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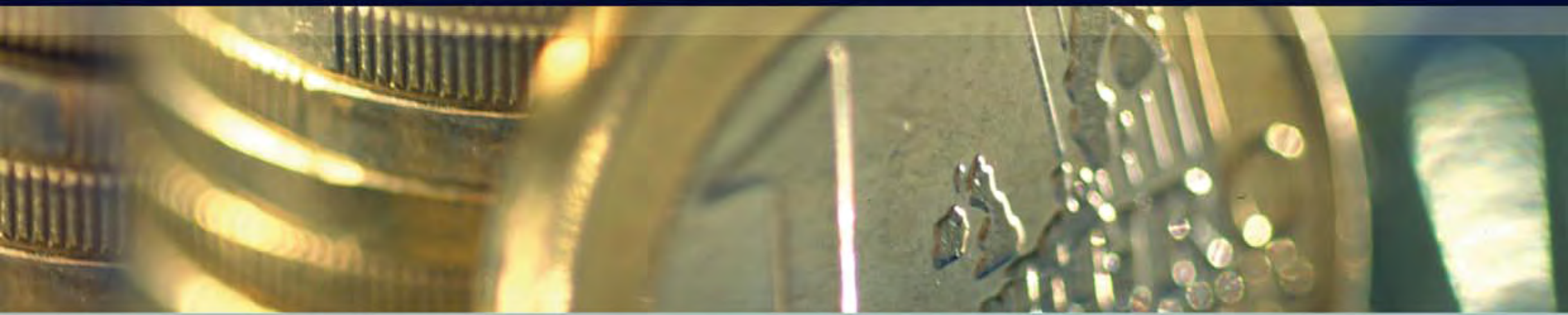

The role of technology in health care expenditure in the EU

Kamil Dybczak and Bartosz Przywara

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1. Introduction

A common principle of all highly developed societies is the provision of at least basic health care services to each member of society by the public sector free of charge. As a result, in most industrialised countries, and notably in all Member States of the European Union, health care constitutes a significant share of public expenditure. At the present time, total expenditure on health care in the EU accounts for between 4 and 11% of GDP, out of which between 3 and 9% of GDP is financed from public sources[1]. Moreover, as it accounts for between 10 and 18 % of total government spending[2], health care is therefore among the most significant items of social public expenditure.

Public expenditure on health care has been growing over most of the second half of the 20th century, not only in absolute terms, but also in relation to the national income. This practically constant increase was a result of profound economic, institutional, social and technological changes which occurred all over the industrialised world. Such changes led to an increase in public awareness, expectations, and demand for health care on the one hand, and to improvements in capacity of both the medical industry and providers allowing them to offer better, faster and more reliable, albeit often more expensive, health care on the other hand.

There are a large number of factors which affect health care expenditure but the complexity of their interaction makes it difficult to draw precise lines which would identify their individual impact on health care expenditure growth. However, a number of econometric tools exist that can be used to make an approximate estimation of the relative impact of the respective variables on health care production and spending. This can be done on the basis of past observations but the main interest for policymakers, industry and the general public lies in the explanatory power of such an exercise and its usefulness in predicting future developments in the health care sector. Such is the purpose of the joint European Commission-Economic Policy Committee (EC-EPC) long-term projections of age-related items of social expenditure[3], which has been the inspiration and methodological basis for the analysis presented in this publication.

Taking as a basis the fundamental methodology used to project public health care expenditure, including mainly demand-side factors, such as demographic structure, income and health status of the population, the paper proposes to expand the model into the supply side by adding a supplementary module assessing the future impact of technological progress on public health care spending. Following a thorough analysis of the literature it concludes that there are no scientifically reliable forecasts of the future developments in the medical

[1] Health including acute health care and long-term nursing care. Figures for 2007. Source: Eurostat.
[2] Figures for 2005. Cyprus with only 6% of general government outlays spent on health care is the only EU Member State beyond the indicated range. Source: European health for all database (HFA-DB), World Health Organisation Regional Office for Europe.
[3] The final report on the long-term budgetary projections is presented in European Commission and Economic Policy Committee (2009), while details of the methodologies and underlying data are discussed in European Commission and Economic Policy Committee (2008).

technology. Consequently, the only feasible way to project future evolution of spending driven by technological factors seems to be an extrapolation of the past trends, with all the caution required, while interpreting and using the results in the future policy debate.

The paper concentrates mainly on the impact of non-demographic factors, in particular on the impact of technology development on health care expenditure. Section 2 briefly summarizes the outcomes of the relevant literature on the main factors found to impact on health care expenditure. Section 3 presents the discussion of the available data and results of econometric specification of the interaction between a number of variables in determining health care spending. Section 4 describes how the results of that exercise are used to project the long-term impact of technological progress on health care expenditure, with the methodology based on the EC-EPC model. Finally, section 5 concludes with the possible interpretations of the results and the description of the caveats surrounding such types of exercises.

2. Drivers of health care costs – overview of the literature

Notwithstanding the huge effort invested in the analysis of health care expenditure development and its determinants, to-date neither theoretical analysis nor empirical studies have provided unanimous conclusions. Thus, despite the significant efforts, an analysis of aggregate health care expenditure is an ongoing research topic.

As for all public goods, the analysis of factors driving changes in health care expenditure differs, necessarily, between the micro and macro level. The existence of a number of legal and institutional restrictions regulating the provision of health care goods and services to the population constrains the functioning and alters the outcome of the market mechanisms driving individual citizens' and companies' behaviour at a micro level. In the context of health care, the universal health insurance coverage present - at least for a number of basic treatments - in practically all EU Member States, has arguably the largest impact on the individual behaviour of agents. In particular, universal coverage and high subsidies considerably reduce the elasticity of demand for health care with respect to both prices and income. In such a situation, while health care utilisation and spending is generally only linked to an individual's wealth to a limited degree, the market failure phenomena (moral hazard, information asymmetry) may drive patients to demand and providers to "produce" more health care than is justified by the actual health status. Those mechanisms do not work at the aggregate national level where income elasticity tends to be high, depending on the ability of the society to afford the high quality health care provided to each individual. On the other hand, even in the countries with the highest income, elasticity of overall public demand is limited by the budgetary caps, as health care is still mainly financed from public, limited sources[4]. In sum, the analysis of drivers behind the evolution in health care spending is far from straightforward and must clearly distinguish between the macro and micro level, and take account of a complex network of interactions between patients, providers and payers as well as the division between public and private sector.

The general approach to health care expenditure dates back to the seminal analysis by Newhouse (1977 and 1992). Using a decomposition of the health care expenditure growth, he

[4] It is difficult to assess price elasticity at the aggregate level, except for the price of health care relative to the prices in the other sectors of economy. In this sense prices in health care tend to increase faster than in the general economy due to the Baumol effect, described further.

identified a series of factors potentially responsible for a development in the health care expenditure to GDP ratio. The role of aggregate income, demographic structure, productivity differences across economic sectors and technological progress is discussed among others. In particular, Newhouse stresses the role of technological progress. The remaining factors are found to be possibly responsible for growth in health care expenditure, but their role appears to be rather limited.

Following Newhouse's research, a number of studies provided a quantitative analysis of the health care expenditure drivers, concentrating either on separate factors or aiming at finding the interactions between them.

2.1. Demographic structure

An ageing population is the most obvious factor behind increasing health care expenditure over the recent decades. Constantly growing life expectancy together with permanently low fertility rates have resulted in the gradual evolution of the demographic structure of populations that began with the last baby-boom period in the 1950's and 1960's and is not expect to shift sharply over the next decades. The effect of those changes has been a gradual increase in the share of older people in the population and – more recently – relative shrinkage of the young cohorts. This evolution has had an obvious impact on the demand for health care. Although the use of health care depends ultimately on the health status and not the age of a person itself, elderly people use health care more often and more intensively than young cohorts. Thus, the relative increase in the proportion of the elderly population contributes to the increase in demand for and expenditure on health care.

Whilst this intuitive relationship is supported by most researchers, its strength is controversial. Most econometric studies analysing the common impact of a series of factors attribute more importance to income, technology and institutional factors, agreeing that demographic change has a positive, though relatively minor impact on health care spending. Contributing to this stream, Oliveira Martins and de la Maisonneuve (2006) analysed the dynamics of health care expenditure by distinguishing between demographic and non-demographic factors. As the authors claim, the impact of demographic factors seemed to be quite weak while the impact of non-demographic factors prevailed over the last decades.

The group of non-demographic factors is usually represented by income growth, relative-price movements in the supply of health services and, arguably most significant but at the same time least understood, medical technology.

2.2. Income

Most studies agree that the link between health care expenditure and the demographic structure is becoming weaker over time, as, despite generally improving health status, the consumption of health care keeps increasing. This phenomenon is due to the growing share of health care expenditure both in household budgets and in the public government spending which, in turn, is driven by the increasing awareness of the health status, growing public expectations on the level of health care provision guaranteed by the state and growing availability of new technologies allowing to tackle new, previously untreatable, diseases. While it is generally agreed that the growth in national income brings about the increase in health care spending, the strength of this relationship, or the value of income elasticity of demand, remains uncertain. As mentioned in the previous section, a different perspective must be taken when analysing the issue at individual and aggregate level. At the individual level, the existence of health insurance makes the demand for health care, to a large extent[5], independent of an individual's income, which means that demand is highly inelastic. At the aggregate level, the situation is different: health care spending depends mainly on the level and composition of government expenditure, which evolves in line with the wealth of society. Nonetheless, here again, existing studies have not managed to provide a clear estimate of the income elasticity coefficient. On one hand, cross-country comparisons may intuitively suggest that health care is a luxury good, especially in the countries where health care is not yet a universally available public good (for example, the growth in health expenditure in the south-European countries in the 1960s and 1970s exceeded the rate of growth in more advanced economies of the EU, but also their own GDP growth rate). On the other hand, more recent time series data suggest the opposite, especially as universal provision of health care is a fact in most industrialised countries today (GDP growth can hardly be solely responsible for faster increase in health care expenditure). Econometric studies do not provide clear evidence for one or the other hypothesis, finding elasticity coefficients either greater or smaller than one[6].

The reasons for such variability in results could be due either to the different data sources, or to methodological problems. The outcomes of the empirical research studies were deeply influenced by advances in modern econometric techniques, e.g. time series and panel data techniques. In other words, the use of new methods and techniques often changed the view on existing theories and its empirical validation.

Early analyses of the health care expenditure focused mainly on the relationship between this variable and national income, e.g. Culyer (1990) and Hitiris and Posnett (1992). Although additional variables were proposed by theory, the empirical work did not verify their usefulness in predicting health care expenditure in general. Thus, the existence of a positive correlation between health care expenditure and aggregate income was the main and only robust conclusion at that time. As rather simple estimation techniques were applied in the above mentioned studies, the estimated parameters have been found to be potentially biased.[7] In particular, the income elasticity was very often found to be higher than one, indicating that health care may have features of a luxury good (e.g. Newhouse, 1977).

The progress in time series and panel data techniques, e.g. development of, in particular, unit root and cointegration techniques, has brought new insights when analysing health care expenditure development. A number of papers demonstrated that the results obtained and conclusions proposed at that time could have been flawed due to so-called spurious regression between variables analysed or omitted variable bias.

Initially, the analysis of stationarity and cointegration was carried out in a country-by-country manner, i.e. the properties of each cross-section representative were studied separately. Several papers tested a degree of integration of particular variables, demonstrating that the variables, usually involved when analysing health care expenditure, are not stationary. As a consequence of non-stationarity in the time series, a battery of alternative cointegration tests were applied in order to assess if standard estimation techniques can be applied or further adjustment to variables and techniques are needed. Although the conclusions proposed are far from uniform, it seems that, based on the above mentioned studies, health care expenditure

[5] At least for the basic treatments where public insurance covers all (or large part) of the fees.
[6] For an overview of econometric studies, together with estimated income elasticities, see Getzen (2000).
[7] See Dreger and Reimers (2005) or van Elk, Mot and Franses (2009) for a discussion on the possible omission variable bias in early studies.

and national income appear to be non stationary and cointegrated, see Hansen and King (1994), Blomqvist and Carter (1996), Gerdtham and Lothgren (2000).

As the concepts of stationarity and cointegration have only been practically introduced into the panel data framework in the course of the last decade, they have been used extensively in health care expenditure analysis in order to make use of the increased number of observations and degree of freedom of pooled data, see for example Okunade and Murthy (2002), Ariste and Carr (2002), Dreger and Reimers (2005), van Elk et al (2009) among others. Once again, no general conclusion has been proposed by the empirical research. Despite this fact, it seems that the bulk of analyses tend to claim that health care expenditure and aggregate income are integrated of degree one and cointegrated.

The fact that health economists have still not agreed upon either main conclusions or methods has been confirmed recently, as Jewell et al (2003), Carrion-i-Silvestre (2005) and Clemente et al (2004) extended the analysis of health care expenditure and aggregate income by introducing structural breaks. The authors propose, and document, that health care expenditure are mainly affected by government decisions and other exogenous factors such as a business cycle position etc. Not surprisingly, after introducing several structural breaks, both health care expenditure and aggregate income are found to be stationary[8].

2.3. Relative prices in the health care sector and Baumol effect

As explained by Newhouse (1992), health care spending has grown faster than income, which indicates that the effects of technology and relative prices seem to play a significant role in upwards pressure on health-care expenditure.

A possible explanation of the strong growth in the ratio of health care expenditure to GDP seems to be the so-called Baumol effect. In his study, Baumol (1976) distinguishes between two types of sectors depending on the level of labour productivity growth, i.e. high and low productivity sectors. In general, labour intensive sectors, such as health care, are characterised by a low labour productivity growth. As, in the long-run, nominal wages in both sectors are related, wages in the low productivity sector rise to the same extent as in the high productivity sector, which results in growing price differentials between the two. In addition, if demand for the low productivity sector good is inelastic, as in the case of health care, the ratio of expenditure on these goods to GDP increases over time. Following this argument, one can explain increasing health care expenditure to GDP over time. The difficulty consists in the lack of reliable sectoral estimates of labour productivity, but may be partially offset by decomposing the overall spending growth into increases in volume and price. Occurrence of strong increases in prices relative to the other sectors may be evidence of the productivity gap and thus existence of Baumol effect. However, focusing on the empirical evaluation of the Baumol effect, Newhouse (1992) questioned its role, arguing that it is very difficult to assess labour productivity growth in the health care sector and it is certainly not obvious that labour productivity within this sector must be lower compared to other high productivity sectors. On the other hand, Baumol's conjecture was empirically tested and found statistically significant only recently by Hartwig (2007) and Pomp and Vujic (2008). In particular, Hartwig (2007) suggests that development of health care expenditure in OECD countries over the past forty years is in line with Baumol's theory. Concerning policy recommendations, Hartwig (2007) seems to be sceptical about efforts to offset permanent growth in health care expenditure in

[8] A comprehensive overview of aggregate health care related literature is provided for example by Hartwig (2007).

the long-run. He suggests that, following Baumol's theory, only an increase in labour productivity in the health care sector can lead to stabilisation of health care expenditure to GDP ratio.

2.4. Medical technology

Medical technology is arguably the most important supply factor affecting the entire process of development, production, delivery and financing of health care. While precise estimates of its contribution to the improvement in longevity and health status are still lacking, recent studies tend to attach to it an ever more crucial role in the explanation of health expenditure. Technology, defined as 'the drugs (pharmaceuticals and vaccines), medical equipment, health-care procedures, supportive systems, and the administrative systems that can tie all these disparate elements together'[9] are considered as the main driver of health care costs in today's developed societies. The first attempt to quantify the impact of technology is attributed to Newhouse (1992), who found that the bulk of health care expenditure growth in the industrialised countries can be attributed to technological growth[10]. A great deal of further studies has supported Newhouse inference, see for example Okunade and Murthy (2002). Recently, Oliveira Martins and de la Maisonneuve (2005) pointed out that since, over the last decades, health care spending has grown faster than the aggregate income, the effects of technology and relative prices seem to significantly affect health care expenditure development.

Given the lack of empirical data and a uniform methodology to quantify the impact of medical technology on health care costs, three general approaches have been used in practice to estimate the size of its effect[11].

- The *residual approach* is based on the assumption that technology is responsible for all changes not accounted for by the other quantifiable factors. In practice, the effect of demographic changes, changes in health status, prices and income is subtracted from total increase in expenditure and the remaining part (residual) is attributed to changes in technology. Such a method avoids the difficulty of specifying the direct measure of technological progress and covers all types of technology used in the process of health care provision. On the other hand, however, it provides only a rough, indirect and, often, overestimated measure of the effect of technological progress as the residual includes, apart from technology itself, a series of other not quantified factors, such as institutional setting, behaviour, environment, education, etc. The examples of the studies using residual approach include: Newhouse (1992), Peden and Freeland (1998), Oliveira Martins and de la Maisonneuve (2005) and the present study.

- The *proxy approach* uses an alternative measure to proxy the total impact of technology. An existing indicator is then introduced into the equation explaining the health care spending, assuming its changes follow the evolution of technology. The examples include: Okunade and Murthy (2002), where total R&D spending is found to

[9] OECD (1998), p. 9.
[10] Other quantifiable factors (insurance coverage, income per capita, demographic changes, supplier-induced demand, sectoral productivity gains) account for less than half of the growth in real medical expenditure).
[11] For an overview of existing methods see : Freeland et al. (1998), Pammolli et al. (2005) and Productivity Commission, Australian Government (2005).

be a long-run driver of health care expenditure per capita, and Di Matteo (2005), where such a proxy is just time.

- *Case studies* analyse the effect of a specific technology on the cost of treating a particular medical condition. They can play an important role in the process of developing new drugs or technological applications, but their contribution to the analysis of overall health care costs is very limited. In this context, the most useful studies are those focusing on the most significant conditions (selected according to prevalence rate, contribution to overall mortality or disability, etc.), which can be extended to the wider spectrum of medical conditions. The examples of such studies include i.a. Cutler and McClellan (2001) where the costs and benefits of introducing a new technology were compared for five selected conditions, or Baker et al. (2003), where supply of ten selected technologies was compared to health care utilisation and spending.

Although empirical evidence clearly points to the cost-increasing effect of new technologies, whether a particular technology increases or decreases costs depends on its impact on unit cost and the level of use or on whether the treatment complements or replaces the existing methods. Broadly speaking, if the expected outcome is to treat in a better, faster and more efficient way diseases and medical conditions that have already been treatable before, the new technology is likely to reduce the use of other (less efficient/more costly) services and overall unit cost without changing the scope of treated population and therefore reduce total cost per patient. If the new method supplements the existing instrumentation and its purpose is to expand the treatment into the conditions that have not been treatable previously due to scientific (the methods of treatment are simply unknown) or economic (the methods of treatment are known, but enormous costs make it unfeasible on a larger scale) reasons, it will probably have a cost-increasing effect. Obviously, this picture is a highly schematic one and a number of other economic and behavioural mechanisms can influence and alter the budgetary effect of the new technologies, contingent on the legal and institutional setting currently in place. For example, in case of fixed budgets payment mechanisms, more cost-efficient technologies can hardly reduce overall expenditure simply because the providers will carry out proportionately more treatments at a lower unit cost to fulfil the budget (rebound effect). On the other hand, extra savings may be expected if a decrease in the relative price of a given type of treatment (due to e.g. the introduction of a new technology) reduces the use of the other, more expensive, substitute types of care (substitution effect).

Another classification (proposed by Thomas, 1975) of the new technologies brought to market follows their expected medical effect and allows to distinguish two general types. On the one hand, so-called 'halfway technologies' do not prevent or cure disease, but they simply treat the symptoms or, in extreme cases, aim at saving life while not improving health status. The use of such technologies leads to the extension of lifespan, but also to longer and more costly treatment. Thus in spite of obvious social and human gains, their financial impact is clearly negative. On the other hand, 'high technologies' offer prevention or complete cure, which typically decreases or eliminate the burden of disease and brings cost-efficient outcomes[12]. According to Weisbrod (1991), most technologies brought to market in the second half of the twentieth century (with the exception of vaccines) represented 'halfway technologies'. However, fast development of biomedicine over the last decade may give way to the

[12] Thomas specifies also the third group, 'nontechnologies' which are the procedures undertaken in case of diseases which are intractable or poorly understood.

appearance of several 'high technologies' based on genetic mapping and other techniques that allow for understanding origins of diseases and successfully prevent their advance.

Although there are some reasons to be optimistic about the future development of cost-reducing technologies, the currently prevalent consensus, confirmed by the quantitative analyses and combined with the argument on the existence of the Baumol effect, states that the cost-increasing effects of developing new technologies prevail and the overall impact on expenditure tends to be positive.

Identification of the main factors behind the progress of medical technologies helps in understanding its budgetary effects. Creation and development of new technologies are driven by both demand and supply side forces. On the one hand, they are 'pulled' by consumer demand driven by disposable income and increasing expectations linked to the growing living standards. Demand for health care technology grows, as much as demand for health care in general, as the population becomes wealthier and more aware of the health care needs and new opportunities created by technological innovations. On the other hand, development of new technologies is 'pushed' on the supply side by science, researchers, medical industry and providers. Practically all participants of the market for medical goods and services have stake in the development and fast diffusion of new, often high cost technologies[13]: the main users of technology, and thus customers for innovators, are not the patients themselves, but the hospitals and physicians; clinicians are often actively involved in the process of developing and assessing the medical technologies; hospital managers often find rapid adoption of new technologies rewarding in a competitive environment; public is strongly influenced by the news on the benefits of new technologies.

The supply of new technologies depends also on the type of health insurance contracts and the rules regulating the relationships between insurers and providers. Whether the system is supportive for investments in technological progress depends mainly on the definition of health care goods and services covered by insurance. If (i) the system is retrospective and cost-based (the amount of reimbursement is not specified ex-ante by a contract between insurer and patient or provider) thus allowing payments for all incurred costs and (ii) benefits covered by the insurance are not precisely specified as a list of existing procedures and drugs, the R&D sector has incentives to develop new technologies, as it has the guarantee that its investment will pay back. If, on the contrary, the system is prospective and defines ex-ante the budgets for health providers and the list of benefits to be reimbursed, industry does not invest in the new technologies, knowing that they cannot be practically adopted before an often lengthy and costly process of registering them as the reimbursed benefits is finished. A strong factor affecting development of medical technology is also the level of competition between providers and insurers regulated by the law. On the one hand, the more freedom the patients have when choosing the provider and the type of treatment, the more incentives the providers have to differentiate their offer and supply the most effective and efficient treatments. On the other hand, in a highly standardised market for health insurance, any additional treatment or drug covered by an insurance contract may be a decisive factor encouraging patients to the sign it with the insurer offering the widest or most differentiated coverage.

[13] See Rutten and Bonsel (1992).

2.5. Other factors

Apart from the above-mentioned factors, a number of other variables have been tested for the impact on the health care expenditure. These included mainly institutional (e.g. share of publicly provided or financed health care, role of GP's as an independent entity and gatekeeper, density of physicians, etc.) and behavioural (e.g. alcohol and tobacco consumption) variables, but no clear evidence was found to support the hypothesis on the significant role of any individual factor.

3. Assessing the impact of medical technology on health care spending

3.1. Econometric model: detailed specification

Following the literature we estimate health care expenditure developments introducing both demographic and non-demographic factors. As proposed by the literature, we estimate the impact of the above mentioned factors on health care expenditure for each European country covered by OECD health care statistics[14]:

$$HCE_t = \alpha_1 + \alpha_2 GDP_t + \alpha_3 OVER80_t + \alpha_4 BELOW20_t + \alpha_5 trend_t + \varepsilon_t . \quad (1)$$

Afterwards we pool the data set and estimate the following model:

$$HCE_{i,t} = \alpha_1 + \alpha_2 GDP_{i,t} + \alpha_3 OVER80_{i,t} + \alpha_4 BELOW20_{i,t} + \alpha_5 trend_{i,t} + \varepsilon_{i,t} . \quad (2)$$

where HCE represents the logarithm of the real per capita health care expenditure in national currency units.[15] GDP represents the logarithm of the real per capita GDP in national currency unit, OVER80 and BELOW20 stand for the ratio of people over 80 and below 20 years to the total population, *trend* is the deterministic trend.[16]

The variables used: GDP, HCE_TOT and HCE_PUB are easily accessible via the OECD Health database, but the development of variables characterising technological progress and relative-price movements are usually not at our disposal. In particular, reliable data on relative price developments for a sufficiently long time period is almost impossible to find. Thus, the impact of technological trend and relative price development on health expenditure is estimated by using only one aggregate non-demographic factor. The literature proposes that the development of this factor can be proxied by a deterministic trend term[17]. However, such

[14] The sample covers 20 OECD members from Europe. Unfortunately, the majority of RAMS (the 12 recently acceded MSs) countries are not OECD members thus RAMS countries are under represented in the sample. Because of the membership in AWG, Norway was included in the EU15 group.

[15] Equation (1) and (2) were estimated separately for HCE being total health care expenditure (HCE_TOT) and public health care expenditure (HCE_PUB). Data can be downloaded from http://www.ecosante.org/index2.php?base=OCDE&langh=ENG&langs=ENG&sessionid=

[16] There are alternative possibilities for a variable which represents demographic factors. Usually ratio of people over 65 to total population or dependency ratio is applied.

[17] Still, there are some exceptions like Okunade and Murthy (2002) who confirmed a significant and stable long-run relationship between per capita real health care expenditure, per capita real income and technological

a deterministic trend variable also captures development of other trending variables (not only technology growth and relative prices).

When applying time series methods one needs to pay special attention to the existence of stochastic trends (non stationarity), the existence of cointegrating relationship and possible endogeneity among dependent and explanatory variables.

3.2. Non stationarity (Unit roots)

After Culyer (1990), Hitiris and Posnett (1992) and others claimed that there seems to be a strong relationship between HCE and aggregate income, Hansen and King (1994) pointed out that it is possible that the strong positive correlations observed between HCE and GDP in the previous studies were a result of non-stationarity in the respective time series, rather than evidence of an actual economic relationship. Hansen and King (1994) showed that two-thirds of the variables tested (HCE and GDP per capita in real terms) were found to be non-stationary in levels and no country possessed a data set that was entirely stationary in levels. The non-stationarity of real per capita HCE and GDP was indicated also by Blomqvist and Carter (1996) and Gerdtham and Lothgren (2000). Using alternative unit root tests, MacDonald and Hopkins (2002), Okunade and Murthy (2002) among others, found strong evidence of unit roots in both GDP and HCE data when the data are considered as a panel.[18]

Applying augmented Dickey-Fuller unit root tests to our sample leads to the conclusion that the logarithm of real per capita health care expenditure and the log of real per capita GDP have a unit root, i.e. in most cases a H_o hypothesis of a unit root cannot be rejected. Still in some cases the test outcomes suggest that the two mentioned series could be stationary once a deterministic trend is introduced. When interpreting the results of Table 1 caution must be exercised since the power of this test is rather low in a small sample[19].

In order to obtain more reliable evidence concerning stationarity of the analysed variables, country specific time series are pooled and alternative panel unit root tests are applied. First, the existence of a common unit root in all time series is tested following Levine, Lin and Chun and Breitung tests. Second, allowing for existence of individual-specific unit roots Im, Peseran, Shin and a panel version of Phillips Peron test are applied[20]. Each time a constant and a deterministic trend enter the test equation. Based on the outcomes of all four tests, see Table 2, both HCE_TOT and HCE_PUB are rejected to be stationary at 10% significance level. Concerning stationarity of GDP, evidence is not actually clear; still assume the null hypothesis of GDP stationarity is in general rejected.

Thus, following economic intuition and the outcomes of several studies we assume that HCE_TOT, HCE_PUB and GDP are (1).

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change, proxied by total R&D expenditure. Albrecht, Neyt and Verbeke (2005) proxy the impact of new technologies on health care expenditure by the number of researchers.

18 On the other hand, recently Carrion-i-Silvestre (2005) suggested that the panel data set of HCE is stationary after the structural breaks are introduced into the model. Since most of the breaks are associated with reforms aimed to extend the coverage and benefits of health care, this argument is in line with the fact that governments play a major role in the financing of HCE in most of the OECD countries, and therefore, it is a consequence of a strong correlation between HCE and GDP.

[19] Thus, due to a limited number of observations, the series could be claimed to be an I(1) process even if it is I(0) in fact.

[20] An overview of panel data unit root and cointegration tests is provided by Banerjee (1999).

Table 1. Augmented Dickey-Fuller test[21]

	HCE_TOT	HCE_PUB	GDP
AT	0.72	0.61	0.41
BE	0.21	NA	0.36
CZ	0.01	0.03	0.78
DK	0.83	0.09	0.03
FI	0.26	0.27	0.03
FR	0.46	0.29	0.35
DE	0.00	0.00	0.18
GR	0.17	0.02	0.42
HU	0.83	0.93	0.00
IE	0.82	0.67	0.84
IT	0.30	0.62	0.85
LU	0.40	0.28	0.41
NL	0.08	0.06	0.45
NO	0.32	0.02	0.38
PL	0.04	0.24	0.10
PT	0.00	0.24	0.12
SK	0.89	0.45	0.21
ES	0.26	0.01	0.09
SE	0.06	0.01	0.47
UK	0.60	0.90	0.75

Note: The values represent p-values of the Ho that the series has a unit root. The Ho is rejected if the p-value is smaller than or equal to the significance level. If significance level is 0.1 than Ho is rejected when p-value<= 0.1.

Table 2. Panel unit root tests

	HCE_TOT	HCE_PUB	GDP
Common unit root test:			
LLC	0.06	0.12	0.00
Breitung	0.23	0.31	0.47
Individual unit root test:			
IPS	0.10	0.37	0.00
PP	0.90	0.62	0.04

Note:
Common unit root test: LLC - Levin, Lin, Chu; Breitung.
Individual unit root test: IPS - Im, Peseran, Shin; PP-Fisher Chi-square.
The values represent p-values of the Ho that the series has a unit root. The Ho is rejected if the p-value is smaller than or equal to the significance level. If significance level is 0.1 than Ho is rejected when p-value<= 0.1.

3.3. Cointegration

The problem of regressing non-stationarity variables disappears in case their linear combination is stationary. In such a situation, OLS estimates in levels are superconsistent.

Hansen and King (1994) conclude that there is practically no evidence that the two series (HCE and GDP) are cointegrated for any country, i.e. that there is no long-run relationship between HCE and GDP. On the other hand, Blomqvist and Carter (1996) confirm the existence of a cointegration in the country-by-country case. The null hypothesis of no cointegration was rejected at the 5% level for 16 countries. In addition, after pooling country variables, the authors concluded that HCE and GDP are I(1) and are cointegrated around a linear trend.

[21] Applying Phillips-Peron test does not change the results significantly. See table 9 in the Annex.

A similar conclusion, i.e. the existence of the long run equilibrium relationship between HCE and GDP, using panel cointegration tests was confirmed by Gerdtham U. G., Lothgren M. (2000), Dreger and Reimers (2005) or by Okunade and Murthy (2002).

Using the Dickey-Fuller approach, on a country-by-country basis, in testing cointegration in our sample leads to the conclusion that health care expenditure and GDP per capita are not cointegrated in a number of case cases (see Table 3)[22]. The presence of a cointegration relationship was tested for all countries even when both series are I(0) or one series is I(0) and the second one is I(1) or vice versa[23].

A number of panel cointegration tests has been introduced recently, in order to provide more plausible evidence of cointegration relationship among variable[24]. Table 4 provides outcomes of two tests proposed by Pedroni and by Kao. All these tests extend the Engle-Granger framework to tests involving panel data, i.e. the residual-based cointegration tests.

The individual country-by-country tests do not provide clear evidence of the existence of the cointegration relationship between the variables for all countries, see Table 3. On the contrary, based on the panel cointegration tests in Table 4, the null hypothesis of no cointegration relationship can be rejected. As a consequence, taking into account our results and recently published studies we assume that HCE and GDP are cointegrated for all countries and decide to estimate the long-run relation between these variables using OLS. A full dynamic error correction model estimate, taking into account the adjustment mechanism over time, is not feasible given the lack of data.

[22] When applying Johansen's cointegration test the conclusions are almost the same. See Tab 10 in the Annex.
[23] See for example Muscatelli and Hurn (1992) who advocate this approach. It should be noted that it is not fully methodologically correct in this case.
[24] See Banerjee (1999) for an overview and discussion of existing panel cointegration tests.

Table 3. Cointegration test (Dickey-Fuller two stage approach)

	HCE_TOT	HCE_PUB
AT	0.7	0.2
BE	0.3	NA
CZ	0.0	0.0
DK	0.8	0.2
FI	0.2	0.2
FR	0.0	0.0
DE	0.5	0.7
GR	0.3	0.0
HU	0.1	0.1
IE	0.0	0.1
IT	0.5	0.7
LU	0.0	0.1
NL	0.0	0.0
NO	0.0	0.0
PL	0.1	0.3
PT	0.0	0.1
SK	0.2	0.4
ES	0.2	0.2
SE	0.5	0.7
UK	0.3	0.7

Note: The values represent p-values of the Ho that the residual series has a unit root, i.e. that the variables (HCE, GDP and over_65) are not cointegrated. The Ho is rejected if the p-value is smaller than or equal to the significance level. If significance level is 0.1 than Ho is rejected when p-value<= 0.1.

Table 4. Panel cointegration tests.

	HCE_TOT	HCE_PUB
Pedroni		
Panel ADF	0.03	0.00
Group ADF	0.03	0.00
Kao	0.00	0.00

Note: The values represent p-values of the Ho that the the variables (HCE, GDP and over_65) are not cointegrated. The Ho is rejected if the p-value is smaller than or equal to the significance level. If significance level is 0.1 than Ho is rejected when p-value<= 0.1.

3.4. Technology trend estimation

Following Blomqvist and Carter (1996) and Ariste and Carr (2002), we extended the model by a linear time trend. Such a deterministic trend is expected to account for the impact of technological change on health care expenditure. The authors stress that their estimates of the deterministic trend coefficient are very imprecise and vary widely in magnitude between countries. However, their trend coefficient estimates suggest that HCE in the sample of countries tends to rise by as much as 2% per year even if income remains constant. Okunade and Murthy (2002) also confirm a significant and stable long-run relationship among HCE, GDP and technological change (this time proxied by total R&D expenditure). As suggested earlier, this can be taken as support for the growing consensus that the technology growth has been the most important determinant of the growth in the cost of health care in industrialized countries since the World War II.

Table 5 presents the results when estimating equation (1) using OLS. The results should be interpreted with caution, especially for Recently Acceded Member States (RAMS) countries where the length of time series is extremely short.

Table 5. Single equation estimates

		HCE_TOT		HCE_PUB				HCE_TOT		HCE_PUB	
AT	cons	-12.76	**	-19.85	***	IT	cons	-11.78		-24.75	*
	GDP	1.95	***	2.65	***		GDP	1.80	*	2.95	*
	ABOVE 80	-0.01		0.03			ABOVE 80	0.04		0.10	
	BELOW 20	0.02		0.03			BELOW 20	0.04	***	0.10	***
	trend	0.01		0.00			trend	0.01		0.01	
BE	cons	-20.80	***			LU	cons	29.69		34.35	*
	GDP	2.80	***				GDP	-1.63		-1.93	*
	ABOVE 80	0.18					ABOVE 80	-0.58		-0.62	
	BELOW 20	0.02					BELOW 20	-0.27		-0.34	
	trend	-0.02					trend	0.10	***	0.10	***
CZ	cons	16.00		12.91		NL	cons	3.09		9.24	*
	GDP	-0.51		-0.35			GDP	0.31		-0.06	
	ABOVE 80	0.31		0.23			ABOVE 80	0.05		-0.44	
	BELOW 20	-0.06		-0.03			BELOW 20	0.01	*	-0.05	**
	trend	0.01		0.02			trend	0.02	**	0.03	
DK	cons	-0.82		-7.01		NO	cons	-15.18	***	-15.85	***
	GDP	0.57	*	0.93	**		GDP	2.00	***	2.04	***
	ABOVE 80	0.39	***	0.67	***		ABOVE 80	0.17		-0.01	
	BELOW 20	0.08	***	0.13	***		BELOW 20	0.01		0.02	
	trend	0.00		-0.01			trend	-0.02		-0.01	
FI	cons	3.40	*	3.31		PL	cons	9.13	**	7.89	*
	GDP	0.49	***	0.58	***		GDP	-0.31		0.20	
	ABOVE 80	0.23	***	0.26	***		ABOVE 80	-0.11		-0.10	
	BELOW 20	-0.05	***	-0.08	***		BELOW 20	-0.03		-0.08	***
	trend	-0.01		-0.02	**		trend	0.05	***	-0.01	
FR	cons	4.75		5.65		PT	cons	-4.90	*	-7.41	
	GDP	0.26		0.18			GDP	0.94	***	1.28	***
	ABOVE 80	0.08	*	0.09			ABOVE 80	-0.32	**	-0.17	
	BELOW 20	-0.03		-0.04			BELOW 20	0.04		0.02	
	trend	0.02		0.02			trend	0.08	***	0.05	**
DE	cons	-7.77	**	-7.41	*	SK	cons	-22.08		-9.20	
	GDP	1.42	***	1.36	***		GDP	0.54		1.44	
	ABOVE 80	0.05		0.05			ABOVE 80	0.19		0.11	
	BELOW 20	0.03		0.02			BELOW 20	0.86		0.05	
	trend	0.01	***	0.01	**		trend	0.09		-0.01	
GR	cons	3.73		-4.43	*	ES	cons	-9.30	***	-11.13	***
	GDP	0.32		1.04	***		GDP	1.44	***	1.44	***
	ABOVE 80	0.00		-0.20			ABOVE 80	0.13		0.02	
	BELOW 20	-0.03		0.01			BELOW 20	0.05	***	0.08	***
	trend	0.02		0.04	***		trend	0.02	***	0.05	***
HU	cons	-23.35	**	-26.50	**	SE	cons	-1.26		-0.03	
	GDP	1.95	***	2.04	***		GDP	0.87	***	0.71	*
	ABOVE 80	-0.05		0.05			ABOVE 80	-0.65	***	-0.86	***
	BELOW 20	0.20	*	0.26	**		BELOW 20	0.03	**	0.05	***
	trend	0.07		0.07			trend	0.07	***	0.10	***
IE	cons	-0.78		-1.68		UK	cons	4.43	***	5.34	**
	GDP	0.98	**	1.19	**		GDP	-0.02		-0.26	
	ABOVE 80	-0.61	***	-0.86	***		ABOVE 80	0.07		0.10	
	BELOW 20	-0.02		-0.04			BELOW 20	0.04	***	0.07	***
	trend	0.01		0.00			trend	0.04	***	0.05	***

*Note: *** statisticaly significant at 1% level, ** statisticaly signicicant at 5% level, * statisticaly significant at 10% level*

The coefficient corresponding to GDP is interpreted as an elasticity of HCE with respect to GDP. The coefficient is to be positive and close to one. Estimates both below and above one can be supported on theoretical grounds. The coefficients corresponding to OVER80 and BELOW20 are interpreted as a semi-elasticity of HCE with respect to the development of demographic factors. In particular, OVER80 represents the impact of a higher ratio of older people in the population, while BELOW20 represents the effect of a higher ratio of young people in the population on health care spending. The empirical age profiles of health care spending reveal that in general the estimated coefficient related to OVER80 is expected to be positive and the coefficient related to BELOW20 is expected to be rather negative. The coefficient corresponding to *trend* can be interpreted as an average annual growth rate of HCE due to technology and other non-demographic factors.

The estimated parameters are characterised by a quite high degree of dispersion.[25] In particular, the limited size of data sample leads to bizarre results in case of some countries as CZ, FR, LU, NL and UK. Taking into account only statistically significant results, we see that the average growth rate of per capita health care expenditure varies from 1 to 10% per annum. In an effort to obtain more robust results, we pooled the individual country data. In addition, to reflect the accession year to the EU, we split the data set in EU 15 and RAMS subgroups.[26]

Table 6. Pooled fixed effect regression estimates

		HCE_TOT		HCE_PUB	
EU	cons	0.30		0.49	
	GDP	0.68	***	0.65	***
	OVER 80	0.02		0.01	
	BELOW 20	-0.01	*	-0.01	*
	trend	0.02	***	0.02	***
EU_15	cons	0.69		0.76	
	GDP	0.65	***	0.67	***
	OVER 80	-0.02		-0.08	**
	BELOW 20	-0.01	**	-0.02	***
	trend	0.02	***	0.02	***
RAMS	cons	3.04	*	5.88	***
	GDP	0.56	**	0.50	
	OVER 80	0.16	***	0.23	***
	BELOW 20	0.01		-0.03	**
	trend	0.03	***	0.03	

*Note: *** statistically significant at 1% level, ** statistically significant at 5% level, * statistically significant at 10% level*

As indicated in Table 6, for both total and public health care spending, the trend coefficient for EU15 countries is about 0.02, while in the case of RAMS countries, the coefficient is slightly higher (0.03). The difference in the level of the trend parameter between EU15 and RAMS countries can be explained by the lower level of health care standards in RAMS countries and their tendency to converge to EU level in the following years.

The estimated value of income elasticity seems to be rather low (below 1). The surprisingly low value of the income elasticity can be a result of introducing mainly a time *trend*, the

[25] The high degree of dispersion among individual country parameters was confirmed for example by Blomqvist and Carter (1996).
[26] In Table 4, EU15 group comprises of AT, BE, DK,FI, FR, DE, GR, IE, IT, LU, NL, NO, PT, ES, SE, UK and the group of RAMS covers only CZ, HU, PL and SK.

OVER80 and BELOW20 variables, all growing remarkably in case of a majority of the countries over the period 1960-2006.

As well as in the case of the country-by-country estimates the effect of demographic factors, approximated by OVER80 and BELOW20, is mixed. On the EU level, BELOW20 coefficients are negative and statistically significant for both HCE_TOT and HCE_PUB, meaning that higher proportion of younger people in the society reduces the ratio of health care expenditure to GDP. On the contrary, the ratio of health care spending to GDP tends to increase as the proportion of older people in the population increases, still this relation was not found to be statistically significant. In case of EU_15 countries, the elasticities related to both variables representing demographic development (BELOW20 and ABOVE80) are negative, still statistically significant only for BELOW20 variable. On the contrary, the same elasticities were estimated to be positive in case of RAMS countries. This time ABOVE80 variable was found to be statistically significant while BELOW20 was not. Our results are in line with conclusions by Oliveira Martins and de la Maisonneuve (2006) who claim the impact of demographic factors to be relatively weak while the impact of non-demographic factors prevailed over the last decades.

As already mentioned, we introduce a linear trend into our calculations in order to proxy the effect of technology development on health care spending. This was a pragmatic choice as alternative variables describing the effect of the technology are difficult to find. Unfortunately, introducing a linear trend into our estimations affects the outcome of our estimates. In particular, the trend captures not only the impact of technology but also the impact of all other trending variables. In addition, introducing a deterministic trend into our model leads to a high degree of multicollinearity among variables and thus makes the estimates less precise, i.e. increases a standard effort of the estimates.[27]

4. Projecting the long-term budgetary impact of technological progress

The econometric specification described in the previous section may serve as a basis for a tentative estimation of the future impact of technological progress on the public expenditure on health care. For this purpose, the standard macrosimulation model used in the European Commission and Economic Policy Committee long-term budgetary projections (European Commission and EPC, 2009) can be extended by a module which estimates the financial impact of technological progress. Obviously, given the large uncertainties surrounding future developments in medical technology such an exercise must be based on the strong assumption of the continuation of the past trends (correlation coefficients and elasticity estimates) in the future.

4.1. Methodology

The European Commmission-Economic Policy Committee (EC-EPC) projections of public health care expenditure are based on the simple macrosimulation model based on the expected

[27] In order to demonstrate the effect of the time trend on our regressions, we re-estimate the pooled fixed effect model when excluding the trend. The pooled fixed effect estimates excluding the time trend are presented in Table 11 in the Annex. As expected, after excluding a time trend the variables characterising demographic development turn to be statistically significant and of an expected sign.

demographic and income changes affecting the overall demand for health care. According to this methodology, current public expenditure on health care is decomposed into per capita public spending and total population. For each year of the projections, total expenditure is calculated by multiplying population and per capita spending for each cohort and adding spending on all cohorts. To keep the spending constant in real terms (as percentage of GDP) per capita expenditure is assumed to grow in line with the evolution of GDP per capita, but in order to reflect the impact of national income the elasticity is assumed to exceed unity[28]. Data on health care spending per capita have been reported by the EU Member States in the form of age-related expenditure profile disaggregated into genders and 5-year age cohorts. Population projections are the standard EUROPOP2008 projections established by Eurostat for each age and year up to 2060, while GDP growth projections have been prepared internally by the European Commission (DG ECFIN) in a close cooperation with the representatives of the Member States gathered in the Ageing Working Group attached to the Economic Policy Committee[29].

Extending this basic methodology to include the technology component consists of adding two additional and partially counterbalancing elements. On the one hand, an extra increase in per capita health care expenditure due to non-demographic drivers is added on top of the demographic and income effect. This is simply done by adding additional component, equal to the estimate of *trend* coefficient obtained from the econometric model, to the yearly rate of growth. On the other hand, the income effect is weakened by applying an income elasticity lower than unity (and equal to the estimate of the coefficient corresponding to *GDP* in the model specification). This effect is due to the fact that growth in national income is correlated with technological progress. In the basic projection methodology, in the absence of a separate estimate, high income elasticity coefficient incorporates significant part of the technology impact, which is not the case in the extended model, where adjusted income elasticity coefficient reflects only other, non-technological channels.

As in any long-term projection, one should assume a convergence towards stationary steady state conditions, so the two discussed effects are assumed to gradually disappear over time. In practical terms, it is done by applying a simple convergence rule to both elements added to the projection model[30]. However, the uncertainty on the speed of the adjustment process call for caution while interpreting the results. For that reason two separate variants have been constructed: in the first one full adjustment over entire projection period (2007-2060) is assumed, in the second one, the impact of technology is assumed to disappear after 30 years (by 2038).

Although estimates are available for all countries covered by the analysis, their values differ considerably (see table 3), depending strongly on data availability and time series length. The latter is especially short for the recently acceded Member States, which limits the reliability of data and quality of results for that group of countries. In such case, it has been decided to use the panel data estimates based on the figures from all the countries included in the analysis.

[28] Following own calculations and estimates of income elasticity found in empirical literature, the coefficient of elasticity used in the projections (AWG reference scenario) is assumed to be 1.1 in the base year (2007), converging to unity at the end of the projection period (2060).

[29] For the details of the methodologies and the underlying data, see: European Commission and Economic Policy Committee (2008).

[30] Additional component to the yearly increase starts in 2008 from the value resulting from the econometric specification (estimate of *trend* coefficient) and converges towards zero at the end of the projection period. The same applies to income elasticity which, in exchange, evolves from the obtained value (estimate of *GDP* coefficient) in 2008 to unity in 2060.

To conclude, given all the mentioned reservations, the extra impact of technology added on top of demographic and income effect amounts to about 2% per year in 2008 (first year of projection) and linearly converges towards zero by 2060. On the other hand, income elasticity coefficient defining the impact of GDP per capita changes on per capita health care expenditure is 0.7 in 2008 and gradually converges to 1 by the end of the projection period.

4.2. Results

Tables 7 and 8 show the results of the technology scenario using as input data the results of the econometric exercise presented in section 3.

Table 7. Public health care spending as % of GDP – projections with the technology effect disappearing by 2060

	2007	2010	2020	2040	2060	*Change 2007-2060*	*difference from AWG reference scenario*
BE	7,6	8,1	9,7	12,9	14,1	*6,5*	*5,3*
BG	4,7	4,8	5,4	6,8	7,5	*2,8*	*2,0*
CZ	6,2	6,5	7,7	10,7	12,4	*6,2*	*4,0*
DK	5,9	6,3	7,8	10,2	11,1	*5,2*	*4,2*
DE	7,4	7,9	9,7	13,3	14,6	*7,2*	*5,4*
EE	4,9	5,0	5,7	7,4	8,6	*3,6*	*2,4*
IE	5,8	6,2	7,4	10,2	12,1	*6,3*	*4,5*
EL	5,0	5,2	6,2	8,5	9,6	*4,7*	*3,3*
ES	5,5	5,9	7,0	9,8	11,2	*5,6*	*4,0*
FR	8,1	8,7	10,4	13,7	14,9	*6,8*	*5,5*
IT	5,9	6,3	7,5	10,2	11,1	*5,3*	*4,2*
CY	2,7	2,9	3,4	4,6	5,4	*2,7*	*2,1*
LV	3,5	3,5	3,9	5,1	5,7	*2,3*	*0,9*
LT	4,5	4,6	5,2	6,9	7,9	*3,4*	*2,3*
LU	5,8	6,1	7,1	9,6	10,6	*4,8*	*3,6*
HU	5,8	6,0	7,0	9,5	11,0	*5,2*	*4,0*
MT	4,7	5,2	6,7	10,4	12,8	*8,1*	*4,8*
NL	4,8	5,1	6,4	8,6	9,3	*4,5*	*3,5*
AT	6,5	6,9	8,5	11,6	12,8	*6,3*	*4,8*
PL	4,0	4,2	4,9	6,6	7,6	*3,6*	*2,6*
PT	7,2	7,7	9,3	12,4	14,3	*7,1*	*5,2*
RO	3,5	3,6	4,1	5,6	6,7	*3,2*	*1,8*
SI	6,6	6,9	8,2	11,3	12,7	*6,1*	*4,2*
SK	5,0	5,1	6,1	8,5	10,0	*5,1*	*2,8*
FI	5,5	5,9	7,2	9,7	10,5	*5,0*	*4,1*
SE	7,2	7,6	9,0	11,5	12,6	*5,4*	*4,6*
UK	7,5	8,0	9,5	13,0	14,9	*7,4*	*5,4*
NO	5,6	6,3	8,0	11,5	13,3	*7,6*	*6,3*
EU27	6,7	7,1	8,5	11,6	13,0	*6,3*	*4,8*
EU15	6,9	7,3	8,8	11,9	13,3	*6,4*	*4,9*
EU12	4,7	4,8	5,6	7,6	8,9	*4,2*	*2,9*

Source: European Commission, EPC

Table 8. Public health care spending as % of GDP – projections with the technology effect disappearing over 30 years

	2007	2010	2020	2040	2060	*Change 2007-2060*	*difference from AWG reference scenario*
BE	7,6	8,1	9,5	11,4	11,8	*4,1*	*2,9*
BG	4,7	4,8	5,3	6,2	6,4	*1,7*	*1,0*
CZ	6,2	6,5	7,7	9,6	10,4	*4,2*	*2,0*
DK	5,9	6,3	7,6	9,1	9,3	*3,3*	*2,4*
DE	7,4	7,9	9,5	11,7	12,1	*4,7*	*3,0*
EE	4,9	5,0	5,7	6,7	7,3	*2,3*	*1,1*
IE	5,8	6,2	7,2	9,1	10,1	*4,2*	*2,5*
EL	5,0	5,2	6,1	7,5	8,0	*3,1*	*1,7*
ES	5,5	5,9	6,9	8,7	9,3	*3,8*	*2,1*
FR	8,1	8,7	10,2	12,1	12,4	*4,3*	*3,1*
IT	5,9	6,3	7,4	9,0	9,2	*3,4*	*2,3*
CY	2,7	2,9	3,4	4,1	4,5	*1,8*	*1,2*
LV	3,5	3,5	3,9	4,6	4,8	*1,4*	*0,0*
LT	4,5	4,6	5,1	6,2	6,6	*2,2*	*1,0*
LU	5,8	6,1	7,0	8,5	8,9	*3,1*	*1,9*
HU	5,8	6,0	7,0	8,6	9,3	*3,5*	*2,3*
MT	4,7	5,1	6,6	9,3	10,7	*6,0*	*2,7*
NL	4,8	5,1	6,3	7,6	7,8	*2,9*	*2,0*
AT	6,5	6,9	8,3	10,3	10,7	*4,2*	*2,6*
PL	4,0	4,2	4,9	5,9	6,4	*2,4*	*1,4*
PT	7,2	7,7	9,1	11,1	12,1	*4,9*	*3,0*
RO	3,5	3,6	4,0	5,1	5,7	*2,2*	*0,8*
SI	6,6	6,9	8,1	10,1	10,6	*4,0*	*2,1*
SK	5,0	5,1	6,0	7,7	8,4	*3,5*	*1,2*
FI	5,5	5,8	7,1	8,6	8,8	*3,3*	*2,4*
SE	7,2	7,6	8,8	10,2	10,5	*3,3*	*2,5*
UK	7,5	8,0	9,4	11,6	12,5	*5,0*	*3,0*
NO	5,6	6,3	7,9	10,3	11,4	*5,7*	*4,4*
EU27	6,7	7,1	8,4	10,3	10,8	*4,1*	*2,6*
EU15	6,9	7,3	8,7	10,6	11,1	*4,2*	*2,7*
EU12	4,7	4,8	5,6	6,8	7,5	*2,8*	*1,5*

Source: European Commission, EPC

These results suggest a large increase in public health care expenditure over the projection period, exceeding significantly the outcomes of the scenarios which do not take account of the potential impact of medical technology on health care expenditure. The difference between the results of the presented scenarios and those of the AWG reference scenario[31] (presented in the last column of the tables) may be interpreted as the expected impact of technology (and other supply factors not related to the increase in the national income) on public health expenditure. Estimated at between 2.6 and 4.8% of GDP, it turns out to be significantly stronger than both the impact of demographic changes (approximate 1.7% of GDP[32]) and extra effect of assumed higher income elasticity (0.4% of GDP[33]).

A total increase of between 4 and 6.5% of GDP (in absolute terms) shows that continuation of the past trends in the public spending on health care, even under a strong assumption of the extra effect fading away with time, almost doubles the current level of spending, which would put a significant pressure on the public finances and the probable need to implement measures limiting the spending increase which may – together with the other items of age-related social spending - jeopardise the sustainability of public finances in many European countries.

5. Conclusions

Progress in medical science and the development of new technologies strongly affect public expenditure on health care in most industrialised countries of the world. Although it is found to account for the highest share of spending growth, it is also the most difficult factor to quantify. Incomplete knowledge of the interactions between technology and other factors affecting health care expenditure constrains the reliability of past analysis. Uncertainty surrounding future developments limits the predictive ability of the extrapolation of the past trends into the future. However, bearing in mind the caveats of such an exercise, the analysis of the past developments can teach us a lot about the interactions between technology and other factors. Moreover, an attempt to project their joint impact on the overall and public health care expenditure can serve as a good approximation of future needs of financial resources and expected pressure on public finances coming from this constantly developing and growing sector of activity.

A number of econometric tools were applied in order to estimate the expected impact of the technological progress on health care expenditures. Following the literature, a widely accepted specification of health care equation was used to estimate the annual trend growth rate of per capita health care expenditure for individual countries and pooled data.

Taking into account the recent results provided by the economic literature, single OLS and pooled fixed effect regressions have been estimated. At individual country level a very wide dispersion in the trend growth rate of health-care expenditure was found. This may be due to

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[31] AWG reference scenario is the central scenario of the projections, illustrating expected combined impact of three main quantifiable factors: demographic change, evolution in the health status and the national income. For details, see European Commission and Economic Policy Committee (2009), p.137.
[32] Average EU27 increase (2007-2060) in public spending on health care in the *pure demographic scenario*. See European Commission and Economic Policy Committee (2009), p.130.
[33] Average EU27 difference in public spending on health care projected according to the *income elasticity* and *pure demographic* scenarios (2007-2060). In methodological terms, the difference between the two lies in the assumed income elasticity of demand (and spending) for health care. While in the *pure demographic* scenario it is unitary and constant, in the *income elasticity* scenario it converges linearly from 1.1 in 2007 to 1 in 2060. See European Commission and Economic Policy Committee (2009), p.134.

other country-specific factors affecting health-care expenditure not captured in the estimation. Based on the results for pooled regressions, HCE trend growth rate was estimated at 2% and 3% p.a. for the EU15 and RAMS countries respectively, which can be assigned mainly to technological progress, or to other non-demographic factors. At the same time, the regression analysis show an income elasticity lower than 1 (around 0.7 on average). These results may be considered to represent an underlying, average trend in health-care expenditure, estimates to be somewhat lower for the EU15 countries than for the RAMS countries.

Applying the econometric estimates to the macrosimulation health care expenditure model, constructed by the European Commission and the Economic Policy Committee for the long-term budgetary projections, allows for the calculation of the expected increase in health care expenditure over the next decades due to demographic, income and technological factors. Although the results of the exercise vary considerably according to the imposed assumptions, the effect of technology is generally found to considerably exceed both demographic and income effects.

Nevertheless, these results should be interpreted with caution and a number of caveats should be borne in mind. First, the budgetary impact estimated in the presented models do not solely include the effect of future developments in the cost of 'medicines (pharmaceuticals and vaccines), medical equipment, health-care procedures, supportive systems, and the administrative systems that can tie all these disparate elements together'[34]. In fact, it also reflects other non-demographic factors (except for national income), such as a number of cost drivers not covered by the presented specifications. These are non-quantifiable factors such as institutional and legal setting of health care system, developments in prices of health care goods and services etc.

Second, given the lack of knowledge on the future developments in medical technology, projected evolution of health care expenditure is calculated using estimates based solely on the past observations. Given the strong assumption on simple extrapolation of past trends, the results may be considered as tentative given the very long projection horizon.

Third, given the fact that the potential for technological development depends on the financial resources available for capital investment in the medical sector, the econometric analysis should clearly differentiate between the two sources of influence in order to avoid collinearity. Indeed, impact of technology may be partially reflected in the relation between health care spending and national income[35].

In conclusion, as, together with public pensions, long-term care and other age-related spending items, health care contributes strongly to the expected pressures on the public spending in the years and decades to come, advances in medical technology and their impacts on health care expenditure raises obvious concerns in relation to the future evolution of social spending and sustainability of public finances. However, given its relevant contribution to growing longevity and improving health status, the role of technology is considered as positive and any attempt to contain its development must be based on objective cost-effectiveness analysis. Such studies, comparing a new technology's costs and benefits should

[34] Definition of medical technology, as quoted in OECD (1998).
[35] This is the case of the *income elasticity* scenario in the EC-EPC budgetary projections which, while projecting higher spending in countries with higher potential GDP growth, accounts to some extent for technological progress.

be considered when formulating future policies on the coverage and reimbursement affecting patients' and providers' incentives to use cost-effective types of treatment.

6. References

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- Annex

Table 9. Philips-Perron unit root test

	HCE_TOT	HCE_PUB	GDP
AT	0.6	0.6	0.0
BE	0.2	NA	0.0
CZ	0.5	0.4	0.1
DK	0.8	0.4	0.0
FI	0.6	0.6	0.5
FR	0.5	0.3	0.4
DE	0.0	0.0	0.2
GR	0.2	0.0	0.2
HU	0.8	0.9	0.0
IE	0.7	0.9	0.9
IT	0.7	0.9	1.0
LU	0.7	0.6	0.7
NL	0.6	0.3	0.5
NO	0.4	0.1	0.6
PO	0.1	0.0	0.1
PT	0.0	0.2	0.4
SK	1.0	1.0	0.8
ES	0.1	0.0	0.5
SE	0.7	0.6	0.9
UK	0.5	0.8	0.4

Note: The values represent p-values of the Ho that the series has a unit root. The Ho is rejected if the p-value is smaller than or equal to the significance level. If significance level is 0.1 than Ho is rejected when p-value<= 0.1.

Table 10. Number of cointegrating relations using Johansen's cointegration test

	HCE_TOT	HCE_PUB
AT	1	1
BE	1	1
CZ	1	1
DK	0	1
FI	1	1
FR	1	1
DE	1	1
GR	0	1
HU	1	1
IE	1	1
IT	0	0
LU	1	1
NL	1	0
NO	1	1
PL	1	1
PT	1	1
SK	NA	NA
ES	0	1
SE	0	0
UK	0	0

Table 11. Pooled fixed effect regression estimates when excluding deterministic trend

		HCE_TOT		HCE_PUB	
EU	cons	-4.09	***	-2.82	***
	GDP	1.13	***	1.00	***
	OVER 80	0.11	***	0.10	***
	BELOW 20	-0.01	*	-0.01	**
	trend				
EU_15	cons	-4.78	***	-3.85	***
	GDP	1.19	***	1.14	***
	OVER 80	0.11	***	0.04	
	BELOW 20	0.00		-0.02	***
	trend				
EU_10	cons	1.34		5.76	***
	GDP	0.68	***	0.65	**
	OVER 80	0.21	***	0.23	***
	BELOW 20	-0.03	***	-0.03	***
	trend				