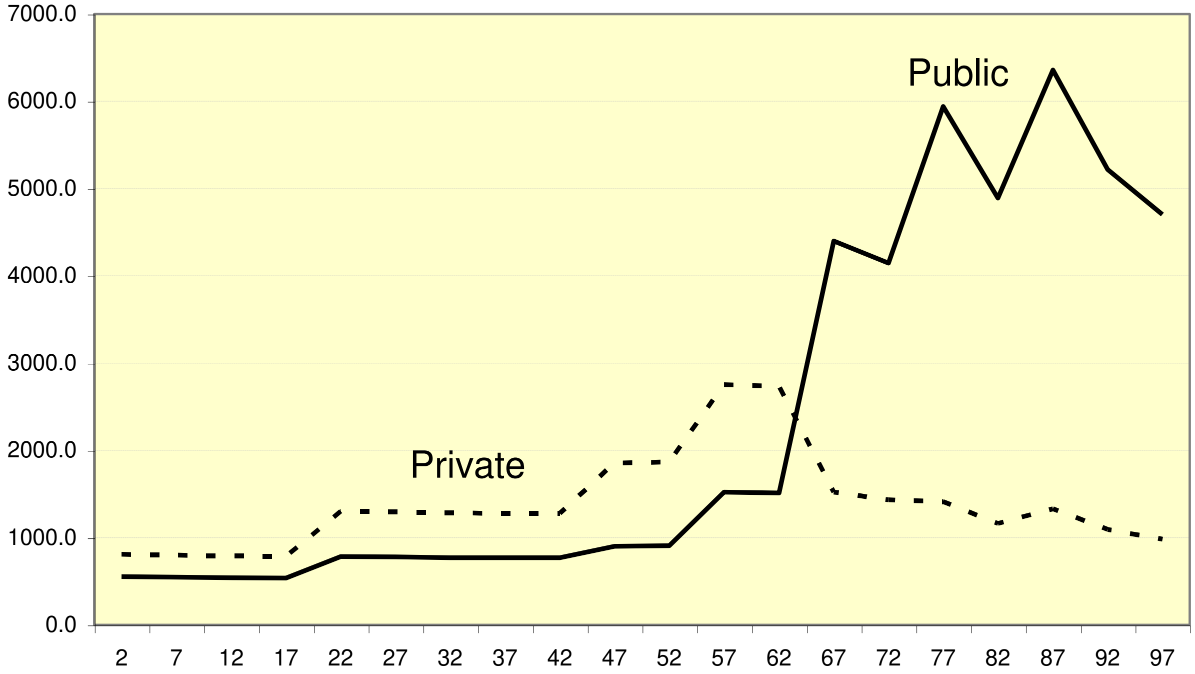
(in % of GDP per capita)



1. Expenditure per capita in each age group divided by GDP per capita, 1999.
Source: ENPRI-AGIR, national authorities and authors' calculations.

Figure 4.2 Public and private health expenditure per capita[1]
In US$ PPPs

United States

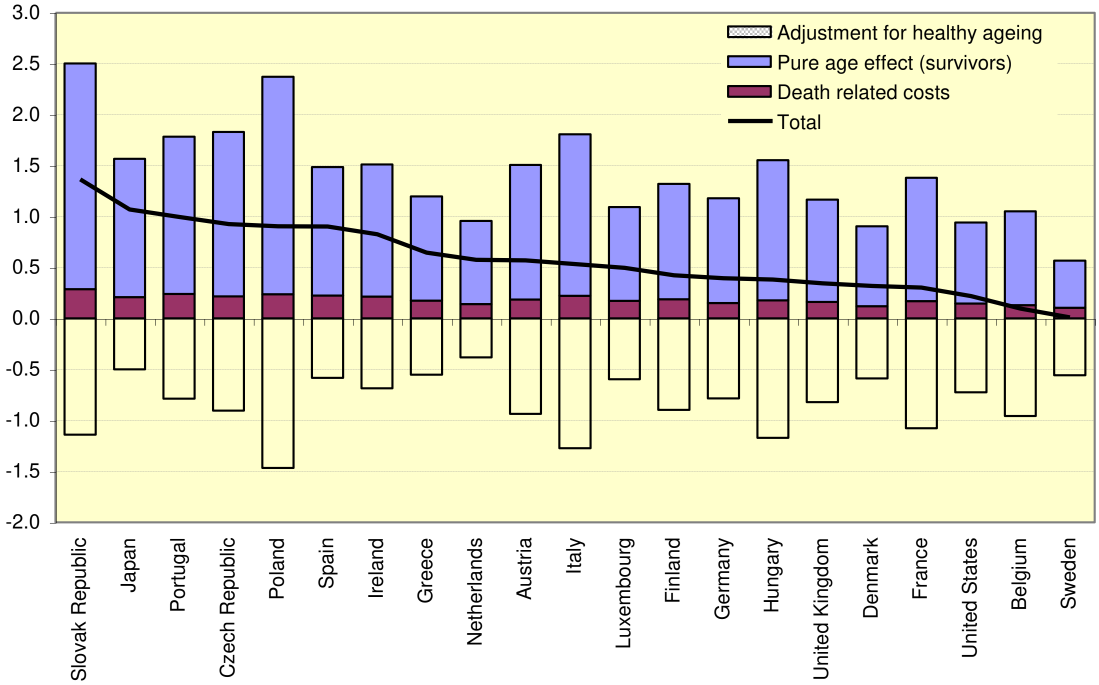


(1) Excluding long-term care
Source: US Centers for Medicare and Medicaid Services, Office of Actuary, National Health Statistics Group

Figure 4.3 Demographic effects on health care expenditure

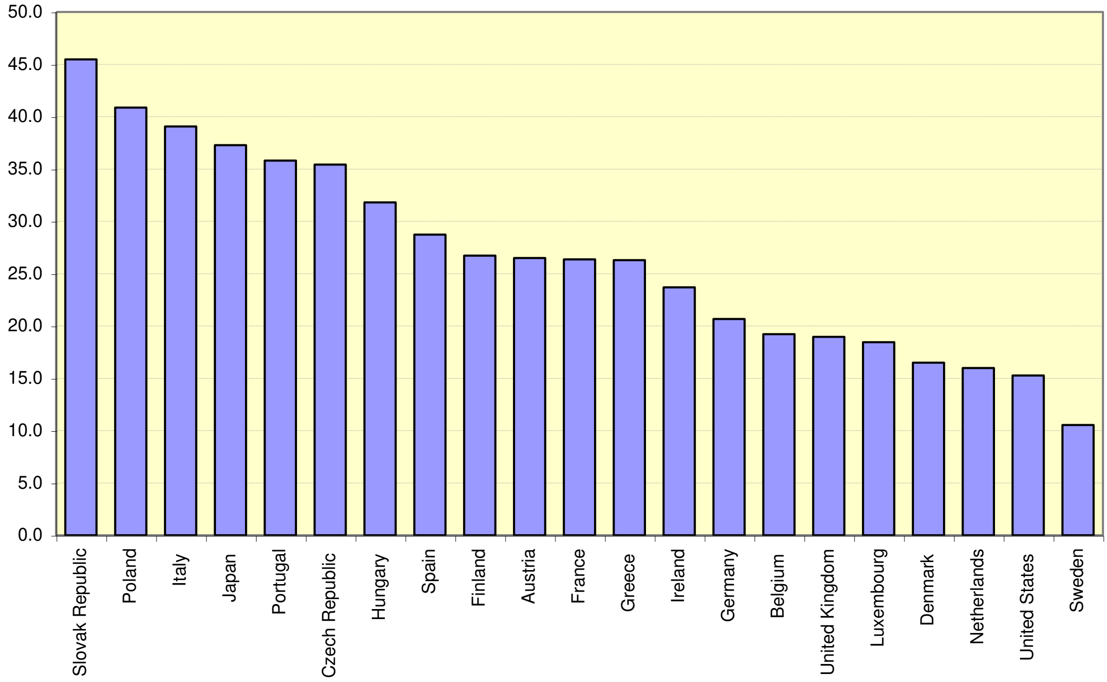
A. **Public health care expenditure**

Increase in % points of GDP 2005-2050



B. **Increase in the old-age dependency ratio between 2005 and 2050** [1]

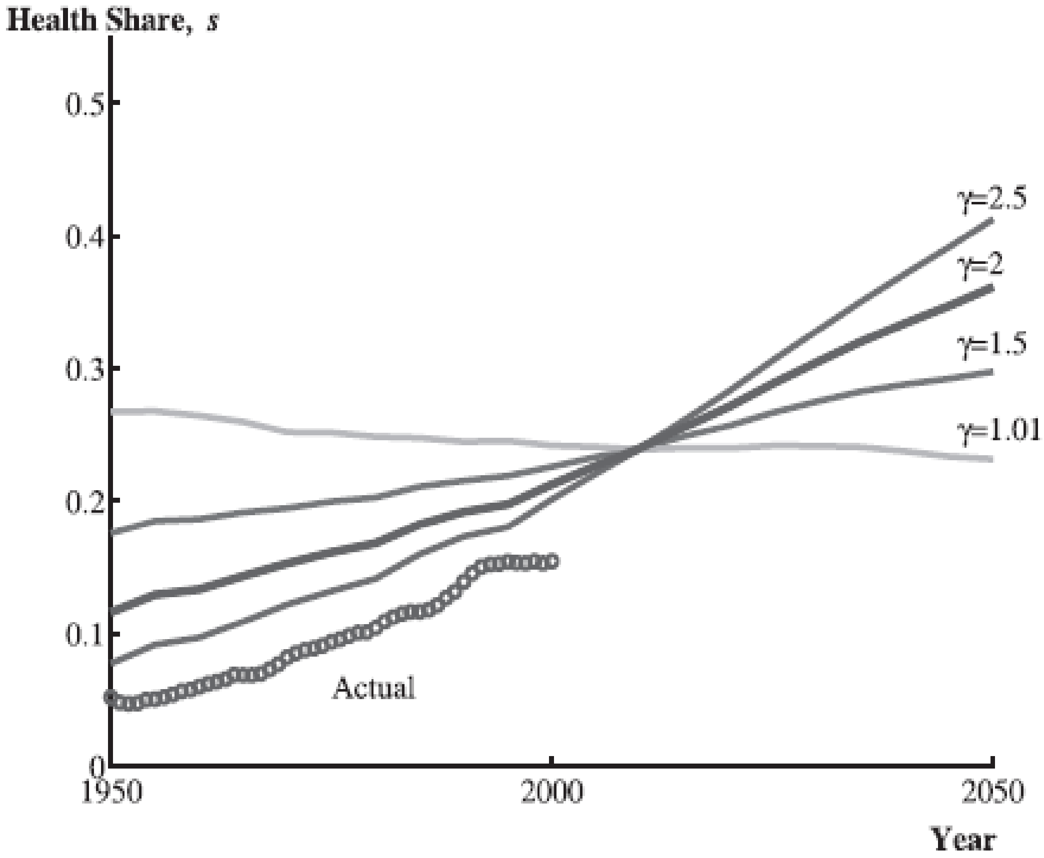
(In percentage points of working age population)



1. Ratio of population aged 65 and over to population aged 15-64.

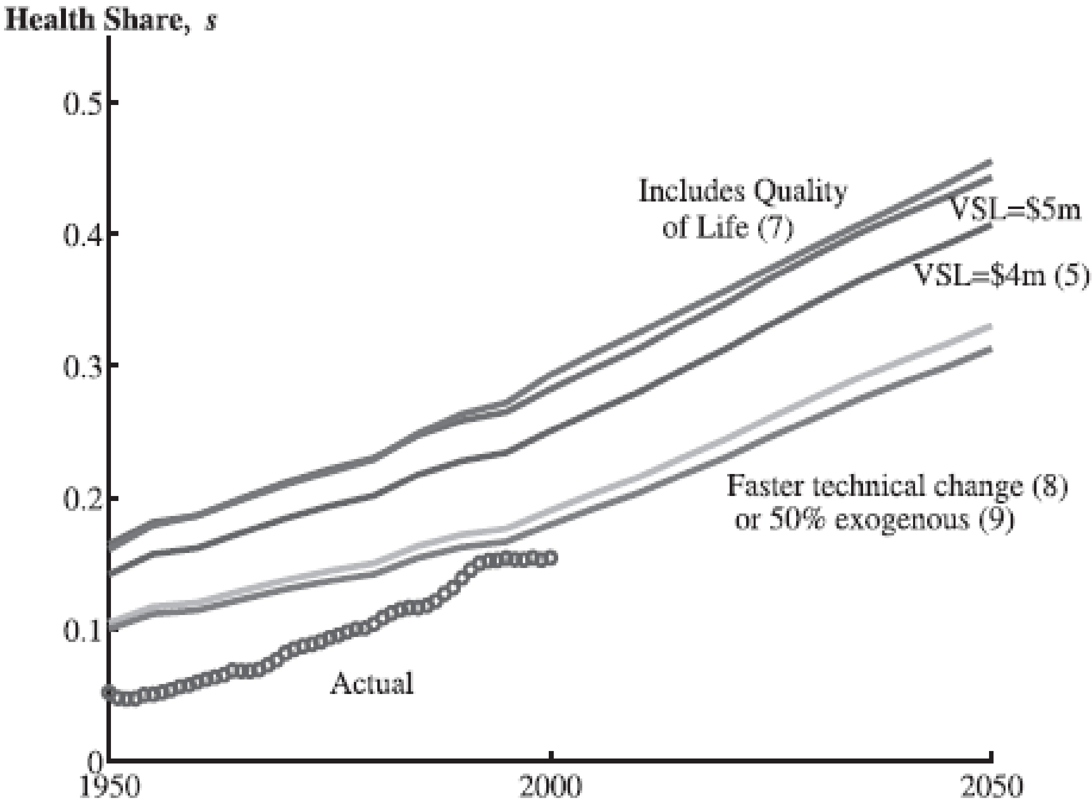
Source: Oliveira Martins and de la Maisonneuve (2006).

Figure 4.4: The increase in the optimal share of spending devoted to health care



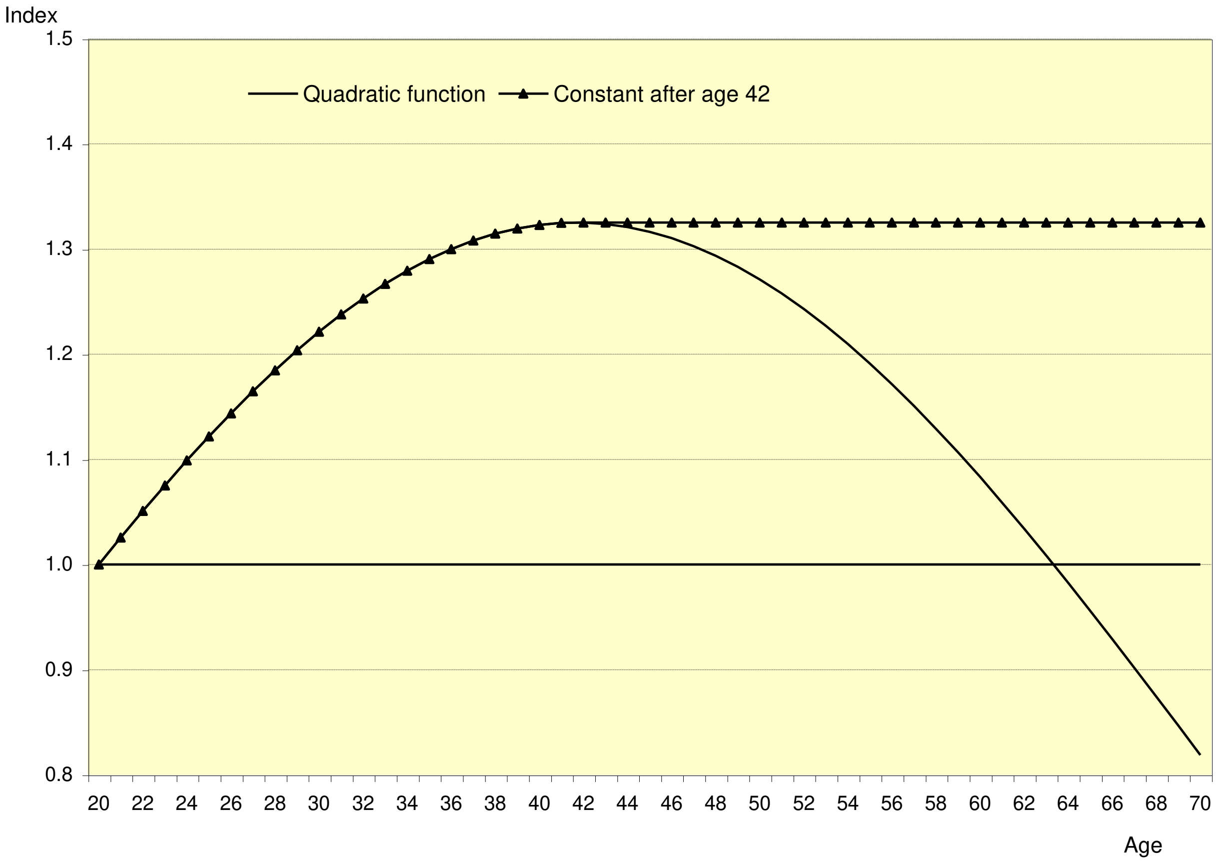
Source: Hall and Jones (2007)

Figure 4.5: The optimal share of spending devoted to health care



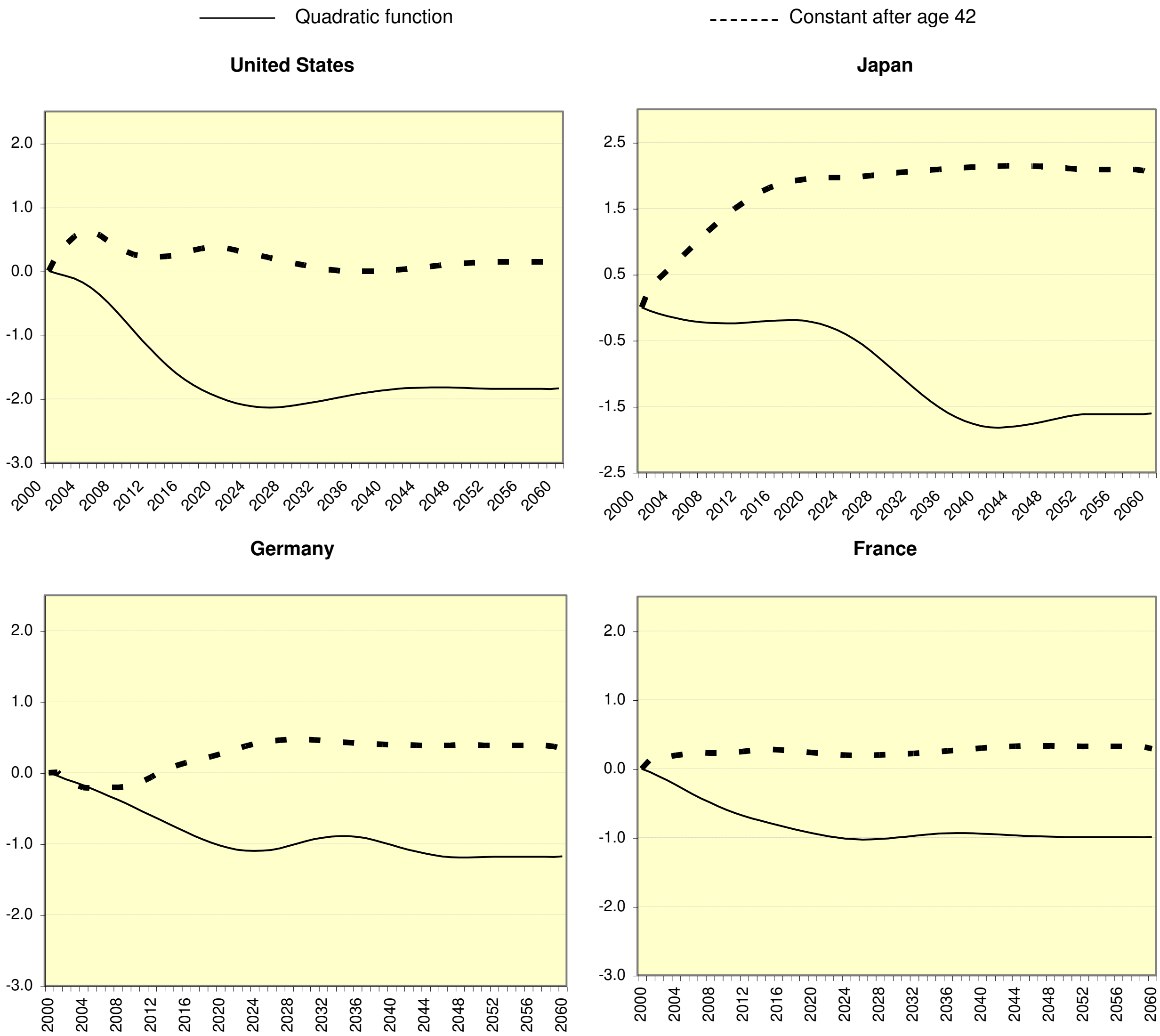
Source: Hall and Jones (2007)

Figure 5.1 Different age-productivity profiles



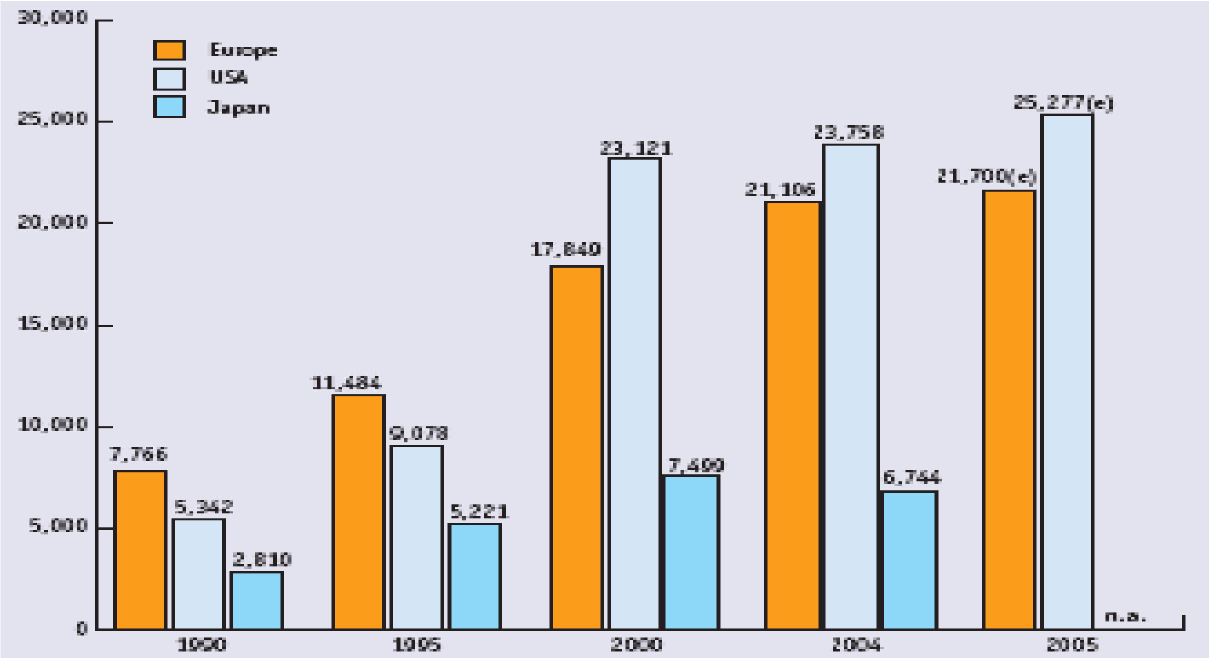
Source: Oliveira Martins et al. (2005)

Figure 5.2 Mechanical impact of ageing on productivity levels
(Per cent changes relative to 2000 levels)



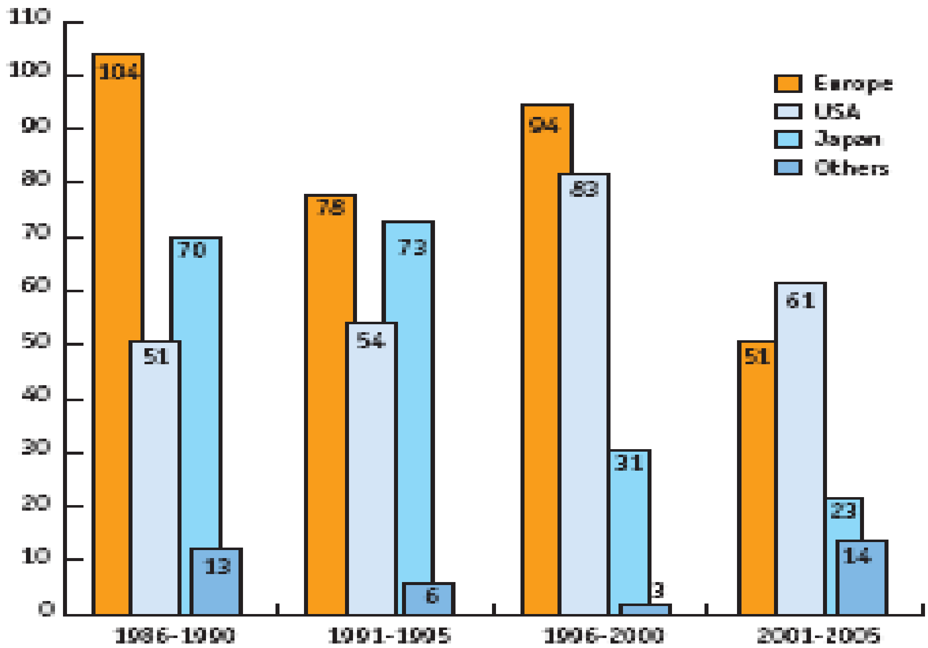
Note: Impact of multiplying the projected change in the structure of the labour force by productivity-age profiles of Figure 5.1.
Source: Oliveira Martins et al. (2005)

Figure 5.3 Pharmaceutical R&D expenditure in Europe, the US and Japan (million €, current exchange rates)



Source: EFPIA (2006)
Note: (e) stands for estimates.

Figure 5.4 New chemical or biological entities



Source: EFPIA (2006)

Table 1.1 Increases in life expectancy for different age groups

Change in years over the last 40 years [1]

	Females					Males				
	at birth	at age 40	at age 60	at age 65	at age 80	at birth	at age 40	at age 60	at age 65	at age 80
United States	6.4	4.5	3.6	3.4	2.3	7.5	5.5	4.1	3.5	1.6
Europe										
Austria	9.3	6.1	5.3	4.9	2.5	10.0	6.1	5.0	4.2	2.2
Belgium	7.3	5.7	5.1	4.7	2.3	6.9	4.9	3.8	3.1	1.4
Czech Republic	5.0	3.4	2.8	2.6	1.4	3.8	1.4	1.4	1.2	0.5
Denmark	4.9	3.3	3.0	3.0	n.a	4.1	2.2	1.8	1.5	n.a
Finland	8.5	7.0	6.1	5.6	2.6	8.7	6.4	4.8	4.0	1.6
France	9.1	6.4	5.8	5.3	3.0	8.2	5.3	4.6	4.0	2.3
Germany	8.3	5.7	4.9	4.6	2.4	7.8	4.5	3.7	3.1	1.6
Greece	8.2	5.7	4.6	4.1	1.2	8.2	3.5	3.2	2.9	1.4
Hungary	5.6	2.3	2.6	2.5	1.5	1.3	-2.6	-0.3	0.3	0.9
Ireland	7.3	5.0	3.8	3.3	n.a	6.1	3.7	2.5	2.0	n.a
Italy	10.1	n.a	n.a	n.a	n.a	9.1	n.a	n.a	n.a	n.a
Luxembourg	9.1	6.6	5.8	5.3	3.4	8.4	5.0	3.8	3.1	1.5
Netherlands	5.1	4.4	4.1	3.9	2.1	4.0	2.7	1.8	1.4	0.7
Poland	7.3	3.0	2.7	2.4	1.2	4.8	0.1	0.8	0.9	0.9
Portugal	12.9	4.4	3.5	3.0	n.a	11.5	3.2	2.3	1.7	n.a
Slovak Republic	4.7	n.a	2.2	1.9	n.a	0.8	n.a	-0.7	-0.3	n.a
Spain	10.5	6.4	5.3	4.8	2.0	8.1	4.0	3.3	3.0	1.3
Sweden	7.1	5.6	5.0	n.a	2.6	6.2	4.2	3.4	n.a	1.4
United Kingdom	6.5	4.9	4.1	3.8	2.3	7.5	5.7	4.4	3.7	1.7
EU15 average	*8.3*	*5.5*	*4.7*	*4.3*	*2.4*	*7.7*	*4.4*	*3.5*	*2.9*	*1.6*
Japan	14.4	10.6	9.1	8.3	4.7	12.4	8.1	6.6	5.9	3.1
Memo item:										
OECD average	*9.1*	*5.3*	*4.4*	*4.0*	*2.3*	*8.2*	*4.2*	*3.2*	*2.6*	*1.5*

1. 1960 (or 1961) to 2000 (or 1999).

Source: OECD Health Data.

Table 1.2. Comparison of past with projected gains in life expectancy

In number of years per decade

	(A) average gains 1960-2000	(B) projected gains 2000-2050[1]	Difference (B)-(A)
United States	1.7	1.4	-0.3
Europe			
Austria	2.4	1.4	-1.1
Belgium	1.8	1.6	-0.2
Czech Republic	1.1	1.3	0.2
Denmark	1.1	1.1	-0.1
Finland	2.2	1.5	-0.7
France	2.2	1.8	-0.4
Germany	2.0	1.2	-0.8
Greece	2.1	0.8	-1.3
Hungary	0.9	1.6	0.7
Ireland	1.7	0.9	-0.8
Italy	2.4	1.8	-0.6
Luxembourg	2.2	1.1	-1.1
Netherlands	1.1	0.5	-0.6
Poland	1.5	2.0	0.4
Portugal	3.1	1.1	-2.0
Slovak Republic	0.7	1.5	0.8
Spain	2.3	0.8	-1.5
Sweden	1.7	0.9	-0.7
United Kingdom	1.8	1.6	-0.2
EU15 average	*2.0*	*1.2*	*-0.8*
Japan	3.4	0.8	-2.6
Memo item:			
OECD average	*2.2*	*1.2*	*-0.9*

1. Except for Spain 2026, for Finland, Italy, Poland and United Kingdom 2030.

Source: OECD/DELSA Population database and OECD Health Data.

Table 2.1 Explaining Health Expenditure growth, France

Variation 1992-2000 (%)	Pharmaceutical expenditures	Total expenditures
Total demographic change of which:	**7.63**	**6.35**
part of structural change	*4.61*	*3.36*
part of growing size of population	*3.02*	*2.99*
Changes in practices for a given morbidity	**52.24**	**12.87**
Changes in morbidity	**- 9.24**	**- 9.74**
Changes in age dummies	14.11	-1.55
Other changes	2.53	45.95
Total variation	**67.27**	**53.89**

Source: Dormont, Grignon & Huber (2006)

Table2.2 Micro simulation results for three technologies by the Future Elderly Model.

	Intraventricular cardio defibrillator	**Prevention of Alzheimer's**	**Compound that extends life span (mythical)**
Annual cost Population concerned	$ 37,500 50 % AMI patients	$720 100 % Medicare recipients	$ 365 100 % Medicare recipients
Potential effect	Decrease in mortality rate : 10 %	Delay of 3 years in incidence => decrease in prevalence of 1/3	Increase in life expectancy: +10 years
Cost of one year of life saved	$ 100,000	$ 80,300	$ 8,800
Increase in total Spending for *Medicare in 2030*	+ 3.7 %	+ 8.0 %	+ 13.8 % if healthy + 70.4 % if unhealthy

Source : Goldman *et al.* (2005)

Table 3.1: Pooled OLS regressions: Per capita Public health expenditures

Variable	Group 1 [1]	Group 1 [2]	Group 1 [3]	Group 2 [1]	Group 2 [2]	Group 3 [1]	Group 3 [2]	Group 3 [3]
Per capita GDP	1.661	1.649	1.428	1.48	1.342	1.557	1.441	1.406
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.002	0.011		0.007		0.005	0.002
		[0.168]	[0.000]		[0.000]		[0.000]	[0.161]
POPY			0.762					-1.178
			[0.000]					[0.000]
POPP			0.278					-3.337
			[0.417]					[0.000]
POPO			1.332					-0.836
			[0.000]					[0.000]
Observations	773	773	773	614	614	557	557	557
Countries	30	30	30	19	19	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.2: Pooled OLS regressions: Per capita Private health expenditures

	Group 1			Group 2			Group 3			
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]	[4]
Per capita GDP	1.084	0.962	1.124	1.159	0.678	0.527	1.459	1.117	1.034	1.291
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.017	0.007		0.023	0.019		0.016	0.018	0.025
		[0.001]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
POPY			-0.791			-0.343			1.646	1.305
			[0.014]			[0.000]			[0.000]	[0.000]
POPP			0.387			2.651			2.471	1.348
			[0.629]			[0.000]			[0.000]	[0.029]
POPO			-1.213			-1.333			0.967	-0.045
			[0.000]			[0.000]			[0.006]	[0.847]
Gate-keeping										-0.309
										[0.000]
Public System										-0.206
										[0.000]
Integrated System										-0.736
										[0.000]
Observations	773	773	773	614	614	614	557	557	557	557
Countries	30	30	30	19	19	19	17	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.3: Pooled OLS regressions: Per capita Total health expenditures

	Group 1			Group 2				Group 3			
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Per capita GDP	1.471	1.426	1.345	1.441	1.269	1.243	1.311	1.559	1.459	1.456	1.502
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.007	0.008		0.008	0.005	0.005		0.004	0.004	0.006
		[0.000]	[0.000]		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
POPY			0.087			-0.997	-0.909			-0.093	-0.091
			[0.164]			[0.000]	[0.000]			[0.438]	[0.512]
POPP			-0.14			-2.215	-2.652			-0.268	-1.062
			[0.271]			[0.000]	[0.000]			[0.343]	[0.002]
POPO			0.318			-1.104	-1.111			-0.032	-0.179
			[0.000]			[0.000]	[0.000]			[0.810]	[0.000]
Gate-keeping							-0.119				-0.102
							[0.000]				[0.000]
Public System							-0.171				-0.104
							[0.000]				[0.000]
Integrated System							-0.101				-0.109
							[0.000]				[0.000]
Observations	773	773	773	614	614	614	614	557	557	557	557
Countries	30	30	30	19	19	19	19	17	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.4: One-way fixed effects regressions in the individual dimension Per capita Public health expenditures

	Group 1			Group 2			Group 3		
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
Per capita GDP	1.591	0.936	0.698	1.551	0.933	0.884	1.597	1.017	0.931
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.017	0.021		0.015	0.013		0.014	0.014
		[0.000]	[0.000]		[0.000]	[0.116]		[0.000]	[0.000]
POPY			1.074			0.175			0.241
			[0.000]			[0.111]			[0.000]
POPP			3.704			1.357			1.347
			[0.000]			[0.000]			[0.000]
POPO			1.668			0.814			0.858
			[0.000]			[0.000]			[0.000]
Observations	773	773	773	614	614	614	557	557	557
Countries	30	30	30	19	19	19	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.5: One-way fixed effects regressions in the individual dimension
Per capita Private health expenditures

	Group 1			Group 2			Group 3		
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
Per capita GDP	1.612	0.903	1.053	1.681	0.926	0.935	1.745	0.982	1.026
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.018	0.015		0.019	0.019		0.018	0.019
		[0.001]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
POPY			-0.905			-0.612			-0.406
			[0.000]			[0.001]			[0.022]
POPP			-2.224			-1.69			-1.351
			[0.000]			[0.000]			[0.009]
POPO			-1.619			-1.506			-1.351
			[0.000]			[0.000]			[0.000]
Observations	773	773	773	614	614	614	557	557	557
Countries	30	30	30	19	19	19	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.6: One-way fixed effects regressions in the individual dimension
Per capita Total health expenditures

	Group 1			Group 2			Group 3		
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
Per capita GDP	1.554	0.863	0.779	1.541	0.919	0.877	1.579	0.971	0.905
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.018	0.017		0.015	0.014		0.015	0.014
		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
POPY			0.039			0.098			0.194
			[0.686]			[0.275]			[0.049]
POPP			0.887			0.981			1.048
			[0.008]			[0.000]			[0.000]
POPO			0.361			0.477			0.581
			[0.002]			[0.000]			[0.000]
Observations	773	773	773	614	614	614	557	557	557
Countries	30	30	30	19	19	19	17	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.7: Two-way fixed effects regressions

Group 1 Group 2 Group 3

	Per capita Public health expenditures						Per capita Private health expenditures						Per capita Total health expenditures					
Variable	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]	[1]	[3]
Per capita GDP	0.952	0.719	0.927	0.935	0.972	0.967	0.921	1.047	0.976	0.969	1.089	1.131	0.876	0.814	0.917	0.923	0.949	0.944
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
POPY		1.097		-0.068		-0.01		-0.973		-0.506		-0.255		0.081		-0.067		0.026
		[0.000]		[0.471]		[0.918]		[0.000]		[0.003]		[0.127]		[0.384]		[0.414]		[0.759]
POPP		3.308		-0.013		0.03		-1.857		-1.175		-0.958		0.531		-0.038		0.114
		[0.000]		[0.954]		[0.899]		[0.005]		[0.009]		[0.040]		[0.184]		[0.837]		[0.565]
POPO		1.716		0.504		0.544		-1.685		-1.388		-1.224		0.421		0.264		0.362
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Observations	773	773	614	614	557	557	773	773	614	614	557	557	773	773	614	614	557	557
Countries	30	30	19	19	17	17	30	30	19	19	17	17	30	30	19	19	17	17

Notes: p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.8: One-way error component model in the individual dimension
Per capita Public health expenditures

	Group 1			Group 2				Group 3			
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Per capita GDP	1.591	1.121	0.913	1.547	0.981	0.971	0.992	1.596	1.074	1.045	1.053
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.013	0.016		0.014	0.011	0.01		0.013	0.011	0.011
		[0.000]	[0.000]		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
POPY			0.969			0.041	0.027			0.138	0.129
			[0.000]			[0.812]	[0.874]			[0.453]	[0.484]
POPP			3.247			0.896	0.943			0.902	0.958
			[0.000]			[0.046]	[0.035]			[0.053]	[0.040]
POPO			1.636			0.661	0.658			0.724	0.725
			[0.000]			[0.000]	[0.000]			[0.000]	[0.000]
Gate-keeping							0.015				0.009
							[0.857]				[0.922]
Public System							0.011				0.011
							[0.919]				[0.929]
Integrated System							0.184				0.181
							[0.003]				[0.008]
Observations	773	773	773	614	614	614	614	557	557	557	557
Countries	30	30	30	19	19	19	19	17	17	17	17

Note: The variance-covariance parameters are estimated by using the Swamy-Arora method. p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.9: One-way error component model in the individual dimension
Per capita Private health expenditures

	Group 1			Group 2				Group 3			
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Per capita GDP	1.599	0.938	1.102	1.675	0.913	0.918	0.922	1.745	0.987	1.023	1.035
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.018	0.014		0.019	0.02	0.019		0.018	0.019	0.019
		[0.000]	[0.000]		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
POPY			-0.933			-0.589	-0.596			-0.376	-0.369
			[0.000]			[0.063]	[0.060]			[0.262]	[0.270]
POPP			-2.292			-1.585	-1.677			-1.216	-1.299
			[0.000]			[0.054]	[0.042]			[0.153]	[0.126]
POPO			-1.618			-1.489	-1.517			-1.319	-1.334
			[0.000]			[0.000]	[0.000]			[0.000]	[0.000]
Gate-keeping							-0.239				-0.245
							[0.518]				[0.379]
Public System							-0.361				-0.059
							[0.435]				[0.871]
Integrated System							-0.672				-0.662
							[0.010]				[0.002]
Observations	773	773	773	614	614	614	614	557	557	557	557
Countries	30	30	30	19	19	19	19	17	17	17	17

Note: The variance-covariance parameters are estimated by using the Swamy-Arora method. p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 3.10: One-way error component model in the individual dimension
Per capita Total health expenditures

	Group 1			Group 2				Group 3			
Variable	[1]	[2]	[3]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Per capita GDP	1.543	1.039	0.947	1.537	0.955	0.919	0.913	1.578	1.058	0.994	1.003
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Trend		0.014	0.013		0.015	0.013	0.013		0.013	0.013	0.013
		[0.000]	[0.000]		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
POPY			-0.038			0.058	0.03			0.169	0.152
			[0.697]			[0.696]	[0.685]			[0.273]	[0.324]
POPP			0.591			0.837	0.846			0.879	0.814
			[0.015]			[0.030]	[0.029]			[0.025]	[0.037]
POPO			0.343			0.417	0.421			0.879	0.503
			[0.000]			[0.006]	[0.005]			[0.001]	[0.001]
Gate-keeping							-0.031				-0.033
							[0.803]				[0.707]
Public System							0.014				0.087
							[0.924]				[0.453]
Integrated System							0.017				0.016
							[0.841]				[0.805]
Observations	773	773	773	614	614	614	614	557	557	557	557
Countries	30	30	30	19	19	19	19	17	17	17	17

Note: The variance-covariance parameters are estimated by using the Swamy-Arora method. p-values are in []. Group 1 corresponds to an unbalanced panel of 30 OECD countries for the period 1970-2002; Group 2 corresponds to a nearly balanced panel of 19 OECD countries; Group 3 corresponds to Group 2 excluding Luxembourg and Netherlands. POPY is the share of young (0-14), POPP is middle-age (15-54) and POPO is old-age people (55-74) over the total population.

Table 4.1 Projection of total Health Expenditures, scenario I

Residual at 1% per year (with no transversality condition) and income elasticity 1

	Health expenditure as a % of GDP		Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Health expenditure as a % of GDP
	2000	2005	Increase in % points of GDP 2005-2025						Increase in % points of GDP 2005-2050						2050
United States	12.0	14.3	0.1	0.8	-0.5	0.0	1.7	2.1	0.1	1.1	-1.0	0.0	4.4	4.7	19.0
Europe															
Austria	8.1	8.3	0.1	0.8	-0.6	0.0	1.7	2.1	0.2	1.9	-1.3	0.0	4.4	5.2	13.4
Belgium	7.2	9.4	0.1	0.7	-0.7	0.0	1.7	1.7	0.1	1.3	-1.3	0.0	4.4	4.5	13.9
Czech Republic	6.4	7.1	0.1	1.0	-0.6	0.0	1.7	2.3	0.2	2.3	-1.3	0.0	4.4	5.6	12.7
Denmark	5.8	6.3	0.1	0.7	-0.6	0.0	1.7	2.0	0.1	1.1	-0.8	0.0	4.4	4.8	11.1
Finland	4.2	4.8	0.1	1.2	-0.6	0.0	1.7	2.4	0.2	1.6	-1.3	0.0	4.4	4.9	9.8
France	7.9	9.3	0.1	0.9	-0.7	0.0	1.7	2.0	0.2	1.7	-1.5	0.0	4.4	4.8	14.0
Germany	9.0	9.3	0.1	0.8	-0.6	0.0	1.7	2.0	0.2	1.4	-1.1	0.0	4.4	4.9	14.2
Greece	9.3	9.4	0.1	0.7	-0.4	0.0	1.7	2.1	0.2	1.4	-0.8	0.0	4.4	5.3	14.7
Hungary	6.8	7.9	0.1	1.0	-0.8	0.0	1.7	2.1	0.2	1.9	-1.6	0.0	4.4	4.9	12.8
Ireland	5.7	6.6	0.1	0.7	-0.3	0.0	1.7	2.2	0.2	1.8	-1.0	0.0	4.4	5.5	12.1
Italy	7.1	7.7	0.1	1.0	-0.7	0.0	1.7	2.1	0.2	2.2	-1.8	0.0	4.4	5.1	12.8
Luxembourg	4.4	6.5	0.1	0.5	-0.5	0.0	1.7	1.8	0.2	1.3	-0.8	0.0	4.4	5.1	11.6
Netherlands	6.5	7.8	0.1	0.9	-0.4	0.0	1.7	2.3	0.1	1.1	-0.5	0.0	4.4	5.2	13.0
Poland	5.3	6.3	0.1	1.5	-0.8	0.0	1.7	2.5	0.2	3.0	-2.1	0.0	4.4	5.6	11.9
Portugal	8.8	9.6	0.1	0.9	-0.6	0.0	1.7	2.1	0.2	2.2	-1.1	0.0	4.4	5.7	15.3
Slovak Republic	5.2	5.8	0.1	1.4	-0.8	0.0	1.7	2.5	0.3	3.1	-1.6	0.0	4.4	6.2	12.0
Spain	6.6	7.6	0.1	0.7	-0.4	0.0	1.7	2.2	0.2	1.8	-0.8	0.0	4.4	5.6	13.2
Sweden	5.5	6.1	0.1	0.5	-0.4	0.0	1.7	1.9	0.1	0.6	-0.8	0.0	4.4	4.4	10.5
United Kingdom	5.9	6.8	0.1	0.8	-0.7	0.0	1.7	1.9	0.2	1.4	-1.2	0.0	4.4	4.8	11.7
EU15 average	*6.8*	*7.7*	*0.1*	*0.8*	*-0.5*	*0.0*	*1.7*	*2.1*	*0.2*	*1.5*	*-1.1*	*0.0*	*4.4*	*5.1*	*12.8*
Japan	6.8	7.4	0.1	1.2	-0.4	0.0	1.7	2.6	0.2	1.9	-0.7	0.0	4.4	5.8	13.2

NB: Assumptions used in this scenario:
Healthy ageing : dynamic equilibrium (1 year gains in life expectancy = 1 year in good health)
Income elasticity = 1
Residuals = 1 with no transversality condition
Source : Oliveira Martins and de la Maisonneuve (2006) and author's calculations.

Table 4.2 Projection for Total Health care Expenditures, scenario II

Residual at 1% per year (with no transversality condition) and income elasticity 1.5

	Health expenditure as a % of GDP		Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Health expenditure as a % of GDP
	2000	2005	Increase in % points of GDP 2005-2025						Increase in % points of GDP 2005-2050						2050
United States	12.0	14.3	0.1	0.8	-0.5	1.6	1.7	3.7	0.1	1.1	-1.0	3.8	4.4	8.5	22.8
Europe															
Austria	8.1	8.3	0.1	0.8	-0.6	1.4	1.7	3.5	0.2	1.9	-1.3	3.1	4.4	8.3	16.6
Belgium	7.2	9.4	0.1	0.7	-0.7	1.4	1.7	3.2	0.1	1.3	-1.3	3.4	4.4	7.9	17.2
Czech Republic	6.4	7.1	0.1	1.0	-0.6	0.9	1.7	3.2	0.2	2.3	-1.3	1.9	4.4	7.6	14.6
Denmark	5.8	6.3	0.1	0.7	-0.6	1.4	1.7	3.4	0.1	1.1	-0.8	3.5	4.4	8.3	14.6
Finland	4.2	4.8	0.1	1.2	-0.6	2.0	1.7	4.4	0.2	1.6	-1.3	4.3	4.4	9.3	14.1
France	7.9	9.3	0.1	0.9	-0.7	1.1	1.7	3.0	0.2	1.7	-1.5	2.8	4.4	7.6	16.9
Germany	9.0	9.3	0.1	0.8	-0.6	1.0	1.7	3.0	0.2	1.4	-1.1	2.8	4.4	7.7	17.0
Greece	9.3	9.4	0.1	0.7	-0.4	2.1	1.7	4.2	0.2	1.4	-0.8	3.8	4.4	9.0	18.4
Hungary	6.8	7.9	0.1	1.0	-0.8	2.2	1.7	4.3	0.2	1.9	-1.6	4.4	4.4	9.3	17.2
Ireland	5.7	6.6	0.1	0.7	-0.3	4.2	1.7	6.4	0.2	1.8	-1.0	6.9	4.4	12.4	19.0
Italy	7.1	7.7	0.1	1.0	-0.7	1.1	1.7	3.2	0.2	2.2	-1.8	2.5	4.4	7.6	15.3
Luxembourg	4.4	6.5	0.1	0.5	-0.5	3.3	1.7	5.1	0.2	1.3	-0.8	5.7	4.4	10.7	17.2
Netherlands	6.5	7.8	0.1	0.9	-0.4	1.3	1.7	3.7	0.1	1.1	-0.5	3.5	4.4	8.7	16.5
Poland	5.3	6.3	0.1	1.5	-0.8	3.4	1.7	5.9	0.2	3.0	-2.1	6.4	4.4	12.0	18.2
Portugal	8.8	9.6	0.1	0.9	-0.6	2.0	1.7	4.1	0.2	2.2	-1.1	3.7	4.4	9.4	19.0
Slovak Republic	5.2	5.8	0.1	1.4	-0.8	1.6	1.7	4.1	0.3	3.1	-1.6	2.8	4.4	9.0	14.8
Spain	6.6	7.6	0.1	0.7	-0.4	1.1	1.7	3.3	0.2	1.8	-0.8	2.7	4.4	8.3	15.9
Sweden	5.5	6.1	0.1	0.5	-0.4	1.6	1.7	3.6	0.1	0.6	-0.8	4.0	4.4	8.4	14.5
United Kingdom	5.9	6.8	0.1	0.8	-0.7	1.6	1.7	3.6	0.2	1.4	-1.2	3.8	4.4	8.6	15.4
EU15 average	*6.8*	*7.7*	*0.1*	*0.8*	*-0.5*	*1.8*	*1.7*	*3.8*	*0.2*	*1.5*	*-1.1*	*3.8*	*4.4*	*8.8*	*16.5*
Japan	6.8	7.4	0.1	1.2	-0.4	0.8	1.7	3.5	0.2	1.9	-0.7	2.5	4.4	8.3	15.7

NB: Assumptions used in this scenario:
Healthy ageing : dynamic equilibrium (1 year gains in life expectancy = 1 year in good health)
Income elasticity = 1.5
Residuals = 1 with no transversality condition
Source : Oliveira Martins and de la Maisonneuve (2006) and author's calculations.

Table 4.3 Projection for Total Health Expenditures, scenario III

Residual at 2% per year (with no transversality condition) and income elasticity 1

	Health expenditure as a % of GDP		Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Health expenditure as a % of GDP
	2000	2005	Increase in % points of GDP 2005-2025						Increase in % points of GDP 2005-2050						2050
United States	12.0	14.3	0.1	0.8	-0.5	0.0	3.8	4.2	0.1	1.1	-1.0	0.0	11.4	11.6	25.9
Europe															
Austria	8.1	8.3	0.1	0.8	-0.6	0.0	3.8	4.2	0.2	1.9	-1.3	0.0	11.4	12.1	20.4
Belgium	7.2	9.4	0.1	0.7	-0.7	0.0	3.8	3.9	0.1	1.3	-1.3	0.0	11.4	11.5	20.8
Czech Republic	6.4	7.1	0.1	1.0	-0.6	0.0	3.8	4.4	0.2	2.3	-1.3	0.0	11.4	12.6	19.7
Denmark	5.8	6.3	0.1	0.7	-0.6	0.0	3.8	4.1	0.1	1.1	-0.8	0.0	11.4	11.8	18.1
Finland	4.2	4.8	0.1	1.2	-0.6	0.0	3.8	4.5	0.2	1.6	-1.3	0.0	11.4	11.9	16.7
France	7.9	9.3	0.1	0.9	-0.7	0.0	3.8	4.1	0.2	1.7	-1.5	0.0	11.4	11.7	21.0
Germany	9.0	9.3	0.1	0.8	-0.6	0.0	3.8	4.1	0.2	1.4	-1.1	0.0	11.4	11.9	21.1
Greece	9.3	9.4	0.1	0.7	-0.4	0.0	3.8	4.3	0.2	1.4	-0.8	0.0	11.4	12.2	21.6
Hungary	6.8	7.9	0.1	1.0	-0.8	0.0	3.8	4.2	0.2	1.9	-1.6	0.0	11.4	11.8	19.7
Ireland	5.7	6.6	0.1	0.7	-0.3	0.0	3.8	4.3	0.2	1.8	-1.0	0.0	11.4	12.4	19.0
Italy	7.1	7.7	0.1	1.0	-0.7	0.0	3.8	4.2	0.2	2.2	-1.8	0.0	11.4	12.0	19.8
Luxembourg	4.4	6.5	0.1	0.5	-0.5	0.0	3.8	3.9	0.2	1.3	-0.8	0.0	11.4	12.0	18.5
Netherlands	6.5	7.8	0.1	0.9	-0.4	0.0	3.8	4.4	0.1	1.1	-0.5	0.0	11.4	12.1	19.9
Poland	5.3	6.3	0.1	1.5	-0.8	0.0	3.8	4.6	0.2	3.0	-2.1	0.0	11.4	12.5	18.8
Portugal	8.8	9.6	0.1	0.9	-0.6	0.0	3.8	4.2	0.2	2.2	-1.1	0.0	11.4	12.7	22.3
Slovak Republic	5.2	5.8	0.1	1.4	-0.8	0.0	3.8	4.6	0.3	3.1	-1.6	0.0	11.4	13.2	19.0
Spain	6.6	7.6	0.1	0.7	-0.4	0.0	3.8	4.3	0.2	1.8	-0.8	0.0	11.4	12.5	20.2
Sweden	5.5	6.1	0.1	0.5	-0.4	0.0	3.8	4.0	0.1	0.6	-0.8	0.0	11.4	11.3	17.4
United Kingdom	5.9	6.8	0.1	0.8	-0.7	0.0	3.8	4.0	0.2	1.4	-1.2	0.0	11.4	11.8	18.6
EU15 average	*6.8*	*7.7*	*0.1*	*0.8*	*-0.5*	*0.0*	*3.8*	*4.2*	*0.2*	*1.5*	*-1.1*	*0.0*	*11.4*	*12.0*	*19.7*
Japan	6.8	7.4	0.1	1.2	-0.4	0.0	3.8	4.7	0.2	1.9	-0.7	0.0	11.4	12.8	20.2

NB: Assumptions used in this scenario:
Healthy ageing : dynamic equilibrium (1 year gains in life expectancy = 1 year in good health)
Income elasticity = 1
Residuals = 2 with no transversality condition
Source : Oliveira Martins and de la Maisonneuve (2006) and author's calculations.

Table 4.4 Projection for Total Health care expenditures, scenario IV

Residual at 1% per year (with a transversality condition), income elasticity 1 and expansion of morbidity

	Health expenditure as a % of GDP		Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Death-related costs	Pure age effect (survivors)	Adjustment for healthy ageing	Income effect	Non-ageing residual effect	Total	Health expenditure as a % of GDP
	2000	2005	Increase in % points of GDP 2005-2025						Increase in % points of GDP 2005-2050						2050
United States	12.0	14.3	0.1	0.8	0.0	0.0	1.3	2.2	0.1	1.1	0.0	0.0	1.9	3.2	17.5
Europe															
Austria	8.1	8.3	0.1	0.8	0.0	0.0	1.3	2.2	0.2	1.9	0.0	0.0	1.9	4.0	12.2
Belgium	7.2	9.4	0.1	0.7	0.0	0.0	1.3	2.0	0.1	1.3	0.0	0.0	1.9	3.3	12.7
Czech Republic	6.4	7.1	0.1	1.0	0.0	0.0	1.3	2.4	0.2	2.3	0.0	0.0	1.9	4.4	11.5
Denmark	5.8	6.3	0.1	0.7	0.0	0.0	1.3	2.1	0.1	1.1	0.0	0.0	1.9	3.1	9.4
Finland	4.2	4.8	0.1	1.2	0.0	0.0	1.3	2.6	0.2	1.6	0.0	0.0	1.9	3.7	8.5
France	7.9	9.3	0.1	0.9	0.0	0.0	1.3	2.2	0.2	1.7	0.0	0.0	1.9	3.8	13.0
Germany	9.0	9.3	0.1	0.8	0.0	0.0	1.3	2.2	0.2	1.4	0.0	0.0	1.9	3.5	12.8
Greece	9.3	9.4	0.1	0.7	0.0	0.0	1.3	2.1	0.2	1.4	0.0	0.0	1.9	3.5	12.9
Hungary	6.8	7.9	0.1	1.0	0.0	0.0	1.3	2.4	0.2	1.9	0.0	0.0	1.9	4.0	11.9
Ireland	5.7	6.6	0.1	0.7	0.0	0.0	1.3	2.1	0.2	1.8	0.0	0.0	1.9	3.9	10.5
Italy	7.1	7.7	0.1	1.0	0.0	0.0	1.3	2.4	0.2	2.2	0.0	0.0	1.9	4.4	12.1
Luxembourg	4.4	6.5	0.1	0.5	0.0	0.0	1.3	1.9	0.2	1.3	0.0	0.0	1.9	3.4	9.9
Netherlands	6.5	7.8	0.1	0.9	0.0	0.0	1.3	2.3	0.1	1.1	0.0	0.0	1.9	3.2	11.0
Poland	5.3	6.3	0.1	1.5	0.0	0.0	1.3	2.9	0.2	3.0	0.0	0.0	1.9	5.1	11.4
Portugal	8.8	9.6	0.1	0.9	0.0	0.0	1.3	2.3	0.2	2.2	0.0	0.0	1.9	4.3	13.9
Slovak Republic	5.2	5.8	0.1	1.4	0.0	0.0	1.3	2.9	0.3	3.1	0.0	0.0	1.9	5.3	11.1
Spain	6.6	7.6	0.1	0.7	0.0	0.0	1.3	2.1	0.2	1.8	0.0	0.0	1.9	3.9	11.5
Sweden	5.5	6.1	0.1	0.5	0.0	0.0	1.3	1.9	0.1	0.6	0.0	0.0	1.9	2.7	8.8
United Kingdom	5.9	6.8	0.1	0.8	0.0	0.0	1.3	2.2	0.2	1.4	0.0	0.0	1.9	3.5	10.3
EU15 average	*6.8*	*7.7*	*0.1*	*0.8*	*0.0*	*0.0*	*1.3*	*2.2*	*0.2*	*1.5*	*0.0*	*0.0*	*1.9*	*3.6*	*11.3*
Japan	6.8	7.4	0.1	1.2	0.0	0.0	1.3	2.6	0.2	1.9	0.0	0.0	1.9	4.0	11.4

NB: Assumptions used in this scenario:
Expansion of morbidity : gains in life expectancy do not translate into years in good health
Income elasticity = 1
Residuals = 1 with a transversality condition
Source : Oliveira Martins and de la Maisonneuve (2006) and author's calculations.

Table 4.5 Estimated marginal cost of saving a life

Age	1950	1980	2000	Robust maximum, 2000	Per year of life saved, 2000	Growth rate, 1950–2000
0–4	10	160	590	(790)	8	7.8
10–14	270	2,320	9,830	(13,110)	152	7.2
20–24	1,170	3,840	8,520	(11,360)	155	4.0
30–34	500	2,120	4,910	(6,540)	108	4.6
40–44	160	740	1,890	(2,520)	52	4.9
50–54	70	330	1,050	(1,400)	39	5.4
60–64	50	280	880	(1,180)	47	5.9
70–74	40	280	790	(1,050)	67	6.2
80–84	40	340	750	(1,000)	125	6.1
90–94	50	420	820	(1,090)	379	5.6

Source: Hall and Jones (2007)

Table 5.1 The size of pharmaceutical markets (€ million)

	1999	2000	2001	2002	2003
EU-15	72,094	29,962	90,100	96,825	103,142
US	124,261	163,439	197,351	208,970	194,061
Japan	50,246	62,606	59,744	55,736	52,092

Source: European Commission (2006)

Table 5.2 Shares of USPTO-granted pharmaceutical patents by countries based on the nationality of the assignee (A) and location of the inventor (I)

	1974-1983			1984-1993			1994-2003		
	Assignee	Inventor	I-A	Assignee	Inventor	I-A	Assignee	Inventor	I-A
EU	28.3%	30.9%	2.6%	27.3%	29.2%	1.9%	23.1%	24.8%	1.7%
USA	59.0%	52.3%	-6.7%	55.2%	50.8%	-4.4%	60.1%	57.3%	-2.8%
Japan	9.3%	9.4%	0.2%	13.4%	13.6%	0.1%	9.2%	9.3%	0.2%

Source: EC (2006)

Table 5.3 Shares of patent citations of USPTO-granted pharmaceutical patents by countries based on the nationality of the assignee (A) and location of the inventor (I)

	1974-1983			1984-1993			1994-2003		
	Assignee	Inventor	I-A	Assignee	Inventor	I-A	Assignee	Inventor	I-A
EU	23.57%	25.50%	1.92%	19.43%	21.33%	1.90%	17.47%	19.06%	1.59%
USA	63.71%	59.33%	-4.38%	67.12%	63.52%	-3.60%	70.39%	68.13%	-2.26%
Japan	9.26%	8.99%	-0.27%	9.55%	9.64%	0.09%	6.00%	6.07%	0.07%

Source: EC (2006)

Table 5.4: Biopharmaceutical Patent citations

	1974-1983	1984-1993	1994-2003
USA			
Patent count	8,943	14,860	36,271
Number of citations*(1)*	6,680	40,332	201,510
Mean number of citations	0.75	2.71	5.56
of which:			
US->US	74.70%	73.00%	74.70%
US->EU	18.29%	18.51%	18.82%
US->JP	5.09%	7.06%	6.77%
EU-25			
Patent count	5,238	8,525	1,5904
Number of citations*(1)*	3,153	15,004	46,396
Mean number of citations	0.60	1.76	2.92
of which:			
EU->EU	55.25%	51.18%	43.64%
EU->US	36.12%	38.83%	49.11%
EU->JP	5.49%	7.96%	7.49%
Japan			
Patent count	1,582	3,845	5,678
Number of citations*(1)*	959	5,833	11,746
Mean number of citations	0.61	1.52	2.07ì
of which:			
JP->JP	40.88%	36.57%	35.96%
JP->US	33.99%	37.68%	42.23%
JP->EU	23.46%	23.90%	22.26%

Source: EC (2006)