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Estimating the drivers and projecting long-term public health expenditure in the European Union: Baumol's «cost disease» revisited

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Abstract

This paper breaks down public health expenditure in its drivers for European Union countries. Baumol's "unbalanced growth model" suggests that low productivity growth sectors, such as health services, when facing an inelastic demand curve result in a rising expenditure-to-GDP ratio. Although national income and relative prices of health services are found to be important determinants of public health expenditure, significant residual growth persists, inter alia, reflecting the impact of omitted variables, such as technological progress, and policies and institutions. Consequently, in order to obtain sensible long term projections, it is necessary to make (arbitrary) assumptions on the future evolution of a time drift/residuals.

JEL Classification: C53; H51; I12

Keywords: ageing costs, health expenditure, health projections, Baumol's "cost-disease" effect, unbalanced growth model, non-demographic drivers.

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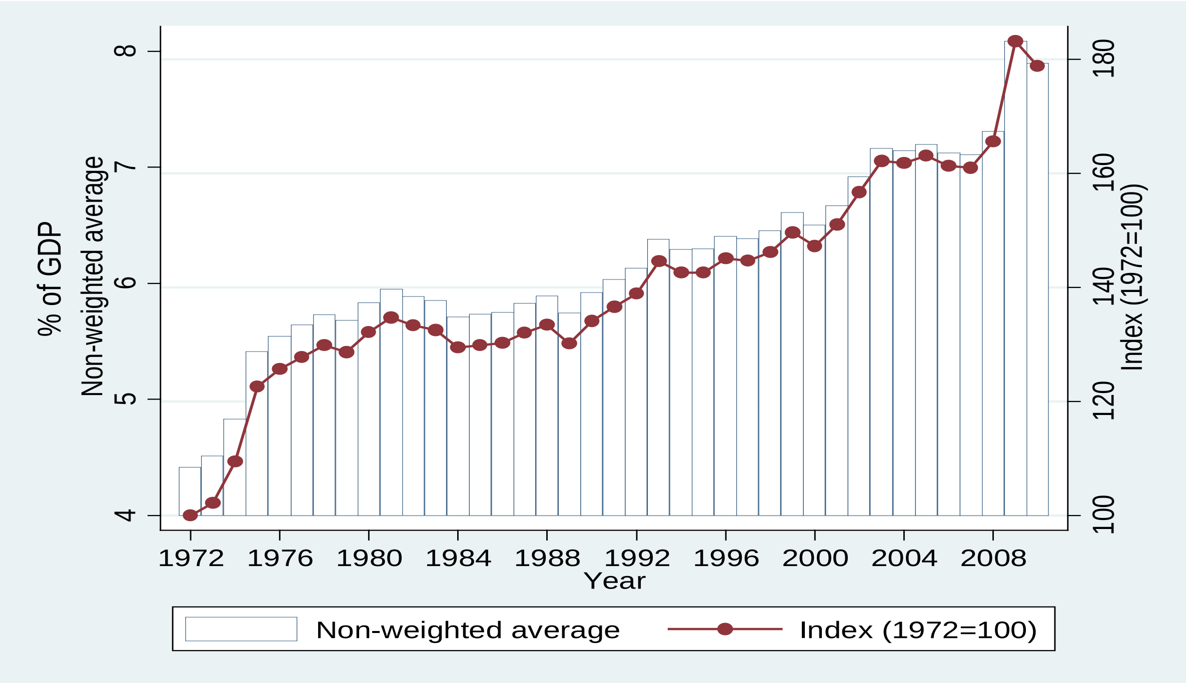
1. Introduction

During most of the second half and especially the last decades of the 20th century, public health expenditure (HE) has been growing faster than national income (Maisonneuve and Martins, 2006).[1] Typically, population size and the age structure, health status, income, health technology, relative prices, and institutional settings have been advanced as explanatory factors. Empirical studies show that demographic factors, such as population ageing, have had a positive effect on expenditure growth, but rather of a second order, when compared with other drivers, such as income, technology, relative prices and institutional settings (European Commission, 2012).

According to Maisonneuve and Martins (2006), public HE (and long-term care expenditure) as a share of GDP grew by some 50% between 1970 and the early 1980s in the OECD area. The rapid increase in expenditure during the 1970s reflected the broadening of insurance coverage in most countries. According to Clements et al. (2012), public HE in advanced countries has been characterised by short periods of accelerated growth followed by periods of cost containment (Docteur and Oxley, 2003). Cost containment policies have been implemented mainly through macroeconomic mechanisms, such as wage moderation, price controls and the postponement of investments. Consequently, growth in public HE as a percentage of GDP decelerated over the 15-year period from 1975 to 1990, although private expenditure on health started to accelerate in the early 1980s.

Graph 1 – Evolution of public health expenditure (1972-2010).[2]



Source: Own calculations based on SHA and national data.
Note: Non-weighted average of available EU-27 countries over the entire period plus Norway, namely AT, DE, DK, ES, FI, PT, SE, UK, and NO.

Maisonneuve and Martins (2006) argue that public containment policies cannot be sustained for long periods, inter alia, because wages have to attract young and skilled workers for the

[1] The cut-off dates for health care expenditure data included in this paper are November 2012 and January 2013, therefore 2010 is usually the last year covered by the analysis. Using preliminary estimates for 2011, Morgan and Astolfi (2013) suggest that as a result of the global economic crisis which began in 2008, health expenditure slowed markedly or fell in many OECD countries recently after years of continuous growth.

[2] Data in levels are adjusted for structural breaks using a procedure suggested in Joumard et al. (2008), namely the average growth rate of spending over the past five years is used to project spending growth in a break year.

health sector, while controlling prices is challenging in the presence of rapid technological progress, and equipment also has to be renovated. Thus, after a long period of cost containment, the growth of public HE picked up after the turn of the century.[3]

Baumol's (1967) seminal "unbalanced growth model" provides a simple but compelling explanation for the observable rise in HE in the last decades. This model assumes divergent productivity growth trends between "stagnant" (personal) services and a "progressive" sector (e.g. manufacturing and agriculture). Due to technological constrains (e.g. difficulty in automating processes), productivity growth is largely confined to the "progressive" sector. Assuming that wages grow at the same rate in the "stagnant" and "progressive" sectors of the economy, then unit labour costs and prices in the "stagnant" sector will rise relative to those in the "progressive" sector. What will happen to the demand for "stagnant" sector products depends on their price elasticity. If it is high, such activities will tend to disappear (e.g. craftsmanship), but if those products are a necessity with low price elasticities (e.g. health, education), their expenditure-to-GDP ratios will trend upwards (Hartwig, 2011a; Baumol 2012).

In this context, it is important to disentangle the factors driving expenditure growth, notably the relative importance of demographic versus non-demographic ones. The literature accounting for HE growth is similar to the economic growth literature, namely it identifies a series of factors, assessing by how much they account for the change in total expenditure (Newhouse, 1992). Results of HE breakdowns, using accounting methods, can then be compared with those obtained using regression analysis (e.g. Maisonneuve and Martins, 2013).

Following analytical work carried out for the 2009 Ageing Report (Dybczak and Przywara, 2010), this note reassesses the impact of non-demographic drivers (NDD) on HE growth. The literature has identified the following main drivers of HE: income, demography, technology, health policies and institutions, and the low productivity growth of health services compared to "progressive" sectors in the economy (i.e. Baumol's "cost-price disease" effect).

The impact of NDD dominates. On average, only approximately 1/10 of the increase in public HE-to-GDP ratios is explained by changes in the age distribution of the population. The remaining 9/10 is attributable to the combined effect of NDD, including rising national incomes, technological progress, the Baumol effect, and health policies and institutions (Maisonneuve and Martins, 2006 and 2013).

As in Clements et al. (2012), this note uses panel regression techniques to estimate the impact of NDD on HE. NDD is defined as the excess of growth in real per capita HE over the growth in real per capita GDP, after controlling for demographic change. Common[4] income and price elasticities of HE are also estimated.[5]

Panel regressions are run using either data in growth rates or in levels, and assuming country-fixed effects. Regressions in levels require assuming that expenditure, income and demographic variables are co-integrated, and estimating the speed of convergence to the long term equilibrium.[6] Data on public HE are primarily taken from the System of Health Accounts (SHA) as provided by the OECD and Eurostat, and if necessary supplemented by

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3 Over the years a variety of "cost containment" techniques have been tried. On balance, these techniques appear to have been beneficial, but they have had primarily a once-and-for-all effect on the expenditure level, leaving the steady state rate of change little affected (Newhouse, 1992).

4 "Average" values across countries.

5 However, the estimated common income elasticity of HE should be taken with some care, because some missing variables (e.g. technology/quality) might bias estimates (see Box 1).

6 Or equivalently, the reabsorption speed of deviations of HE from their long term levels.

national data sources.[7] This paper tests the relevance of Baumol's "unbalanced growth model" using macroeconomic panel data. Ultimately, regression estimates based on the growth rate model specification are used to build a number of long term projection scenarios (up to 2060) for the HE-to-GDP ratio.

The paper is organised as follows. First, an overview of the relevant literature on the main drivers of HE is provided. Second, the data, equation specifications, and regression methods are discussed. Third, country-specific estimates of NDD are calculated, together with a comprehensive sensitivity/robustness analysis of outcomes according to various equation specifications. Westerlund's (2007) panel tests are used for the co-integration of HE, national income, relative prices of health services, and demographic composition variables. Fourth, tests are carried out to assess the relevance of Baumol's "unbalanced growth model", using panel macroeconomic data. Fifth, projection scenarios for the HE-to-GDP ratio, using growth rate equations, are presented up to 2060 and compared with projections calculated using different/alternative methodologies presented in the empirical literature.

2. Drivers of health expenditure (HE) – overview of the literature

Growth in HE depends on a variety of demand and supply related factors. Population size and the age composition, income, medical technology, relative prices, insurance coverage, and health regulations and policies have been probably the most prominent determinants of HE studied in the literature so far.

Demographic factors

Population size and structure

Expenditure on health naturally depends on the number of people in need of health care. This is determined by factors such as population size and the age composition. Expenditure is perceived to increase considerably at older ages, as elderly people often require costly medical treatment due to multi-morbidities and chronic illnesses. Improvements in life-expectancy may therefore lead to increases in health expenditure if not accompanied by improvements in health status.

Health status

However, the relation between life-expectancy and health expenditure is more complex, because it is also influenced by proximity to death. According to the “red herring” hypothesis (Zweifel et al., 1999), age and HE are not related once remaining lifetime (proximity to death) is taken into account. Zweifel et al. (1999) show that the effect of age on health costs is not relevant during the entire last two years of life, but only at the proximity of death does HE rises significantly. Therefore, improvements in life-expectancy due to decreases in mortality rates may even reduce expenditure on health. Empirical studies have partially confirmed this hypothesis.[8] When controlling for proximity to death, age per se plays a less important role in explaining health expenditure increases.

The extent to which living longer leads to higher costs seems to depend largely on the health status of the population. If rising longevity goes hand in hand with better health at older ages, health needs will decline and this may drive down health expenditure (Rechel et. al. 2009). Three competing hypotheses have been proposed for the interaction between changes in life-expectancy and the health status. According to the "expansion of morbidity hypothesis", reductions in mortality rates are counterbalanced by rises in morbidity and disability rates

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[7] Public HE is defined by the "core" functional components of health (SHA categories HC.1 – HC.9), including capital investment in health (HC.R.1). Note that the OECD prefers using current (and not total) public HE (Mainsonneuve and Martins, 2013).

[8] For an overview of the literature see Karlsson and Klohn (2011).

(Olshansky et al., 1991). The "compression of morbidity hypothesis" claims that bad health episodes are shortened and occur later in life (Fries, 1989). The "dynamic equilibrium theory" suggests that decreases in mortality rates and in the prevalence of chronic diseases are broadly offset by an increase in the duration of diseases and in the incidence of long term disability rates (Manton, 1982). There is so far no empirical consensus on which of these three hypotheses is better equipped to explain HE developments.[9]

<u>Non-demographic factors</u>

Income

Income is another key determinant of health care costs (Gerdtham and Jönsson, 2000). A priori, it is unclear whether health expenditure is an inferior, a normal or a superior good, i.e. is the income elasticity of health demand lower, equal or higher than 1? As in the EU a high share of health expenditure is covered by public health insurance schemes, the individual income elasticity of demand is low. At the same time, increases in insurance coverage have strengthened the link between national income and aggregate demand for health services, through the implicit softening of budgetary constraints. In fact, income elasticity tends to increase with the level of aggregation of the data, implying that HE could be both "an individual necessity and a national luxury" (Getzen, 2000). Maisonneuve and Martins (2006) suggest that high income elasticities (above one) often found in macro studies may result from the failure to control for price and quality effects in econometric analysis. More recent studies, tackling some methodological drawbacks of previous ones (e.g. related to omitted variables and/or endogeneity bias), estimate income elasticities of health demand of around one or below (Freeman, 2003; Azizi et al., 2005; Acemoglu et al., 2009).[10]

Acemoglu et al. (2009) attempt to estimate the causal effect of aggregate income on aggregate health expenditures in (Southern) United States regions. They instrument local area income with the variation in oil prices weighted by oil reserves. Their central estimate for the income elasticity is 0.7, with a maximum bound at the 95% interval of 1.1. This result is robust to different specifications with the income elasticity being almost always below one. Consequently, income increases are unlikely to be a primary driver of the increase in the health share of GDP. Their analysis also indirectly suggests that rising incomes are unlikely to be the major driver of medical innovations either. An interesting possibility is that institutional factors, such as the spread of insurance coverage, have not only directly encouraged spending but also induced the adoption and diffusion of new medical technologies (Acemoglu and Finkelstein, 2008).

Technological advances in medical treatments

In the past decades, health expenditure has been growing much faster than what would be expected from changes in demography and income alone. Many studies claim that the gap is filled by technologic advances in the health sector. Innovations in medical technology allow for expanding health care to previously untreated medical conditions and are believed to be a major driver of health expenditure. Smith et al. (2009) suggest that between 27% to 48% of health expenditure since 1960 is explained by innovations in medical technology. Earlier studies estimated that about 50% to 75% of increases in total expenditure were driven by technology (Newhouse, 1992; Cutler, 1995; Okunade and Murthy, 2002; and Maisonneuve and Martins, 2006).

Cutler (2005) argues that technological advances in medical sciences have generated both far-reaching advances in longevity and a rapid rise in costs. Chandra and Skinner (2011)

[9] See for e.g. the Global Forum for Health Research (2008).

[10] For a review of the literature on income elasticity estimates see Annex 3 in Maisonneuve and Martins (2013).

attempt to better understand the links between technological progress in health care and its impact on costs and the effectiveness of treatments. They rank general categories of treatments according to their contribution to health productivity, defined as the improvement in health outcome per cost. Within a model framework, they propose the following typology for the productivity of medical technology: firstly, highly cost-effective innovations with little chance of overuse, such as anti-retroviral therapy for HIV; secondly, treatments highly effective for some but not for all (e.g. stents); and thirdly, "grey area" treatments with uncertain clinical value such as ICU days among chronically ill patients.

Relative prices

Baumol (2012) forcefully restates his well-known thesis that because in personal services industries (e.g. health, education, life performing arts) automation is not generally possible, labour-saving productivity improvements occur in those industries at a considerably slower pace (or only sporadically) and below the average rate for the whole economy. As a result, costs and prices in personal services industries, such as in health, increase at a faster pace than the average inflation rate in the whole economy, leading to a significant and enduring long term trend rise in the corresponding expenditure-to-GDP ratios for those industries facing an inelastic demand curve.

Using US data, Nordhaus (2008) confirmed Baumol's hypothesis of a "cost-price disease" due to slow productivity growth in labour intensive sectors, namely industries with relatively low productivity growth ("stagnant industries") show percentage-point for percentage-point higher growth in relative prices. Using a panel of 19 OECD countries, Hartwig (2008) finds robust evidence in favour of Baumol's hypothesis that health expenditure is driven by wage increases in excess of productivity growth in the whole economy.

Baumol (1967, 2012) highlights the major implication resulting from the fact that some of the industries most affected by the "cost-price disease" greatly impact on society's welfare, such as health, education, justice, policing, fine-arts, etc. Persistent rises in the relative prices of such activities, which are inherent to a process of "unbalanced growth", where labour-saving innovations are difficult to come about in "stagnant" sectors, tend to strain both household and government budgets, potentially resulting in a decline in the quality and/or quantity of (public) provided products and services and/or in their becoming inaccessible to less-favoured groups.[11] This state of affairs threatens to create both *private affluence and public squalor* (Galbraith, 1998). It will also require a gradual shifting of economic resources to activities, such as health and education, which in European countries are mostly financed through taxation.

Regulations

Another important dimension of public health expenditure is the regulatory settings and policies on the provision and financing of expenditure. Regulations may set budgetary constraints, define the extent of public health coverage, and provide behavioural rules and incentives for providers and payers aimed at the financial or medical quality of outcomes. Clements et al. (2012) suggest that reliance on market mechanisms[12] and the stringency of budgetary caps on expenditure are negatively related to public expenditure growth on health,

11 Freeman (2013) makes a similar point: "*If …the observed increasing share of HE in total expenditures is driven more by cost factors, with upward shifting supply and price-inelastic demand, the questions of affordability and access become more important to policy makers*."

12 In Jekner et al. (2010), "market mechanisms" is a factor score resulting from a principal component analysis of 20 qualitative policies and institutions' indicators presented in Joumard et al. (2010). The "market mechanisms" factor score is mainly characterised by the following indexes: i) "private provision" of health (breakdown of physicians and hospital services according to their nature i.e. public or private); ii) "user information" (on quality and prices of various health services); iii) "choice of insurers" (in case of multiple insurers: the ability of people to choose their insurer); and iv) "insurer levers" (insurers' ability to modulate the benefit basket).

while intensity of regulations and degree of centralisation are positively related to public expenditure growth on health.

3. The methodology

3.1. The data

Data on public HE are primarily taken from the System of Health Accounts (SHA) as provided by the OECD and Eurostat, and if necessary supplemented by national data sources.[13] The dataset covers 27 EU Member States[14] and Norway. For some Member States, data series are available since the mid-1970s (see Table 1),[15] although time coverage is unbalanced across countries. Data were collected between November 2012 and January 2013, thereby not including 2011 SHA data.[16]

Table 1 – Adjusted Public Expenditure on Health (1960-2010)
Percentage of GDP, adjusted for structural breaks

	Number of observations	1960	1970	1980	1990	2000	2010		1960-2010	1970-2010	1980-2010	1990-2010	2000-2010
									Differences				
at	51	3.6	3.9	6.1	6.1	7.6	8.4		4.8	4.5	2.3	2.2	0.8
be	16	...	...	...	...	7.1	8.0		...	...	...	...	0.9
bg	18	...	...	...	5.2	3.7	4.2	a)	...	...	...	-1.0	0.5
cy	19	...	...	...	...	2.4	3.3		...	...	...	...	0.9
cz	21	...	...	...	3.9	5.8	6.3		...	...	...	2.4	0.5
de	41	...	5.8	8.7	8.3	8.3	8.9		...	3.1	0.2	0.6	0.6
dk	40	...	...	7.9	6.9	7.3	9.5		...	...	1.6	2.6	2.2
ee	16	...	...	...	...	4.1	5.0		...	...	...	...	0.9
el	26	...	2.3	3.3	3.6	4.8	6.1		...	3.8	2.8	2.5	1.3
es	40	...	...	4.3	5.2	5.2	7.1		...	...	2.8	1.9	1.9
fi	52	1.7	3.3	4.0	5.1	5.1	6.6		5.0	3.3	2.6	1.6	1.5
fr	21	...	...	...	7.4	8.0	9.0		...	...	...	1.6	1.0
hu	20	...	...	...	...	5.1	5.0		...	...	...	...	0.0
ie	25	...	...	...	4.3	4.6	6.4		...	...	...	2.1	1.8
it	23	...	...	...	6.1	5.8	7.4		...	...	...	1.3	1.6
lt	19	...	...	...	3.0	4.5	5.6	c)	...	...	...	2.6	1.1
lu	35	...	...	5.6	5.8	6.4	6.6	c)	...	...	1.0	0.8	0.3
lv	17	...	...	...	2.5	3.2	4.1	b)	...	...	...	1.6	0.9
mt	15	...	...	...	...	4.9	5.8	c)	...	...	...	...	0.9
nl	38	...	...	5.1	5.3	5.0	7.4	c)	...	...	2.3	2.1	2.4
pl	21	...	...	...	4.4	3.8	5.0		...	...	...	0.6	1.2
pt	41	...	1.6	3.6	4.0	6.2	7.1		...	5.5	3.5	3.0	0.9
ro	23	...	...	...	2.9	3.6	4.5	c)	...	...	...	1.6	0.9
se	41	...	5.7	8.1	7.2	6.9	7.7		...	2.0	-0.3	0.5	0.8
si	21	...	...	...	5.6	6.1	6.6		...	...	...	1.0	0.5
sk	16	...	...	...	...	4.9	5.8		...	...	...	...	0.9
uk	39	...	...	4.6	4.6	5.5	8.0		...	...	3.4	3.4	2.5
no	52	2.0	3.5	5.2	5.8	6.4	7.8		5.8	4.2	2.6	2.0	1.4
Total	807												

Source: Own calculations based on SHA and national data.
Notes: In general, latest available data are from 2010, except: a) from 2007, b) from 2008, and c) from 2009.

Using the information on breaks of series included in the dataset,[17] this paper follows the procedure suggested in Joumard et al. (2008) to adjust for structural breaks in the data, namely the average growth rate of expenditure over the past five years is used to project

[13] Public HE is defined by the "core" functional components of health care (SHA categories HC.1 – HC.9), including capital investment in health (HC.R.1).
[14] EU composition prior to Croatia's accession on 1/7/2013.
[15] Data for 11 countries are available since the mid-1970s, namely for AT, DE, DK, ES, FI, LU, NL, NO, PT, SE, and the UK.
[16] As regards regression analysis, exclusion of 2011 data is not expected to change significantly the results. Recall that regressions are also estimated excluding the most recent years in the dataset (2009 and 2010) to check for the overall robustness of results.
[17] Information on breaks exists for AT, BE, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IE, IT, LU, NL, NO, PL, PT, SE, SI, SK, and the UK.

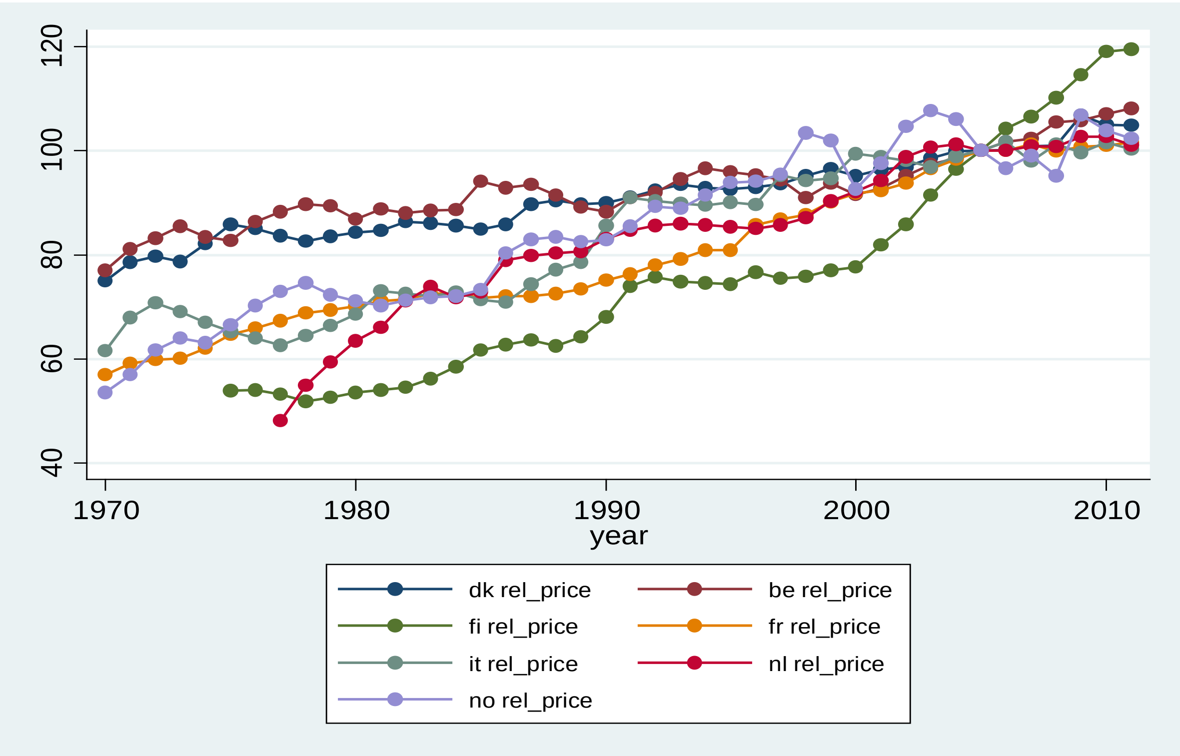
expenditure growth in a break year. Level corrected variables are used to calculate adjusted GDP ratios and estimate regressions in levels (i.e. assuming co-integration).

The following variables are used in all estimated regressions. The relative price index for health services ($p \equiv \frac{p_h}{p_y}$) is the ratio of the health price deflator (p_h) over the GDP deflator (p_y). Nominal public health care expenditure and nominal GDP are deflated using, respectively, the health price index and the GDP deflator with base year 2005, and then converted for the same year using purchasing parity standards (PPS).[18] GDP data (real and nominal), wages and CPI indexes, and PPS are all taken from the European Commission's Ameco database, and population data from Eurostat.

Given the strong evidence suggesting that relative prices of health services have been increasing on a regular basis, it is important to include information on health prices in the regression specifications. Maisonneuve and Martins (2013) use the value-added deflator in the Health and Social Work sectors, taken from the OECD STAN database. Unfortunately for the purposes of this analysis, the geographical coverage of the STAN database is very limited.[19]

Using the OECD STAN database for the seven European countries for which long term series are available, Graph 2 suggests a clear upward trend in relative prices of health services over the last four decades.

Graph 2 – Relative prices of health services (index 2005=100)



Sources: OECD STAN database and DG ECFIN Ameco.
Note: relative prices of health services are calculated as the ratio of the value-added deflator in the Health and Social Work sectors, using the STAN database, over the GDP deflator (Ameco).

Elk et al. (2009) methodology to construct a price index for health services using macro data for wages and prices (the overall consumer price index) is applied in the following way:

[18] The same procedure was followed in Gerdtham et al. (1995) and Barros (1998). For example, the dependent variable (real per capita HE) is valued at constant 2005 prices (in national currency using p_h as deflator) and then converted in PPS for 2005.

[19] Using the OECD STAN database, health prices indices can be obtained for only 13 European countries: AT, BE, CZ, DE, DK, FI, FR, HU, IT, NL, NO, SE, and SI.

$$P_h = W^{\phi} * CPI^{1-\phi} \quad (1)$$

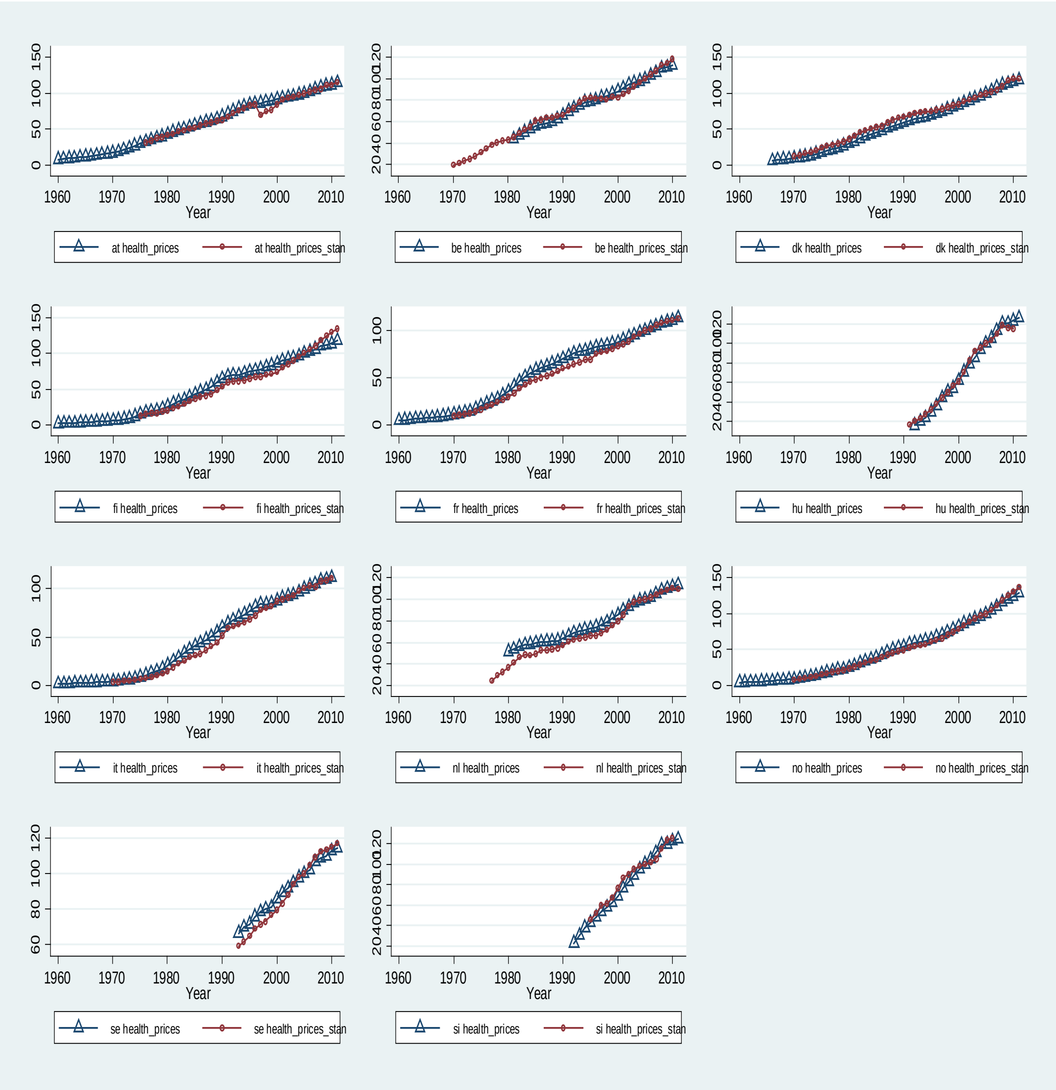
where the price of health services (P_h) is a weighted average of wages for the whole economy (W) and overall consumer prices (CPI). The latter is used because the health sub-component of Eurostat's HCPI is only available since 1996. The weights (ϕ) are country-specific and are calculated using national accounts input-output tables.

$$\phi = \frac{W + {}^{2}/_{3} * IC}{X} \quad (2)$$

where IC and X are total intermediate consumption and total production, respectively, in the Human Health Activities sector of national accounts data (Eurostat). Thus, the weight is defined as the compensation for employees in the health sector plus the estimated compensation for employees in the intermediate consumption part (using for the latter an estimated wage share of 2/3) divided by total production.

The proxy price indices for health services built using (1) and (2) closely follow those taken from the OECD STAN database (Graph 3).

Graph 3 – Comparing health prices indices (index 2005=100).
- OECD STAN versus a proxy based on aggregate Ameco data and input-output national accounts data (Eurostat) -



Sources: OECD STAN database, DG ECIN Ameco, and Eurostat.

3.2. Regression equations

The analysis carried out in this section estimates regressions with total (current and capital) public HE as the dependent variable to obtain income and price elasticities of health expenditure. These elasticities are later used to project future HE-to-GDP ratios. The choice of total public HE as dependent variable reflects the "practical" nature of our problem: we want to build a methodological framework to project long term public HE.

As discussed above, the key determinants of HE are income levels, the Baumol relative prices effect, demographic composition, technological advances, health policies and institutions, and other country-specific factors (e.g. health behaviour, environment, education).

As a starting point, the following generic dynamic equation expressed in levels is considered, which is typical of this literature (e.g. Smith et al. 2009). In the presence of co-integration, it allows to derive the long-term relationship (LTR) and estimate an error correction model (ECM). The latter allows for checking whether there are significant dynamics in the data that correct for imbalances i.e. to estimate the speed of reabsorption of disequilibria.[20]

$$\log h_{i,t} = \alpha'_0 + \alpha' * t + \mu'_i * t + D'_{85} * t + \beta_1 * \log x_{i,t} + \beta_2 * \log y_{i,t} + \beta_3 * \log p_{i,t}$$

$$+\beta_4 * \log h_{i,t-1} + \beta_5 * \log x_{i,t-1} + \beta_6 * \log y_{i,t-1} + \beta_7 * \log p_{i,t-1} \quad (3)$$

where $h_{i,t}$ is real per capita public expenditure on health in country *i* and year *t*; $x_{i,t}$ reflects the demographic structure[21]; $y_{i,t}$ is real per capita GDP; p_{it} is the relative prices of health services;[22] μ'_i denotes country fixed effects; and D'_{85} is a dummy variable that denotes a common shift in the growth rate of per capita expenditure after 1985.[23]

Assuming co-integration, the LTR can be derived as:

$$\log h_{i,t} = \alpha_0 + \alpha * t + \mu_i * t + D_{85} * t + a * \log x_{i,t} + b * \log y_{i,t} + c * \log p_{i,t} + EC_{i,t} \quad (4)$$

with

$a = \frac{\beta_1+\beta_5}{1-\beta_4}$; $b = \frac{\beta_2+\beta_6}{1-\beta_4}$; $c = \frac{\beta_3+\beta_7}{1-\beta_4}$; $\alpha_0 = \frac{\alpha'_0}{1-\beta_4}$; $\alpha = \frac{\alpha'}{1-\beta_4}$; $\mu_i = \frac{\mu'_i}{1-\beta_4}$; $D_{85} = \frac{D'_{85}}{1-\beta_4}$; and $EC_{i,t}$ is the error correction term which is assumed to be stationary.

The corresponding ECM is:

$$\Delta\log h_{i,t} = c + \beta_1 * \Delta\log x_{i,t} + \beta_2 * \Delta\log y_{i,t} + \beta_3 * \Delta\log p_{i,t} + \delta * EC_{i,t-1} \quad (5)$$

with

$$c = \alpha' + \mu'_i + D'_{85};\ \delta = -(1-\beta_3) < 0$$

Assuming co-integration, equation 4 can be estimated using either ordinary least squares (OLS) or instrumental variables methods (IV). IV may alleviate the problem of potential

[20] For practical/feasibility reasons the reduced form equation (3) ignores two-way causation effects between economic growth and health. Within a neo-classical growth model, Barro (1996a) proposes a framework that considers the interaction between health and economic growth, obtaining positive synergies. Better health tends in various ways to enhance economic growth, whereas economic advance encourages further the accumulation of health capital. Using a panel of around 100 countries from 1960 to 1990, Barro (1996b) finds strong support for the general notion of conditional convergence, including a positive impact of life-expectancy on the GDP growth rate. Overall, empirical results suggest a significantly positive effect on growth from the initial human capital stock in the form of better health.

[21] Two strategies are used in the regressions to capture the demographic structure of the population. A first strategy is to use the fraction of the population below 16 (young population ratio), and the fraction of the population above 65 (old population ratio). The second strategy is to use the average age of the population. Results are only reported for the first strategy.

[22] Relative prices ($p \equiv \frac{p_h}{p_y}$) is the ratio between the price of health services (p_h) and the GDP deflator (p_y).

Instead of using the relative prices variable (p), regressions are also estimated (directly) using health prices (p_h) and the GDP deflator (p_y). The two approaches are equivalent, if in the regressions that use the two price variables $\{p_h, p_y\}$, their coefficients sum to zero. This condition is tested using a Wald test (see Tables 6 and 7). Usually, and more specifically for the regressions that assume co-integration (i.e. in levels), the null hypothesis that the two price coefficients sum to zero cannot be rejected.

[23] The dummy variable is statistically significant in regressions with variables in growth rates.

endogeneity of the income variable, using as instrument its lagged values.[24] In equation 5 of the ECM, the crucial parameter to be estimated is δ, which should be negative, giving the speed of convergence of deviations of per capita HE to long term values.

Conversely, if the variables are not co-integrated, but are first order integrated (i.e. I(1)), the first difference of equation 4 should be estimated instead, namely:[25]

$$\Delta \log h_{i,t} = \alpha + \mu_i + D_{85} + a * \Delta \log x_{i,t} + b * \Delta \log y_{i,t} + c * \Delta \log p_{i,t} + \varepsilon'_{i,t} \qquad (6)$$

where Δ is the first difference operator (i.e. $\Delta z_t = z_t - z_{t-1}$).

Equation 6 assumes that real per capita growth in public HE ($h_{i,t}$) is a function of a common growth rate across all countries (α); a country-specific growth rate differential (i.e. country fixed effects: μ_i); a period dummy (D_{85}), signalling a common shift in the growth rate after 1985; real per capita GDP growth rate ($y_{i,t}$); relative prices of health services ($p_{i,t}$); and a population composition effect ($x_{i,t}$). The common growth rate (α) and country-fixed effects (μ_i) capture time-invariant factors, such as institutional settings, and national idiosyncrasies.

It should be noted that relevant aspects, such as medical technology or quality are not considered in the analysis due to limited data coverage and theoretical concerns.[26] Consequently, estimates may be affected by "omitted-variable" bias, which is not possible to "sign" a priori however (Box 1). Ultimately, it can be argued that the presence of biases in the estimates might not be so problematic, because our objective is not to estimate "pure" elasticity effects (e.g. an income Engel curve), but to produce a "sound" methodology for projecting HE.

Summarising, econometric regressions are run using models with variables expressed either in levels (equation 4), which assumes that variables are co-integration, or in growth rates (equation 6), which assumes that variables are first order integrated (i.e. I(1)), but are not necessarily co-integrated.

3.3. Non-stationarity (unit roots) and co-integration

A major subject of the literature on health economics is the relationship between HE and GDP. In spite of their strong positive correlation, it is possible that it results from the non-stationarity (i.e. unit roots) of the respective time series, rather than being evidence of a "true" economic relationship.[27]

Using country-specific tests, Hansen and King (1996) found that two-thirds of the variables tested (per capita real HE and GDP) had unit roots (i.e. were non-stationary in levels). Using also country specific tests, Blomqvist and Carter (1996), Gerdtham and Lothgren (2000) and Dybczak and Przywara (2010) found that HE and GDP generally had unit roots. Using panel unit root tests, MacDonald and Hopkins (2002) and Okuande and Murthy (2002) found strong evidence of unit roots for both HE and GDP, while Dybczak and Przywara (2010), using the panel test allowing for individual unit roots proposed in Im et al. (2003), find that HE has a unit root but rejected the unit root hypothesis for GDP.

[24] Relative prices (*p*) are assumed to be exogenous, because the proxy variable being used (based on wages in the whole economy and CPI inflation) can be treated as an exogenous regressor.

[25] Note that nobody has ever suggested that these series could be second order integrated or higher, thereby running regressions in growth rates (i.e. in first differences) should be sufficient to avoid obtaining spurious results.

[26] Maisonneuve and Martins (2013) include a quality variable of health services by building a proxy that combines data on patents with expenditure on R&D. The authors mention the near "heroic" nature of the assumptions needed to construct such variable.

[27] It is a well-known fact since the 1st half of the twentieth century that the correlation coefficient between unrelated non-stationary time series tends to 1 or -1 as the length of time increases (Yule, 1926).

Applied to our dataset, the Phillips-Perron (1988) country-specific unit root test does not reject the null hypothesis of a unit root for the logarithms of real per capita HE, real per capita GDP, and relative prices of health services for most of the countries (Table 2).

Table 2 – The Phillips-Perron unit root test

	HE		GDP		Rel. Prices	
at	0.33		0.93		0.81	
be	0.23		0.85		0.63	
bg	0.84		0.29		0.53	
cy	0.97		0.99		0.40	
cz	0.04	*	0.01	**	0.56	
de	0.25		0.64		0.22	
dk	0.92		0.85		0.05	
ee	0.92		0.93		0.94	
ie	1.00		1.00		0.86	
it	0.75		0.99		0.00	***
el	0.00	**	0.48		0.35	
es	0.19		0.71		0.00	**
fi	0.17		0.70		0.75	
fr	0.82		0.79		0.02	*
hu	0.61		0.75		0.83	
lt	0.95		0.06		0.97	
lu	0.09		0.83		0.97	
lv	0.24		0.03	*	0.00	***
mt	0.97		0.48		0.93	
nl	0.63		0.79		0.00	**
no	0.86		1.00		0.95	
pl	0.56		0.00	**	0.94	
pt	0.79		0.89		0.21	
ro	0.09		0.07		0.55	
se	0.01	**	0.13		0.98	
si	0.22		0.12		0.10	
sk	0.82		0.57		0.30	
uk	0.63		0.59		0.93	

Note: The values represent p-values of the null hypothesis (H_0) that the series has a unit root.
The H_0 is rejected if the p-value is smaller than or equal to the significance level chosen.
Legend: * p<0.05; ** p<0.01; *** p<0.001.

Recently, use of panel based tests has gained preponderance relatively to country-specific ones for carrying out stationarity analysis. Panel data tests have a number of advantages, namely controlling for time invariant country characteristics, and eventually providing more powerful tests for the stationarity and co-integration of series.

In order to obtain more reliable evidence concerning the stationarity of the analysed variables, panel unit root tests are used (Table 3). First, existence of a common unit root is tested using the Im-Pesaran-Shin test. Second, a panel Fisher-type unit root test is calculated based on country-specific Phillips-Perron tests. Based on the two panel tests, the hypothesis that all GDP panels contain unit roots cannot be rejected. Results for HE are mixed, but the hypothesis that all HE panels are stationary is rejected only at the 1% significance level in the

Im-Pesaran-Shin test. Based on the two tests, the hypothesis that all relative prices panels contain unit roots is rejected.

Table 3 – Panel unit root tests

	HE		GDP		Rel. Prices	
Im-Pesaran-Shin	0.01	**	0.58		0.00	**
Fisher chi-squared a)	0.28		0.17		0.00	***

Note: The values represent p-values of the null hypothesis (H_0) that all panels contain unit roots.
The H_0 is rejected if the p-value is smaller than or equal to the significance level chosen.
Legend: * p<0.05; ** p<0.01; *** p<0.001.
Fisher-type unit root test based on Philips-Perron tests.
a) P-value based on the inverse chi-squared statistic.

Overall, the evidence seems to support the unit root hypothesis, but it is less conclusive on the co-integration hypothesis. For example, Hansen and King (1996) find that country specific tests rarely reject the null hypothesis of no co-integration, and Dybczak and Przywara (2010), also using a country specific test, find that real per capita HE and GDP[28] are not co-integrated in a number of countries. Conversely, using panel co-integration tests the evidence suggests that HE and GDP are co-integrated (Westerlund, 2007).[29]

Following the outcomes of several studies, we assume that the logarithm of per capita HE $h_{i,t}$ (deflated by health prices), the logarithm of per capita GDP $y_{i,t}$ (deflated by the GDP deflator), and the logarithm of the relative prices of health $p_{i,t}$ are all I(1). Furthermore, using Westerlund's (2007) panel co-integration test (Table 4), we find that co-integration of these three variables depends critically on adding or not a deterministic trend to the co-integration relationship. However, even if a deterministic trend is excluded, consideration of a fourth variable, representing the composition of the population, would lead us to accept the null hypothesis of no-co-integration (results not shown).

Table 4 – Calculating Westerlung's ECM panel co-integration test

	Deterministic trend	
	Excluded	Included
	(1)	(2)
Statistic: Pa 1)	-5.857	-4.84
P-value	0	1

1) Pa: Small sample panel statistic

Note: H_0: no co-integration.

Summarising, individual country-by-country tests do not provide evidence of the existence of co-integration relationships for all countries, while tests based on panel co-integration appear to be inconclusive, depending on the inclusion or not of a deterministic time trend. Furthermore, demographic variables could not be included in the co-integration relationship.[30]

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[28] Both variables deflated using the GDP deflator.

[29] The literature concerned with the development of panel co-integration tests has taken three broad directions (Westerlund, 2007). A first approach takes no co-integration as the null hypothesis. Tests within this approach are almost exclusively based on the methodology of Engle and Granger (1987), whereby the residuals of a static (country-specific) least squares regression are subject to a unit root test. A second approach is the basis of the panel co-integration tests proposed by McCoskey and Kao (1998) and Westerlund (2005), taking co-integration as the null hypothesis. A third approach proposed by Westerlund (2007) tests the null hypothesis of no co-integration and are based on structural rather than residual dynamics, and therefore do not impose any common factor restriction. The latter type of tests are panel extensions of those proposed in the time-series context by Banerjee, Dolado and Mestre (1998).

[30] The limited reliability of co-integration tests might be due to the short duration of HE variables (Hewatz anf Theilen, 2002), together with the presence of frequent structural breaks in the data that tend to limit their power (Clemente et al., 2004).

3.4. Country-specific estimates of Non-Demographic Drivers (NDD)

The objective of this paper is to estimate the effects of non-demographic drivers (NDD) on HE or equivalently average residual HE growth by country. Three indicators are calculated: i) country-specific excess cost growth (C); ii) a common income elasticity (η); and iii) a common price elasticity (γ). Given the logarithmic specification of the regressions, the latter two indicators are directly obtained from the estimates. In fact, while the excess cost growth (C) is an "average" over the sample indicator, elasticity indicators are "marginal/point" indicators.

Excess cost growth (C) estimates (or average residual estimates) are defined as:

$$\widetilde{C_\iota} = \frac{\sum\frac{\widetilde{\Delta h_{\iota,t}}|\Delta x_{i,t}=0}{\widetilde{h_{\iota,t}}|\Delta x_{i,t}=0}+\sum\frac{\Delta p_{i,t}}{p_{i,t}}-\sum\frac{\Delta y_{i,t}}{y_{i,t}}}{T_i} \approx \frac{\sum \Delta \log\widetilde{h_{\iota,t}}|\Delta x_{i,t}=0 + \sum \Delta \log p_{i,t} - \sum \Delta \log y_{i,t}}{T_i} \quad (7)$$

with T_i denoting the number of years of data available for country i.[31]

According to equation 7, (C) equals the difference between the (geometric) average growth rate of estimated real per capita (public) HE, after controlling for the impact of demographic composition, minus the (geometric) average growth rate of real per capita GDP. The difference being expressed in GDP units.[32]

Using (4) or (6), the (C) estimate (for the period after 1985) is:

$$\widetilde{C_\iota} = \tilde{\alpha} + \widetilde{\mu_\iota} + \widetilde{D_{85}} + \left(\tilde{b} - 1\right) * \frac{\sum_{t=1985}^{1985+T_i^*-1} \Delta \log y_{i,t}}{T_i^*} + (1 + \tilde{c}) * \frac{\sum_{t=1985}^{1985+T_i^*-1} \Delta \log p_{i,t}}{T_i^*} \quad (8)$$

with T_i^* denoting the number of years of data available for country i after 1985.

[31] A tilde over a parameter means an estimated value.

[32] Presence of the relative prices term is due to the fact that HE and GDP use different deflators.

Box 1: Omitted-variable bias

Economic theory suggests that a quality index, representing technologic progress in the field of medical sciences, ideally should also be included as a regressor in a HE equation (Maisonneuve and Martins, 2013).

Suppose that the true HE model should be represented as:

$$h_t = \alpha * y_t + \beta * p_t + \gamma * z_t + \epsilon_t \qquad \text{(i)}$$

where h_t is real per capita HE; y_t is real per capita GDP; p_t are health services relative prices; and z_t is the "omitted" quality/technology variable. The expected signs of parameters are: $\{\alpha, \gamma\} > 0$ and $\beta < 0$. Note that all 3 correlations, involving the 3 regressors, should be positive.

However, suppose that data on z_t are missing (or are of "poor" quality) and only the following regression can (should) be estimated:

$$h_t = \alpha * y_t + \beta * p_t + \epsilon'_t \qquad \text{(ii)}$$

Using equation (ii) and OLS to obtain income and price elasticity estimates, respectively $\{\hat{\alpha}, \hat{\beta}\}$, it can be shown (e.g. Maddala, 2001, pp. 160) that the expected estimation biases are given by:

$$\underbrace{\mathrm{E}\begin{bmatrix}\hat{\alpha}-\alpha\\ \hat{\beta}-\beta\end{bmatrix}}_{total\ bias} = \gamma * \mathrm{E}\begin{bmatrix}1 & \frac{\sum_t y_t p_t}{\sum_t y_t^2}\\ \frac{\sum_t y_t p_t}{\sum_t p_t^2} & 1\end{bmatrix}^{-1} * \left\{\underbrace{\mathrm{E}\begin{bmatrix}\frac{\sum_t y_t z_t}{\sum_t y_t^2}\\ \frac{\sum_t p_t z_t}{\sum_t p_t^2}\end{bmatrix}}_{omitted-variable\ bias} + \underbrace{\mathrm{E}\begin{bmatrix}\frac{\sum_t y_t \varepsilon_t}{\sum_t y_t^2}\\ \frac{\sum_t p_t \varepsilon_t}{\sum_t p_t^2}\end{bmatrix}}_{endogeneity\ bias}\right\} \qquad \text{(iii)}$$

where **E** is the expectation operator.

According to (iii) there are two possible sources of bias. The endogeneity bias only occurs when $\{y_t, p_t\}$ are endogenous i.e. correlated with the error term ϵ_t. In order to address the latter we calculate IV estimates using as instruments for per capita GDP its lagged value, and assuming that the variable used as a proxy for relative prices is exogenous.

The remaining bias is due to the omitted-variable problem, and its sign is given by:

$$\underbrace{\mathrm{sign}\left(\mathrm{E}\begin{bmatrix}\hat{\alpha}-\alpha\\ \hat{\beta}-\beta\end{bmatrix}\right)}_{?} = \underbrace{\mathrm{sign}\ (\gamma)}_{+} * \underbrace{\mathrm{sign}\left(\mathrm{E}\begin{bmatrix}\frac{\sum_t y_t z_t}{\sum_t y_t^2} - \frac{\sum_t y_t p_t}{\sum_t y_t^2}\frac{\sum_t p_t z_t}{\sum_t p_t^2}\\ \frac{\sum_t p_t z_t}{\sum_t p_t^2} - \frac{\sum_t y_t p_t}{\sum_t y_t^2}\frac{\sum_t y_t z_t}{\sum_t p_t^2}\end{bmatrix}\right)}_{?} \qquad \text{(iv)}$$

The sign of the omitted-variable bias is undetermined, as the correlations between the three regressors (second term in the right side of iv) are all assumed to be positive, and therefore the sign of their differences is a priori unknown.

3.5. Regression estimates

Provided that variables are co-integrated, both equations 4 and 6 can be estimated using either ordinary least squares (OLS) or instrumental variables (IV) methods i.e. regressions can be estimated using variables either in levels or in first differences.[33]

In case variables are not co-integrated but have unit roots, only equation 6 (in growth rates) can be estimated, otherwise for example any (strong) positive correlation between (per capita) HE ($h_{i,t}$) and (per capita) GDP ($y_{i,t}$) could be spurious.

Equations 4 and 6 are estimated using a pooled dataset. This is preferable to running country-specific regressions due to severe data limitations for certain countries (Herwartz and Theilen, 2002).

All considered, given the inconclusive nature of (panel) co-integration tests, which do not appear to be robust to the specification used, together with our inability to include demographic variables in the co-integration relationship, we prefer to use regressions in growth rates (which also include demographic variables) for making HE projections.[34] However, we will also present results obtained using regressions in levels (i.e. assuming co-integration), for sake of completeness and sensitivity analysis.

Although co-integration tests suggest that demographic variables should not be included in the co-integrating vector, regressions in levels are estimated both including and not demographic variables, because our main objective is to estimate the impact of NDD on HE. An error correction model (ECM) should also be estimated to check for the presence of a significant adjustment mechanism, namely to see whether HE converges to its long term equilibrium and in the affirmative case to estimate the speed of convergence.

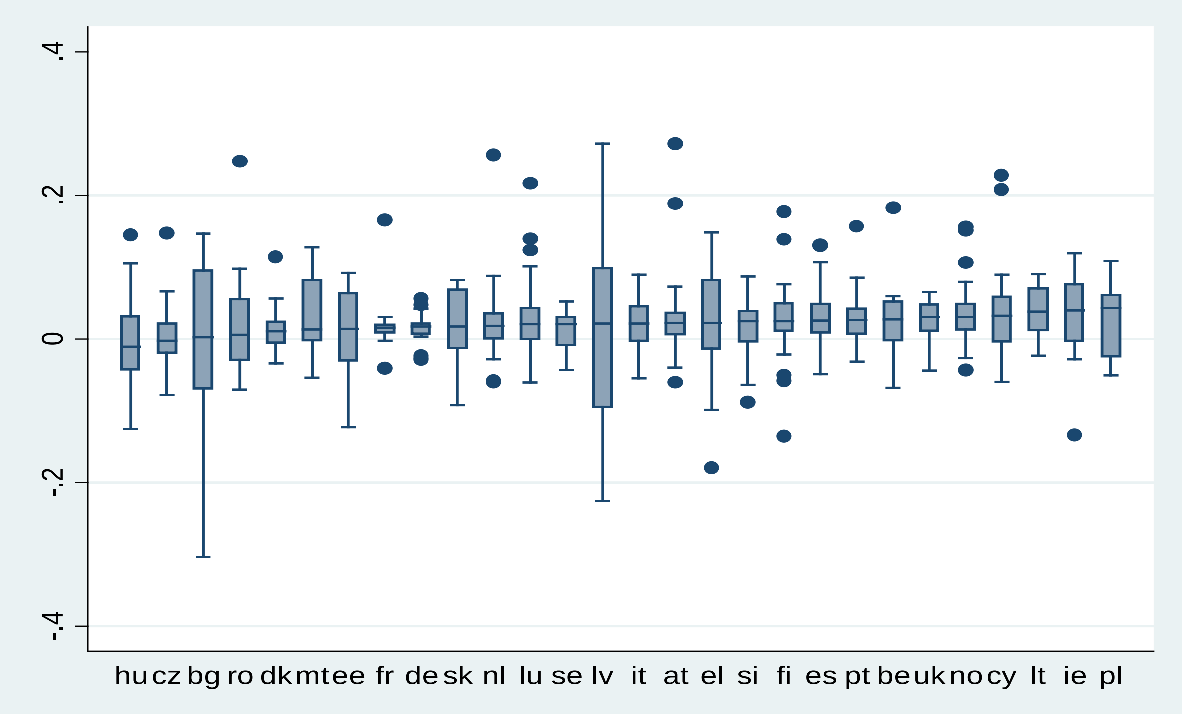
33 The STATA programme is used.

34 It should be noted that regressions with variables in growth rates do not require corrections for breaks in series i.e. periods where there are breaks are simply excluded from the estimation sample.

3.5.1. Regressions in growth rates

For regressions with variables in growth rates, the analysis of the data suggests that there is a wide dispersion in the growth rate of real per capita HE both across time and across countries (Graph 4). The presence of outliers is clearly visible in Graph 4 and Table 5.

Graph 4 – Annual growth rate of (public) per capita HE[35]



Source*:* Own calculations based on SHA and national data.
Countries sorted by increasing order of median values.

Using Cook's measure of distance,[36] the 10% more influential observations in the panel data are identified, displaying both a higher mean and standard deviation (Table 5). Regressions are carried out both including all data points and excluding the 10% more influential observations, as the latter may represent outliers not representative of the "true" relationship. OLS and IV regressions were also carried out because the per capita income regressor is likely to be endogenous, using as instrument its lagged value.

Table 5 – Growth rate of real per capita public HE – breakdown using Cook's distance

Type of observations	Summary of the growth rate of real per capita public expenditure on health		
	Mean	Std. Dev.	Freq.
"Normal"	2.1%	3.5%	575
"Influential"	4.4%	14.1%	64
Total	2.3%	5.6%	639

Source: Own calculations based on SHA and national data.

[35] This boxplot summarises the distribution of the growth rate of real per capita public HE through five numbers: i) the lowest datum still within 1.5 times the inter-quartile range; ii) the highest datum still within 1.5 times the inter-quartile range; iii) the lower quartile; iv) the median, and; iv) the upper quartile. The inter-quartile range is the difference between the upper and lower quartiles and is considered to be a robust measure of statistical dispersion. The presence of outliers is indicated by dots.

[36] Cook's measure of distance is a statistic of the effect of one observation simultaneously on all regression coefficients (Fox, 1991).

Table 6 presents various regressions using data in growth rates (equation 6). Column 1 presents estimates of an OLS regression using all observations (after excluding break points). The OLS regression in column 2 excludes the 10% more influential observations according to Cook's measure of distance.

Table 6 – Regression estimates of real per capita public HE (variables in growth rates, equation 6)

Regressions	OLS	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)	(4a)
Variables	All observations	excl. 10% more influential	All observations	excl. 10% more influential	excl. 10% more influential and 2009 and 2010
Constant	0.030***	0.019***	0.025**	0.01	0.006
Dummy 1985	-0.012	-0.008	-0.012*	-0.008	-0.007
Per capita GDP (income elast.)	0.204*	0.204**	0.775	0.961***	0.838**
Relative prices (price elast.)	-0.325*	-0.144	-0.616***	-0.478*	-0.279*
Young population ratio	0.083	0.059	0.545	0.455*	0.413
Old population ratio	0.2	0.217	0.319	0.183	0.348
Country fixed effects					
be	-0.003	0.010**	-0.002	0.013***	0.011**
bg	-0.021***	-0.022***	-0.028***	-0.033***	-0.031***
cy	0.027***	0.020***	0.039***	0.037***	0.036***
cz	-0.013**	-0.016**	-0.008	-0.014**	-0.021***
de	-0.007	-0.001	-0.004	0.006	0.001
dk	-0.011***	-0.009***	-0.008*	-0.003	-0.002
ee	-0.012*	-0.003	-0.016*	-0.013*	-0.022*
el	0.006	0.013*	0.01	0.019**	0.021***
es	0.008*	0.013***	0.012	0.019***	0.019***
fi	0.005	0.006**	0.006	0.009**	0.007***
fr	-0.007	-0.001	-0.004	0.005	0.004
hu	-0.025***	-0.030***	-0.022***	-0.024***	-0.033***
ie	0.016***	0.025***	0.012*	0.016***	0.025**
it	-0.004	0.002	0.001	0.011	0.01
lt	0.025***	0.023***	0.029***	0.025***	0.006
lu	0.001	-0.002	-0.003	-0.007***	-0.009***
lv	0.003	-0.004	0.013	-0.021**	-0.01
mt	0.011	0.014*	0.016	0.023**	0.023***
nl	0.003	0.001	0.004	0.004	0.007
no	0.012***	0.018***	0.009***	0.015***	0.017***
pl	0.002	-0.001	-0.001	-0.008	-0.005
pt	0.002	0.007	0.007	0.015**	0.015**
ro	0.015**	-0.004	0.015**	0.009	-0.009
se	-0.007*	-0.002	-0.007**	-0.003	-0.002
si	-0.01	-0.003	-0.013*	-0.003	-0.003
sk	0.001	0.010*	0.002	0.007	0.013
uk	0.013***	0.018***	0.014***	0.020***	0.018***
Number of observations	620	563	614	557	513
R squared adjusted	0.032	0.089	.	.	0.008
Wald test (p-value) a)	0.1584	0.1015	0.049*	0.0122*	0.2855
legend: * p<0.05; ** p<0.01; *** p<0.001					

Source: Own calculations based on SHA and national data.
Note: The country dummy for AT was (arbitrarily) set to zero in all regressions for collinearity reasons.
a) Tests the null hypothesis (H_0) of equivalence between the estimated regression and an alternative specification where the relative prices variable is replaced by two variables: health prices and the GDP deflator (results for the latter regression are not shown).

The exclusion of outliers has a significant impact on the estimates, particularly on the price elasticity, which falls (in absolute value) from 0.33 (regression 1) to 0.14 (regression 2). Regressions 3 and 4 contemplate the possibility that per capita GDP is an endogenous regressor, and use as instrument its lagged value. In addition, regression 4 excludes the 10% more influential observations. IV regressions produce income and price elasticity estimates considerably higher (in absolute value) than OLS estimates. Exclusion of outliers in the IV regression increases the income elasticity from 0.78 (regression 3) to 0.96 (regression 4), while the price elasticity falls (in absolute value) from 0.62 (regression 3) to 0.48 (regression 4). Given the apparent acceleration in HE in recent years (Graph 1), regression 4a excludes 2009 and 2010 from the sample and reruns regression 4. Exclusion of recent years has a significant impact on the income elasticity, which declines from 0.96 to 0.84, and on the price elasticity which falls (in absolute value) from 0.48 to 0.28.

An important point to note, with particular relevance when making HE projections, is the presence of a (significantly) positive common time drift of a large magnitude in the estimates i.e. "constant", implying important expenditure growth "residuals". The time drift possibly captures the effects of omitted variables, inter alia, the historical broadening of insurance coverage in health systems across European countries over recent decades, and technological progress. To the extent that the former process is now largely completed, projections of HE should use a dampened value of the time drift estimate.

For regressions using data in growth rates (Table 6), the introduction of a time dummy, representing a common shift in the growth rate of HE in 1985, turns out to be negative but is only statistically significant in regression 3. In line with Maisonneuve and Martins (2006), this could be interpreted tentatively as evidence of a deceleration in the growth rate of HE, following a period of rapid expansion due to the broadening of insurance coverage in most countries.

Regressions are also estimated using the health price ($\mathrm{p_h}$) and the GDP deflator ($\mathrm{p_y}$), instead of using the relative prices variable ($\mathrm{p} \equiv \frac{\mathrm{p_h}}{\mathrm{p_y}}$). The two specifications are equivalent if the null hypothesis that the coefficients of the two prices $\{\mathrm{p_h}, \mathrm{p_y}\}$ sum to zero cannot be rejected. According to a Wald test, regressions 3 and 4 are not equivalent (at 5%) to the corresponding specifications that uses the two price indexes.

3.5.2. Regressions in levels: long-term relation and ECM

Table 7 presents estimations for three regressions using variables expressed in levels (equation 4). Data in levels are adjusted for structural breaks using the procedure suggested in Joumard et al. (2008).[37]

Table 7 – Regression estimates of real per capita public HE (variables in levels, equation 4)

Regressions	OLS	IV	IV
	(5)	(6)	(6a)
			excl. 2009
Variables			and 2010
Constant	-3.8e+01**	-3.1e+01*	-3.1e+01*
Per capita GDP (income elast.)	0.50689	0.66491**	0.63600*
Relative prices (price elast.)	-0.24469	-0.40918	-0.35823
Year	0.01786***	0.01599***	0.01587**
Year * dummy 1985	-0.00002	-0.00002	-0.00002
Country fixed efects			
Year * be	-0.00004	-0.00003	-0.00003
Year * bg	-0.00059**	-0.00050**	-0.00052**
Year * cy	-0.00062***	-0.00059***	-0.00060***
Year * cz	-0.00023**	-0.00019**	-0.00019*
Year * de	0.00004	0.00004*	0.00005*
Year * dk	0.00011***	0.00010***	0.00011***
Year * ee	-0.00046***	-0.00039***	-0.00040**
Year * el	-0.00030***	-0.00027***	-0.00028***
Year * es	-0.00023***	-0.00020***	-0.00021***
Year * fi	-0.00015***	-0.00014***	-0.00014***
Year * fr	0.00004	0.00005*	0.00005*
Year * hu	-0.00032**	-0.00026**	-0.00025*
Year * ie	-0.00017***	-0.00017***	-0.00017***
Year * it	-0.00014***	-0.00012***	-0.00013***
Year * lt	-0.00046***	-0.00039**	-0.00040**
Year * lu	0.00012	0.00007	0.00009
Year * lv	-0.00057***	-0.00049***	-0.00050**
Year * mt	-0.00029***	-0.00024***	-0.00025***
Year * nl	-0.00010***	-0.00010***	-0.00010***
Year * no	-0.00003	-0.00004	-0.00004
Year * pl	-0.00050***	-0.00042***	-0.00044**
Year * pt	-0.00020**	-0.00017**	-0.00017*
Year * ro	-0.00063***	-0.00053**	-0.00054**
Year * se	-0.00002	-0.00001	-0.00001
Year * si	-0.00018**	-0.00015*	-0.00015*
Year * sk	-0.00037**	-0.00031**	-0.00031**
Year * uk	-0.00011***	-0.00010***	-0.00011***
Number of observations	671	665	615
R squared adjusted	0.96433	0.96593	0.96536
Wald test (p-value) a)	0.9608	0.7341	0.7295
legend: * p<0.05; ** p<0.01; *** p<0.001			

Source: Own calculations based on SHA and national data.
Note: The country dummy for AT was (arbitrarily) set to zero in all regressions for collinearity reasons.
a) Tests the null hypothesis (H_0) of equivalence between the estimated regression and an alternative specification where the relative prices variable is replaced by two variables: health prices and the GDP deflator (results for the latter regression are not shown).

[37] Namely the average growth rate of spending over the past five years is used to project spending growth in a break year.

According to a Wald test, in all co-integration regressions (5 to 6a), the null hypothesis that the two model specifications (either with the relative prices variable or with the two price indexes) are equivalent cannot be rejected.

Note again in all co-integration regressions, the large magnitude of the positive constant time drift estimate (i.e. "year") and its high statistical significance, which would have important consequences when making HE projections based on regressions in levels.

Table 8 – Estimation of the error correction model (equation 5)

Regressions	OLS	OLS	OLS
	(7)	(8)	(8a)
Variables			excl. 2009 and 2010
Constant	0.03424***	0.03351***	0.03427***
Dummy 1985	-0.01197	-0.01054	-0.00986
(Lagged) Error Correction (EC)	-0.17081***	-0.17787***	-0.17200***
Per capita GDP	0.17841*	0.18971**	0.16455
Relative prices	-0.27145*	-0.28657**	-0.28644**
Country fixed effects			
be	0.00537	0.00453	0.0041
bg	-0.02373***	-0.01967***	-0.02057***
cy	0.02202***	0.02110***	0.02813***
cz	-0.01251**	-0.01327**	-0.01686**
de	-0.00916*	-0.00990*	-0.01360**
dk	-0.01380***	-0.01413***	-0.01559***
ee	-0.01408*	-0.01494*	-0.01177
el	0.00653	0.00591	0.00938*
es	0.00495**	0.00363*	0.00410*
fi	-0.00008	-0.00147*	-0.00079
fr	-0.00123	-0.00204	-0.0026
hu	-0.02541***	-0.02615***	-0.02706***
ie	0.01137*	0.01025*	0.02393***
it	-0.00539	-0.0063	-0.00646
lt	0.02112**	0.02031**	0.02102*
lu	0.00219	0.00183	0.00018
lv	0.00346	0.00297	0.00189
mt	0.00953*	0.00682	0.01002*
nl	-0.00157	-0.00222	-0.00098
no	0.00748***	0.00577***	0.00635***
pl	0.00201	0.00128	0.00156
pt	0.00965*	0.00876*	0.01053*
ro	0.01051	0.00994	0.01444
se	-0.00984*	-0.01062*	-0.01123*
si	-0.00998*	-0.01089*	-0.00936*
sk	-0.00308	-0.00378	-0.00207
uk	0.00366	0.00273	0.00134
Number of observations	638	638	588
R squared adjusted	0.15121	0.16406	0.159
legend: * p<0.05; ** p<0.01; *** p<0.001			

Source: Own calculations based on SHA and national data.
Note: The country dummy for AT was (arbitrarily) excluded from all regressions for collinearity reasons.

In Table 8, regressions 7, 8 and 8a are the error correction models (ECM) corresponding to the long term co-integration regressions 5, 6 and 6a of Table 7, respectively. It is important to check if the sign of the (lagged) error correction estimate (EC) is negative in order to secure that deviations from the long term relationship are being corrected. Estimates of the (lagged) error correction term are significantly negative at 0.1%, indicating that real per capita public HE deviations from their long term values are corrected each year by about 20% i.e. expenditure deviations take about 5 years on average to converge to their long term ratios.

3.6. On the existence of a steady-state for the HE-to-GDP ratio

We will test the hypothesis of stationarity of the HE-to-GDP ratio both assuming and not co-integration.

Assuming co-integration, the following equation can be estimated:

$$\log h_{i,t} = \mu_i + b * \log y_{i,t} + c * \log p_{i,t} + \varepsilon_{i,t} \quad (9a)$$

Not assuming co-integration, the following equation should instead be estimated:

$$\Delta \log h_{i,t} = b * \Delta \log y_{i,t} + c * \Delta \log p_{i,t} + \varepsilon'_{i,t} \quad (9b)$$

where $h_{i,t}$ is real per capita public HE; μ_i are country fixed effects; $y_{i,t}$ is real per capita GDP; $p_{i,t}$ is the relative prices of health services; and $\varepsilon_{i,t}$ and $\varepsilon'_{i,t}$ are stochastic stationary variables.

Equation (9) can be re-written as the HE-to-GDP ratio ($Z_{i,t}$):

In the levels case (i.e. co-integration):

$$Z_{i,t} \equiv \log \frac{h_{i,t} * p_{i,t}}{y_{i,t}} = \mu_i + (b-1) * \log y_{i,t} + (1+c) * \log p_{i,t} + \varepsilon_{i,t} \quad (10a)$$

In the growth rates case (i.e. no co-integration):

$$\Delta Z_{i,t} \equiv \Delta \log \frac{h_{i,t} * p_{i,t}}{y_{i,t}} = (b-1) * \Delta \log y_{i,t} + (1+c) * \Delta \log p_{i,t} + \varepsilon'_{i,t} \quad (10b)$$

Consequently, estimates of the HE-to-GDP ratio ($\widetilde{Z_{i,t}}$) can be obtained using OLS estimates as follows:

In the levels case (9a):

$$\widetilde{Z_{i,t}} = \widetilde{\mu_i} + (\tilde{b} - 1) * \log y_{i,t} + (1 + \tilde{c}) * \log p_{i,t} \quad (11a)$$

In the growth rates case (9b):

$$\Delta\widetilde{Z_{i,t}} = (\tilde{b} - 1) * \Delta \log y_{i,t} + (1 + \tilde{c}) * \Delta \log p_{i,t} \quad (11b)$$

In the levels case, the hypothesis of stationarity will be tested by regressing $\widetilde{Z_{i,t}}$ on a time trend and testing the coefficient to be zero (i.e. $d = 0$):

$$\widetilde{Z_{i,t}} = \widetilde{\mu_i} + d * t + \varepsilon_{i,t} \quad (12a)$$

In the growth rates case, the hypothesis of stationarity is equivalent to test whether $\Delta\widetilde{Z_{i,t}}$ is different from zero (i.e. $d = 0$):

$$\Delta\widetilde{Z_{i,t}} = d + \varepsilon'_{i,t} \quad (12b)$$

Table 9 – Stationarity of the HE-to-GDP ratio

		d	
In levels (eq. 12a)	$\widetilde{Z_{i,t}}$	1.39%	***
In growth rates (eq. 12b)	$\Delta\widetilde{Z_{i,t}}$	0.02%	

Legend: * p<0.05; ** p<0.01; *** p<0.001.

Stationarity of the HE-to-GDP ratio depends crucially on the existence of a co-integration relationship. Co-integration implies an annual time drift of 1.4% in the HE-to-GDP ratio, whereas no co-integration implies a constant ratio (Table 9).

Assuming co-integration, after controlling for country-fixed effects, our results suggest that the HE-to-GDP ratio has increased on average by 1.4% per year in the last (four) decades. Recall that Graph 1 plots the non-weighted average of the HE-to-GDP ratio for 9 European countries, showing a rise from about 4½% in 1972 to 8% in 2010. This is remarkably in line with back of the envelope calculations based on the $\tilde{d}$ estimate: (4½%*1.014^(2010-1972)≈7½%).[38]

Conversely, if there is no co-integration, we cannot reject the hypothesis that the growth rate of the HE-to-GDP ratio is zero, implying that the ratio tends to a constant value.

3.7. Breakdown of total public expenditure on health in its main drivers: the minor role of ageing

Table 10 presents a breakdown of total per capita real public HE growth into different drivers for the period 1985-2010.

Table 10 – Breakdown of public health expenditure growth (a), 1985-2010 (b)
Annual averages in percentage

	Period	Number of observations	Health spending	Age effect	Income effect (c)	Price effect (d)	Residual
			(1)	(2)	(3)	(4)	(5)=(1)-(2)-(3)-(4)
at	1985-2010	25	2.4	0.1	1.3	-0.4	1.4
be	1996-2010	14	1.7	0.1	1.0	-0.3	0.9
bg	1992-2007	16	-0.1	0.1	2.1	-0.6	-1.7
cy	1996-2011	16	4.5	0.0	0.8	-0.4	4.1
cz	1994-2010	14	0.4	0.1	1.8	-0.9	-0.6
de	1993-2010	18	1.5	0.3	0.8	-0.2	0.6
dk	1985-2010	26	1.0	0.1	0.9	-0.5	0.6
ee	1996-2010	15	0.6	0.1	3.5	-1.4	-1.5
el	1988-2010	23	2.8	0.2	1.3	-0.3	1.7
es	1985-2010	25	3.1	0.1	1.4	-0.3	1.9
fi	1985-2011	25	1.7	0.2	1.3	-0.7	0.9
fr	1991-2010	19	1.2	0.1	0.7	-0.3	0.7
hu	1993-2010	17	-0.5	0.1	1.6	-0.5	-1.6
ie	1996-2010	15	3.3	-0.1	2.5	-0.9	1.8
it	1989-2010	22	1.8	0.2	0.6	-0.1	1.0
lt	1996-2009	12	3.9	0.2	3.1	-2.0	2.5
lu	1985-2009	23	2.2	0.0	2.3	-0.8	0.7
lv	1992-2008	14	2.0	0.2	1.1	-0.8	1.5
mt	1996-2009	14	3.0	0.2	1.3	-0.7	2.2
nl	1985-2009	24	2.9	0.1	1.3	-0.3	1.7
no	1985-2011	25	2.2	0.0	1.2	-0.3	1.3
pl	1993-2010	17	2.3	0.1	3.2	-0.9	0.0
pt	1996-2010	14	2.2	0.2	0.9	-0.4	1.5
ro	2000-2009	10	2.8	0.1	3.4	-1.9	1.3
se	1994-2010	17	1.2	0.0	1.6	-0.6	0.1
si	1993-2010	18	1.4	0.3	2.2	-0.5	-0.7
sk	1996-2010	15	1.9	0.0	2.9	-1.1	0.1
uk	1994-2010	16	3.2	0.0	1.4	-0.5	2.3
Non-weighted avg./total		509	2.0	0.1	1.7	-0.7	0.9
% of total				5.4%	83.9%	-32.4%	43.2%
Weighted average			2.0	0.1	1.2	-0.4	1.1
% of total				7.0%	59.0%	-18.2%	52.1%

(a) Total per capita real public health spending (deflated using a health price index).
(b) Or the longest overlapping period available since 1985.
(c) Assumes an income elasticity of 0.7.
(d) Assumes a price elasticity of -0.4.

Source: Own calculations based on SHA and national data.

[38] Ignoring country fixed-effects.

In line with estimates in the empirical literature, the income and price elasticities are set to 0.7 and -0.4, respectively, while demographic effects are determined using the estimated parameters of regression 1 (Table 6).[39] Results strongly suggest that since 1985 changes in demographic composition played a minor role in driving up total public HE. Using weighted averages, the rise in per capita income explains about 59% of the total increase in expenditure, price effects dampened expenditure by 18%, demographic composition effects accounted for an increase of just 7%,[40] while residual effects accounted for around 52%. This decomposition supports the hypothesis that past trends in expenditure were mainly driven by non-demographic factors, including income and price effects. Note that the importance of residuals is largely due to omitted variables, such as technologic innovations in the medical field and policy regulations.

3.8. Estimates of excess cost growth (C), income (η) and price elasticities (γ)

Estimates of excess cost growth (C, Table 11) vary from 1.0% to 1.6% (weighted average), which seems to be in line with results reported in Clements et al. (2012), which estimated a weighted average of 1.3% for advanced economies.

Table 11 – Estimates of excess cost growth (C)
Annual averages in percentage

	Growth rate equations no co-integration				Level equations co-integration		
	OLS	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(6a)
	All observations	Excl. 10% more influential	All observations	Excl. 10% more influential	All observations	All observations	All observations excl. 2009 and 2010
at	1.1	0.5	1.2	0.6	1.6 (1.4)	1.6 (1.4)	1.5 (1.3)
be	0.9	1.6	1.0	1.7	1.5 (1.4)	1.5 (1.3)	1.4 (1.2)
bg	-1.6	1.3	-2.3	-2.0	1.4 (1.3)	1.4 (1.3)	1.4 (1.3)
cy	4.3	3.6	5.3	4.5	1.7 (1.5)	1.6 (1.4)	1.2 (1.1)
cz	0.0	-0.9	0.7	0.0	2.1 (1.8)	2.0 (1.7)	1.9 (1.7)
de	0.5	0.4	0.7	0.9	1.8 (1.6)	1.6 (1.4)	1.6 (1.4)
dk	0.5	0.3	0.6	0.5	2.1 (1.9)	1.9 (1.7)	1.9 (1.7)
ee	-0.9	-0.7	-0.1	0.2	2.2 (1.9)	2.1 (2.0)	2.0 (1.9)
el	1.6	1.6	2.2	2.3	1.6 (1.4)	1.5 (1.3)	1.4 (1.2)
es	1.6	1.5	2.2	2.4	1.3 (1.1)	1.3 (1.2)	1.1 (1.0)
fi	2.0	1.7	2.1	1.9	2.0 (1.8)	1.8 (1.6)	1.8 (1.6)
fr	0.8	0.8	0.9	1.0	1.8 (1.6)	1.7 (1.4)	1.6 (1.4)
hu	-1.5	-2.3	-0.9	-1.7	1.6 (1.4)	1.6 (1.4)	1.6 (1.4)
ie	2.0	2.4	2.5	2.8	1.4 (1.2)	1.5 (1.4)	1.1 (1.1)
it	0.9	0.9	1.3	1.4	1.5 (1.3)	1.4 (1.2)	1.3 (1.1)
lt	4.2	4.1	5.0	5.1	3.1 (2.8)	2.9 (2.6)	2.9 (2.6)
lu	0.7	0.0	1.0	0.4	1.7 (1.5)	1.7 (1.6)	1.6 (1.5)
lv	2.2	-0.8	2.9	0.2	2.9 (2.6)	2.6 (2.2)	2.6 (2.2)
mt	2.6	2.9	3.0	3.3	2.1 (1.9)	2.0 (1.7)	1.9 (1.7)
nl	1.1	0.4	1.5	0.8	1.4 (1.2)	1.4 (1.2)	1.2 (1.1)
no	2.1	2.1	2.0	2.0	1.5 (1.3)	1.5 (1.3)	1.3 (1.1)
pl	0.0	-0.8	1.0	0.3	1.2 (1.1)	1.3 (1.3)	1.3 (1.2)
pt	1.7	1.6	2.0	2.1	1.8 (1.6)	1.7 (1.5)	1.5 (1.3)
ro	2.7	3.7	3.5	4.4	2.9 (2.5)	2.7 (2.4)	3.0 (2.7)
se	0.3	0.3	0.5	0.5	1.8 (1.6)	1.7 (1.5)	1.7 (1.5)
si	-0.9	-0.3	-0.3	0.6	1.2 (1.1)	1.3 (1.2)	1.0 (1.0)
sk	0.5	1.0	1.6	2.0	1.9 (1.7)	1.9 (1.7)	1.6 (1.5)
uk	2.4	2.4	2.7	2.6	1.6 (1.4)	1.6 (1.4)	1.4 (1.3)
Non-weighted avg.	1.1	1.0	1.6	1.5	1.8 (1.6)	1.7 (1.5)	1.6 (1.5)
Trimmed non-weighted avg. a)	1.1	1.1	1.6	1.2	1.7 (1.5)	1.6 (1.4)	1.6 (1.4)
Weighted average	1.1	1.0	1.4	1.4	1.6 (1.5)	1.6 (1.4)	1.5 (1.3)
Standard deviation	1.5	1.5	1.6	1.7	0.5 (0.4)	0.4 (0.3)	0.5 (0.4)

Source: Own calculations based on SHA and national data.
a) Non-weighted average of the values within ± 1 standard deviation.
Note: In columns 5 to 6a, there are two values in each cell. The first refers to the model in levels without demographic variables, the second (in parenthesis) refers to the corresponding model including two demographic variables, namely the young and old age population ratios.

[39] The OLS regression 1 in Table 6 is used. According to these estimates: a 1% increase in the fraction of the population below 16 ("young population ratio") increases per capita real public HE by 0.08%; while a 1% increase in the fraction of the population above 65 ("old population ratio") increases per capita real public HE by 0.2%.

[40] Note that this reflects historical developments, not representing a projection of future developments. In the 2012 EPC-EC Ageing Report, the impact of ageing on health expenditure up to 2060 is calculated instead using specific age profiles by country and gender.

Including demographic variables in level regressions (i.e. co-integration) reduces both the average and the standard deviation of excess cost growth, respectively, by about 0.2 and 0.1 percentage points (see values in parenthesis in columns 5 to 6a of Table 11).

Graph 5 – Estimates of excess cost growth (C)

Source: Own calculations based on estimates of regressions 4 or 6.

Across European countries, the estimated non-weighted average of excess cost growth (C) amounts to 1.5% and 1.7%, respectively, using regression 4 (in growth rates) or regression 6 (in levels), although displaying large variations across countries (Graph 5).

Table 12 – Common income (η) and price elasticities (γ) estimates

	Growth rate equations no co-integration				Level equations co-integration		
	OLS	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(6a)
	All observations	Excl. 10% more influential	All observations	Excl. 10% more influential	All observations	All observations	All observations excl. 2009 & 2010
Income elast. (η)	0.20 *	0.20 **	0.77	0.96 ***	0.51 (0.57)	0.66 (0.75)	0.64 (0.73)
Price elast. (γ)	-0.32 *	-0.14	-0.62 ***	-0.48 *	-0.24 (-0.33)	-0.41 (-0.51)	-0.36 (-0.47)
legend: * p<0.05; ** p<0.01; *** p<0.001							

Source: Own calculations based on SHA and national data.
Note: In columns 5 to 6a, there are two values in each cell. The first refers to the model in levels without demographic variables, the second (in parenthesis) refers to the corresponding model including two demographic variables, namely the young and old age population ratios.

Income elasticity (η) estimates are mostly below 1, while those obtained using IV are significantly higher than using OLS. Overall, results are in line with recent income elasticity estimates of health expenditure.[41] For example, Maisonneuve and Martins (2013) suggest an income elasticity of HE centred around 0.8 (revising downwards their previous unitary

[41] See Appendix 3 in Maisonneuve and Martins (2013) for a review of recent literature on income elasticity estimates.

estimate made in 2006). Assuming homogenous responses of HE to income across US States in a panel over 1996-1998, Freeman (2003) finds that HE is a necessity good with elasticity in the range of 0.8 to 0.85. Acemoglu et al. (2009), using carefully designed econometric techniques to identify causality effects of income on HE, and using data for the Southern United States, find an income elasticity below unit (0.72 with an upper interval value of 1.13).

The estimates for the price elasticity (γ) are correctly signed and lower than 1 (in absolute value) as expected (i.e. inelastic demand), while those obtained using IV are significantly higher (in absolute value) than those obtained using OLS. Price elasticity estimates around -0.4 are similar to those obtained in other empirical studies (e.g. Maisonneuve and Martins, 2013).

Recall that in the breakdown exercise of public HE presented in Table 10, and in order to facilitate comparisons with other studies, the stylised values used for the income and price elasticities are 0.7 and -0.4, respectively.

4. Long term projections of the total public HE-to-GDP ratio

This section presents long term projections (up to 2060) for the total public HE-to-GDP ratio, using equation (6) in growth rates (regression 4 in Table 6).[42] Given the uncertainty regarding the existence of a co-integration relationship, involving HE, relative prices and income, as results depend on the inclusion or not of a deterministic time trend, projections are calculated using regressions in growth rates. In addition, using growth rate estimates allows considering the impact of population composition effects, which was not possible using regressions in levels as demographic variables are not part of the co-integration vector. Furthermore, given that the aim is to calculate long term projections, it is perhaps wiser to use a model that seems to be consistent with a constant steady-state for the HE-to-GDP ratio (see section 3.6).

The model specification used to estimate total public HE fits well with the European Policy Committee-European Commission (EPC-EC) methodology to project long term age related costs (DG ECFIN-EPC (AWG), 2012), because the macroeconomic variables used to project future HE are available in the long term age related projections, namely real GDP, GDP prices, wages, labour productivity, and demographic variables. However, in order to produce reasonable (i.e. within plausible bounds) projections, some kind of a priory judgment is still needed about the relevance of historical trends for determining future values of the deterministic time drift (ψ_t),[43] and future values for the pass-through of productivity gains into relative price increases (ϕ_i).

4.1. Derivation of the formula for the projection of HE-to-GDP ratios

Dividing health services prices (equation 1): $P_h = W^{\phi} * CPI^{1-\phi}$ by the GDP deflator (p_y), we obtain an expression for relative prices: $p \equiv \frac{P_h}{P_y} = \left(\frac{W}{P_y}\right)^{\phi} * \left(\frac{CPI}{P_y}\right)^{1-\phi}$. Assuming that CPI and GDP inflation are identical, we can express the growth rate of relative prices as:

$$\hat{p} = \phi * \widehat{\left(\frac{W}{P_y}\right)} \quad (13)$$

where a hat over a variable means a growth rate (i.e. the first difference of the logarithm).

[42] In a nutshell, OECD's assumptions on future HE residuals are common across countries, while the IMF uses country-specific excess cost growth estimates of HE (for a more comprehensive comparison of the different methodologies see Box 2).
[43] with $\psi_t \equiv \alpha + \mu_i + D_{85}$. When a deterministic time trend plays such a crucial role we are effectively proxying for effects we do not fully understand.

Furthermore, assuming that real wages ($\frac{W}{P_y}$) are proportional to labour productivity (lp), it follows that:

$$\hat{p}_{i,t} \approx \phi_i * \widehat{lp}_{i,t} \quad (14)$$

In line with Baumol's "unbalanced growth theory", equation (14) states that relative prices of health services grow proportionally with (overall) labour productivity, implicitly assuming that there is limited labour productivity growth in the health sector. Note that the factor of proportionality is country-specific (ϕ_i), reflecting the fraction of labour costs in total costs in the human health sector of national accounts data.

Equation 6 can be rewritten as the HE-to-GDP ratio ($Z_{i,t}$):

$$\Delta\log Z_{i,t} \equiv \Delta\log\frac{h_{i,t} * p_{i,t}}{y_{i,t}} \approx \psi_t + a * \Delta\log x_{i,t} + (b-1) * \Delta\log y_{i,t} + (1+c) * \Delta\log p_{i,t} \quad (15)$$

Using (14) and the definition of elasticities into (15):

$$\hat{Z}_{i,t} \approx \psi_t + a * \hat{x}_{i,t} + (\eta - 1) * \hat{y}_{i,t} + (1+\gamma) * \phi_i * \widehat{lp}_{i,t} \quad (16)$$

where $\psi_t \equiv \alpha + \mu_i + D_{85}$ is a common time drift; and η and γ are the income and price elasticities, respectively.

Equation (16) links changes in the HE-to-GDP ratio to a common time drift: ψ_t; a country-specific income effect: $(\eta - 1) * \hat{y}_{i,t}$; a labour productivity/Baumol effect: $(1+\gamma) * \phi_i * \widehat{lp}_{i,t}$; and changes in demographic composition: $a * \hat{x}_{i,t}$.

Furthermore, per capita GDP (y) and labour productivity (lp) are linked by the identity:

$$y_{i,t} \equiv lp_{i,t} * \left(1 - ur_{i,t}\right) * ar_{i,t} \quad (17a)$$

where labour market variables, respectively, the unemployment (ur) and activity rates (ar) are present.

Taking the first difference of the logarithm, equation (17a) can be expressed in growth rates as:

$$\hat{y}_{i,t} \approx \widehat{lp}_{i,t} - \Delta ur_{i,t} + \widehat{ar}_{i,t} \quad (17b)$$

Equations (16) and (17b) indicate that per capita GDP (or labour productivity), together with labour market variables (both unemployment and activity rates) drive the dynamics of the HE-to-GDP ratio.

4.2. Calibration and results

Estimates of equation (6) in growth rates (regression 4 in Table 6) are used for the income, price elasticities, and demographic effects.

Note that instead of using a country-specific time drift ($\psi_i \equiv \alpha + \mu_i + D_{85}$), a common time drift ($\psi_t$) is used (0.59%), calculated as the non-weighted average over the 28 countries considered in the analysis (EU27 and Norway), thereby correcting for the excessive amplitude of country-specific estimates in order not to extrapolate country-specific idiosyncrasies over a long period.[44]

[44] A necessary condition for a steady-state of the HE-to-GDP ratio (equation 16) is for the time drift to be "forced" to converge to zero over ($\lim_{t\to\infty} \psi_t = 0$), or less constraining, for the HE-to-GDP ratio to be bounded away from implausible high values. This eventually requires dampening the positive time drift, which requires making arbitrary assumptions (Maisonneuve and Martins, 2013). The time drift is likely to decrease in future relatively to historical trends, reflecting, inter alia, completion of the process of broadening insurance coverage of health systems, but it is likely to "converge" to a strictly positive value as the time drift includes technological progress in the health sector. The trajectory assumed for ψ_t during the projection period has a significant impact on the results.

ϕ_i is the weight of labour costs in total health expenditure. In the projections, it is assumed that there is a marginal improvement in the pass-through of productivity gains to relative price increases, specifically, ϕ_i is reduced by 10% in the entire projection period over historical values. This reduction is a proxy for limited/sporadic reductions in the labour content of production (technological progress) in the health care sector.[45]

Exogenous variables for population by single age, real GDP, GDP prices, and labour productivity are taken from DG ECFIN's Winter 2013 economic forecasts and a March 2013 update of the 2012 Ageing Report for the period up to 2060.[46]

Table 13 – Public HE-to-GDP ratio projections[47]

	2010	2060		
		Cost-pressure scenario, constant	Cost-containment scenario, linear	Cost-containment scenario, geometric
		(1)	(2)	(3)
at	8.4	14.6	12.6	11.5
be	8.0	13.8	11.9	10.9
bg	4.3	8.8	7.5	6.9
cy	3.3	5.8	4.9	4.5
cz	6.3	12.3	10.6	9.7
de	8.9	15.2	13.1	12.0
dk	9.5	16.9	14.5	13.3
ee	5.0	10.5	9.0	8.3
el	6.1	9.4	8.1	7.5
es	7.1	12.0	10.3	9.4
fi	6.6	12.3	10.5	9.7
fr	9.0	15.1	12.9	11.9
hu	5.0	9.1	7.8	7.2
ie	6.4	11.8	10.1	9.3
it	7.4	12.2	10.5	9.7
lt	5.5	11.5	9.9	9.1
lu	6.5	11.3	9.7	8.9
lv	4.0	8.5	7.3	6.7
mt	5.8	10.7	9.2	8.4
nl	7.4	12.9	11.1	10.2
pl	5.0	9.2	7.9	7.2
pt	7.1	11.9	10.2	9.4
ro	4.4	8.2	7.0	6.5
se	7.7	14.4	12.4	11.4
si	6.6	12.5	10.7	9.9
sk	5.8	11.3	9.7	8.9
uk	8.0	14.6	12.5	11.5
eu15 a)	7.6	13.2	11.4	10.4
eu27 a)	6.5	11.7	10.1	9.3

Source: Own calculations based on estimates of equation 6 (regression 4 in Table 6), using "exogenous" variables from DG ECFIN's Winter 2013 economic forecasts and a March 2013 update of the 2012 Ageing Report.
a) Non-weighted average.

[45] This could as well be interpreted as a reduction in the labour content of intermediate consumption in the health sector.

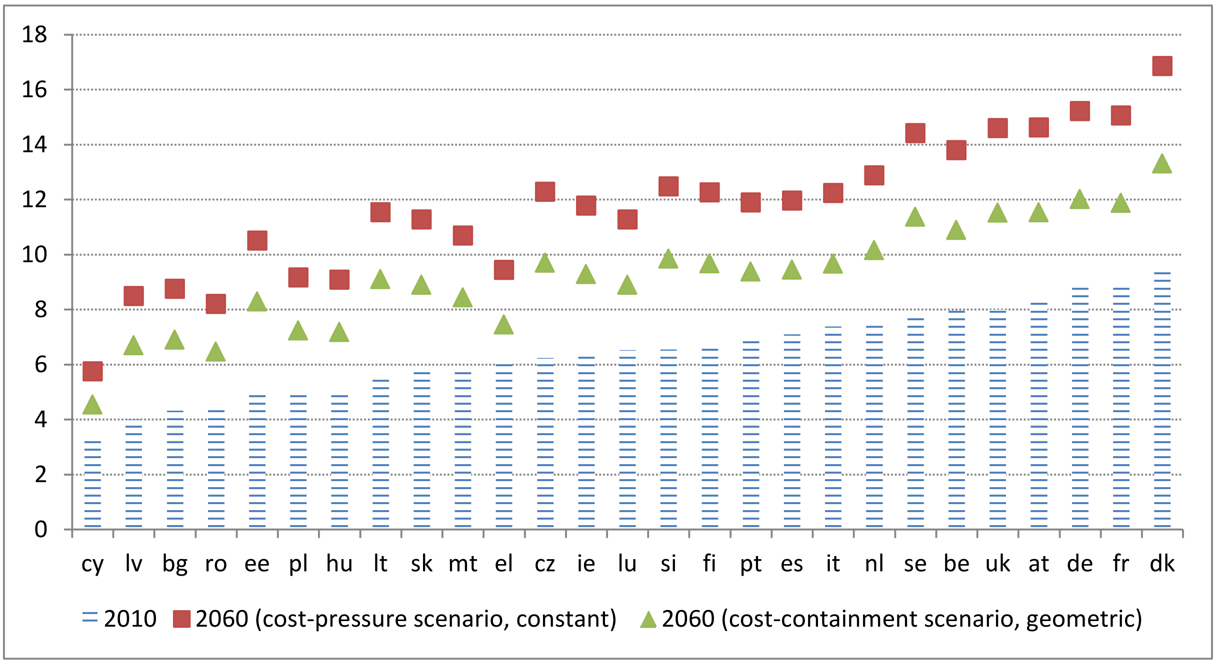
[46] Taking into account a few pension peer reviews endorsed by the EPC in the first half of 2013.

[47] Projections presented in Table 13 are preliminary, therefore subject to subsequent revisions as the underlying methodology is improved, although these values should already provide a good qualitative assessment of final results.
Following Acemoglu et al. (2009) and Maisonneuve and Martins (2013), use of a lower income elasticity of around 0.7 to 0.8 could be envisaged, instead of using a nearly unitary elasticity of 0.96 (estimate of regression 4 in Table 6). Note that including all observations (regression 3 in Table 6) or excluding the years 2009 and 2010 together with the 10% more influential observations from the sample (regression 4a in Table 6) would both reduce the income elasticity to 0.78 and 0.84, respectively. *Ceteris paribus*, a lower income elasticity would reduce the HE-to-GDP ratio (equation 16).

Equation (16) subsumes three alternative scenarios for a common time drift (ψ_t) between 2010 and 2060: i) constant ("cost-pressure"); ii) linear decreasing to zero ("linear cost-containment"); and iii) geometric decreasing to a very low value ("geometric cost-containment").[48]

The cost-pressure scenario sets a common time drift at the annual value of 0.59 p.p. during the entire projection period, which together with other demographic and non-demographic effects yields a considerable increase in the projected public HE-to-GDP ratio from 6.5% in 2010 to 11.7% in 2060 (non-weighted average of the EU27, Table 13 and Graph 6). Two cost-containment scenarios are calculated as well. One assumes the linear reduction in the time drift from 0.59 p.p. in 2010 to zero in 2060, and another assumes a geometric (i.e. accelerated) reduction in the time drift from 0.59 p.p. in 2010 to 1% of 0.59 p.p. in 2060 (or 10% of 0.59 p.p. in 2035). Even in the scenario that projects an accelerated reduction in the common time drift, the public HE-to-GDP ratio is still expected to increase by just under 3 p.p. of GDP from 6.5% in 2010 to 9.3% in 2060 (non-weighted average of the EU27).[49]

Graph 6 –Public HE-to-GDP ratio projections (%)



Source: Own calculations based on estimates of equation 6 (regression 4 in Table 6), using "exogenous" variables from DG ECFIN's Winter 2013 economic forecasts and a March 2013 update of the 2012 Ageing Report.

As a whole, projections shown in Table 13 and Graph 6 represent an acute reminder of the need to proceed with the efforts to curb HE growth and improve the efficiency of health systems. In fact, in the absence of additional control measures (i.e. in the "cost-pressure" scenario), projection outcomes suggest on average a near doubling of the HE-to-GDP ratio across the EU between 2010 and 2060.

[48] In the "geometric cost-containment" scenario, the common drift is assumed to decline from 0.59% in 2010 to 1% of 0.59% in 2060. In their cost-containment scenario, Maisonneuve and Martins (2013) also assume that the common "residuals" converge (linearly) from 1.7% in 2010 to 0% in 2060.

[49] It should be recalled that all three scenarios presented in Table 13 assume a 10% reduction in the labour productivity/relative prices pass-through parameter (ϕ_i) due to the assumption of limited/sporadic labour savings in the health sector, including in the consumption of intermediate goods.

Box 2: Different strategies to project the non-demographic component of public HE

- ***IMF: Clements et al. (2012)***
  - Projections of non-demographic and non-income related HE equal estimates of excess cost growth of public health expenditure. Excess cost growth (C) is defined as the excess of growth in real per capita health expenditures over the growth in real per capita GDP, after controlling for the effect of demographic change. Clements et al. (2012) estimate a panel regression with country fixed-effects.
  - The following model specification is used:

$$\Delta \log h_{i,t} = \alpha + \mu_i + a * \Delta \log x_{i,t} + b * \Delta \log y_{i,t} + \varepsilon_{i,t} \qquad \text{(i)}$$

  - Country-specific excess cost growth (C) estimates are calculated as:

$$\widetilde{C_i} = \frac{\sum \frac{\widetilde{\Delta h_{i,t}}|_{\Delta x_{i,t}=0}}{\widetilde{h_{i,t}}|_{\Delta x_{i,t}=0}} - \sum \frac{\Delta y_{i,t}}{y_{i,t}}}{T_i} \approx \frac{\sum \Delta \log \widetilde{h_{i,t}}|_{\Delta x_{i,t}=0} - \sum \Delta \log y_{i,t}}{T_i} = \tilde{\alpha} + \widetilde{\mu_i} + \left(\tilde{b} - 1\right) * \frac{\sum \Delta \log y_{i,t}}{T_i} \qquad \text{(ii)}$$

  - with a tilde denoting estimates, and T_i the number of years of data available for country *i*. (C) equals the difference between the (geometric) average growth rate of estimated real per capita public HE, after controlling for the impact of demographic composition, minus the (geometric) average growth rate of real per capita GDP.
  - Equation (6) estimated in this paper differs from equation (i) by the inclusion of a relative price variable (p) and a time dummy (D_{85}). The excess cost growth equation (ii) becomes (equation 8):

$$\widetilde{C_i} = \tilde{\alpha} + \widetilde{\mu_i} + \widetilde{D_{85}} + \left(\tilde{b} - 1\right) * \frac{\sum \Delta \log y_{i,t}}{T_i} + (1 + \tilde{c}) * \frac{\sum \Delta \log p_{i,t}}{T_i} \qquad \text{(iia)}$$

  - Summarising, Clements et al. (2012) equate non-demographic and non-income related HE growth to country-specific excess cost growth (C) estimates, keeping them unchanged at estimated/historical values during the entire projection period (i.e. up to 2050).
- ***OECD: Maisonneuve and Martins (2006 and 2013)***
  - Overall, demographic drivers explain relatively little of past developments in health spending; therefore, non-demographic drivers must play an important role, namely income growth and a residual growth component.
  - Based on the most recent findings from the empirical literature, an income elasticity of 0.8 is used. This represents a downward revision from the unitary elasticity used in Maisonneuve and Martins (2006).
  - The unexplained expenditure residual is derived using a growth accounting framework, which identifies past average growth of health expenditures due to age and income effects (assuming a given value for the income elasticity).
  - In order to interpret this residual, an econometric equation is also estimated, incorporating explicitly the effects of prices and a proxy for quality/technological progress.

Box 2: Different strategies to project the non-demographic component of public HE (continuation)

- The following panel regression, with country fixed-effects is estimated:

$$\log\left(\frac{he}{N}\right) = \alpha_c + \theta * \log(Demo) + \beta * \log\left(\frac{P}{P_Y}\right) + \gamma * log(Q) + \varepsilon * log\left(\frac{Y}{N}\right) + \tau * T + u \quad \text{(iii)}$$

- where α_c corresponds to country fixed-effects; *he* denotes health volumes (deflated for price and quality); *Demo* is the demographic effect captured by the average age of the population; *P* are health prices; P_Y is the GDP deflator; *Q* is a quality/technology index for health services; *N* is total population; *T* is a deterministic time trend; and *u* is a randomly distributed residual.
- Using estimates of regression (iii), the overall effect of relative prices and technology is estimated to have increased HE by 0.8% per year in the OECD area. Estimates suggest that the residual expenditure is also driven by other factors, such as changes in policy and institutions which are loosely captured by a time trend, accounting for 0.9% of the increase in health expenditure per year. On average in the OECD area, these estimates suggest that residual growth has increased HE by a total of around 1.7% (i.e. 0.8%+0.9%) per year.
- The estimated total expenditure residual of 1.7% in the OECD area compares with an expenditure residual of 2% obtained using the accounting framework, therefore 0.3% remains unexplained. As a consequence, the projections use 1.7% as the starting value for residual expenditure growth.
- The health expenditure residual component is projected as a whole. Furthermore, a common residual growth is assumed for all countries in order not to extrapolate country-specific idiosyncrasies over a long period, namely country fixed-effects.
- Maisonneuve and Martins (2013) present two main projection scenarios: i) a "cost-containment scenario" assuming that some policy action is taken to curb expenditure pressures, thereby allowing for a gradual reduction in the average residual growth from 1.7% in the starting period to 0% in 2060; and ii) a "cost-pressure scenario", where the average residual growth is assumed to remain constant at a growth rate of 1.7% over the projection period.

• ***EPC-EC: European Commission (DG ECFIN)-EPC (AWG) (2011), and European Commission (DG ECFIN)-EPC (AWG) (2012a)***

- The joint work carried out by the European Policy Committee (Ageing Working Group) and the European Commission (DG ECFIN) on long term age related expenditure acknowledges the significant role played by non-demographic drivers of HE.
- In the 2012 Ageing Report (AR), the following panel equation was estimated in order to identify non-demographic effects:

$$\Delta\log h_{i,t} = \alpha + \mu_i + D_{85} + \mathrm{a} * \log x_{i,t} + \mathrm{b} * \Delta\log y_{i,t} + \varepsilon_{i,t} \qquad \text{(iv)}$$

- Note that equation (iv) ignores a number of important explanatory variables, namely relative prices. This is likely to bias upward the income elasticity estimate, which will capture effects due to omitted variables.

Box 2: Different strategies to project the non-demographic component of public HE (continuation)

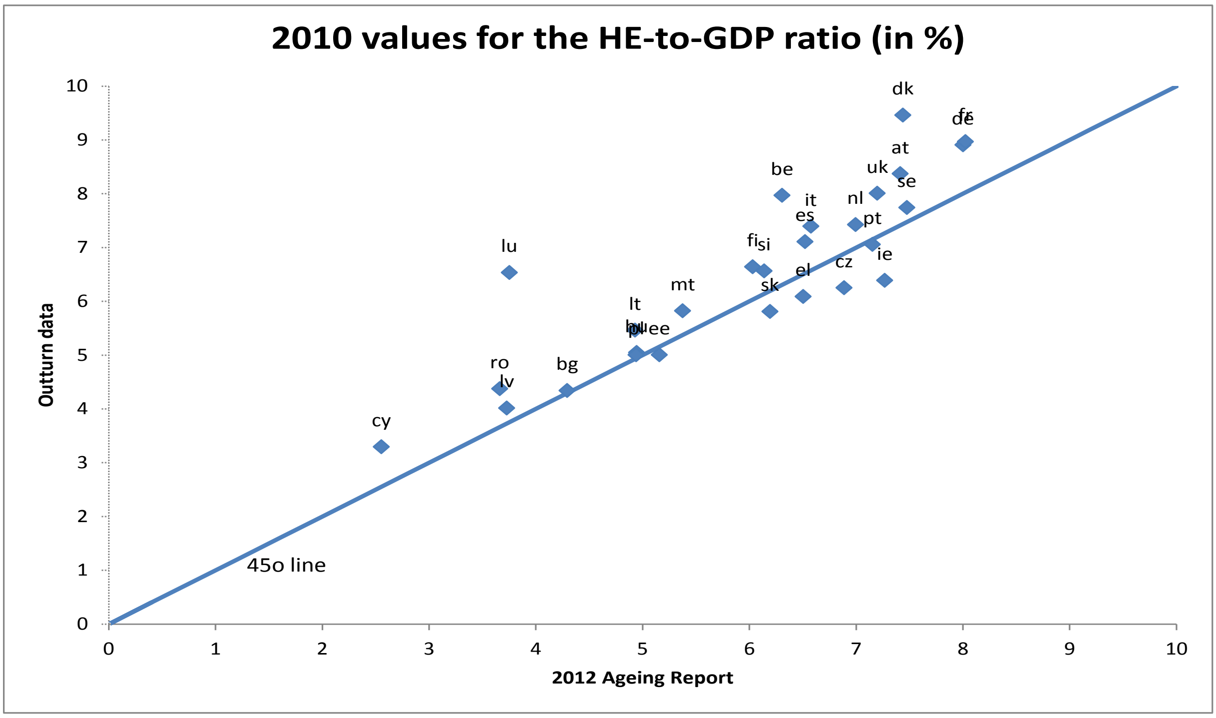
- The two main long term HE projection scenarios included in the 2012 AR consider non-demographic effects. Non-demographic effects are introduced using a common across all EU Member States income elasticity above unit. In the reference scenario, the income elasticity decreases from 1.1 in 2010 (the starting period of the projection) to 1 in 2060; whereas in the risk scenario it decreases from 1.3 in 2010 to 1.0 in 2060.

4.3. Comparison with other projections

Table 14 presents an adaptation of Table 4.3 of Maisonneuve and Martins (2013), describing major aspects of the different projection "technologies", namely the demographic assumptions ("Health ageing"), and non-demographic drivers, such as income, price elasticity and a time drift/residual growth component.[50] Covering these "fields" of analysis, Table 14 compares a few long term projections of the HE-to-GDP ratio, coming from the EPC-EC (2), the IMF (1), the OECD (2), and (2) from this paper.

As a consequence of different assumptions, the EPC-EC projections (both baseline and risk scenarios) are the lowest, largely because they do not consider a time drift (or residual growth). However, we should recognise that EPC-EC projections for 2010 have also been severely affected by a significant projection bias. In fact, outturn data for the HE-to-GDP ratio in 2010 are on average across the EU between ½ and ¾ p.p. of GDP above the baseline scenario of the 2012 Ageing Report (Graph 7).[51]

Graph 7 –Outturn data for 2010 compared with the 2012 Ageing Report baseline scenario



Source: Own calculations and the 2012 Ageing Report.

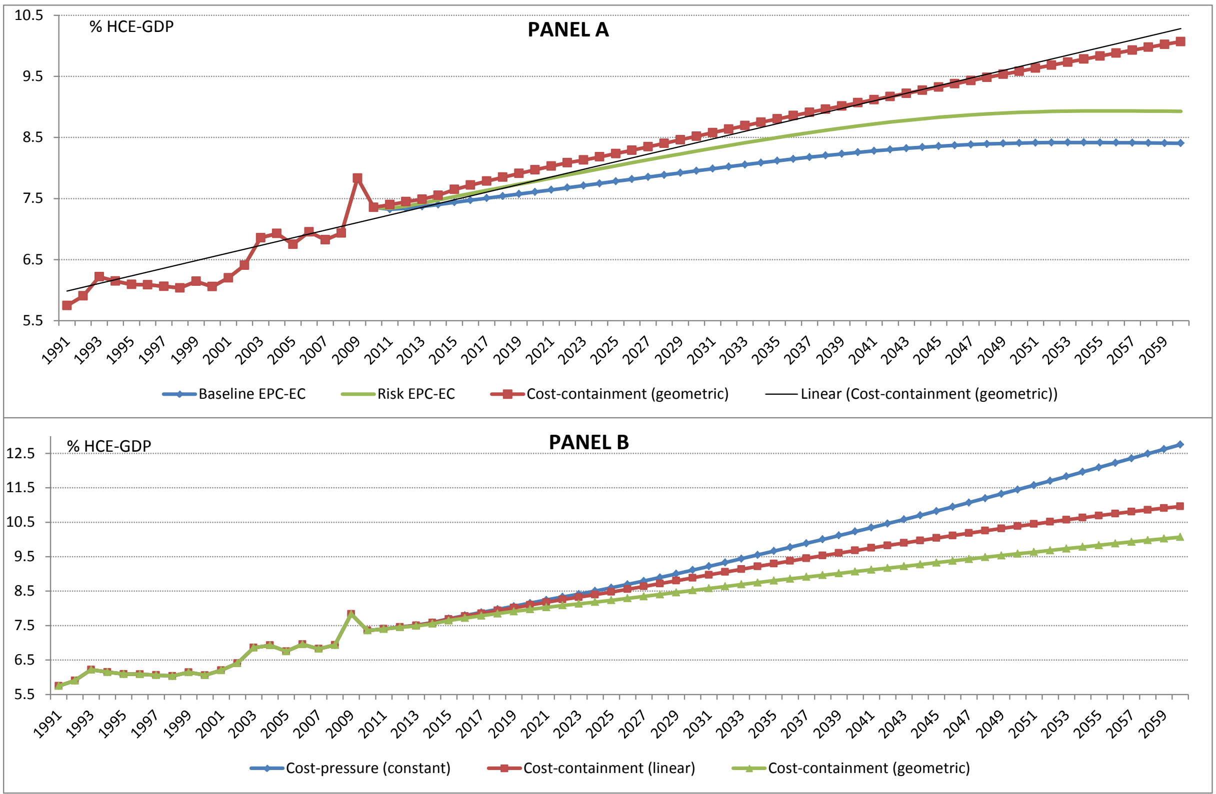
[50] See Box 2 for a brief overview of different projection methodologies.

[51] Table 14 also presents values for the EPC-EC scenarios adjusted (one-by-one) for the 2010 projection bias.

In the IMF projections, the assumption of a low income elasticity is broadly offset by considering country-specific residual growth. IMF projects an increase of 4.5 p.p. in the public HE-to-GDP ratio for the EU15 between 2010 and 2050, largely exceeding EPC-EC projected increases of only 1.0 p.p. and 1.5 p.p. in the baseline and risk scenarios, respectively.[52] Although being difficult to compare to OECD projections (as IMF projections end in 2050), IMF results seem to lie in between OECD's cost-containment and cost-pressure scenarios.

Applying the methodology developed in this paper, the cost-pressure scenario projects a slightly lower variation in the HE-to-GDP ratio than OECD's corresponding one (a variation of +5.6 p.p. versus +6.2 p.p. in the period 2010-2060 for the EU15), whereas the reverse occurs for the cost-containment scenario (a variation of +2.8 p.p. versus +2.4 p.p. in the period 2010-2060 for the EU15). Overall, the projection scenarios based on the developed methodology are by and large equivalent to OECD's corresponding ones (Table 14). However, it should be acknowledged that the methodology developed in this paper uses econometric estimates of population composition effects on per capita expenditure to calculate ageing costs, whereas all other methodologies use age profile estimates of HE, together with an assumption on the impact of rises in life-expectancy on the duration of periods in good health.

Graph 8 – Projections of the HE-to-GDP ratio for a selected group of countries a)



Source: Projections based on estimates of regression 4 (Table 6), and on an update of the 2012 Ageing Report.
a) Non-weighted average of AT, DE, DK, EL, ES, FI, FR, IT, LU, LV and the NL.

Graph 8 presents a number of HE-to-GDP projections for an aggregate of EU Member States.[53] Panel A presents the cost-containment (geometric) scenario and the two EPC-EC health scenarios (baseline and risk) included in the 2012 Ageing Report – European

[52] A one-to-one correction of the 2010 projection bias suggests an increase of 1.8 p.p. and 2.3 p.p. (i.e. more 0.8 p.p.), respectively, in the baseline and risk scenarios.

[53] The non-weighted average of 11 EU Member States for which sufficiently long series are available (AT, DE, DK, EL, ES, FI, FR, IT, LU, LV, and the NL).

Commission (DG ECFIN)-EPC (AWG) (2012). A linear trend, derived from the cost-containment scenario, is also included to facilitate the interpretation of results. Graph 8 (Panel A) suggests that the cost-containment scenario largely follows a linear extrapolation of actual data, although a negative gap emerges at the end of the projection period. Conversely, the two EPC-EC scenarios are clearly below this "mechanical" linear extrapolation of historical trends, largely reflecting the absence of a time drift (or residual growth). Panel B presents the three scenarios calculated using the methodology developed in this paper.

A considerable degree of uncertainty surrounds the exercise of making long term projections for health expenditure, and this is not only because small annual errors – if not centred around zero – accumulate into large discrepancies.[54] Uncertainty reflects a multitude of common problems in the health empirical research area, such as omitted variables,[55] unbalanced datasets, breaks in series, heterogeneity across countries not captured adequately by country fixed-effects, the role of technical progress, model misspecification, etc.; all potentially yielding biased and inefficient estimates, thereby contributing to large residuals or a remaining unexplained large and positive time drift in HE.

Nevertheless, the econometric methodology adopted in this paper is able to generate sensible future projections based on past trends, with results being in line with the existing literature, namely pointing towards a rising fiscal challenge of public HE. Also, the analysis implicitly considers other factors, besides ageing, income and relative prices to explain (future) HE developments, although these factors remain bundled in country fixed-effects and in a deterministic time drift.

[54] For example, a 1 p.p. difference in projections by 2060 (i.e. over 50 years) corresponds to an annual systemic error of just 0.02 p.p..

[55] Especially those related to policies and the institutional framework.

Table 14 –Public expenditure on health: a comparison of different projections

Methodology	Current paper (Cost-containment geometric scenario)	Current paper (Cost-pressure constant scenario)	EPC-EC (Reference scenario)	EPC-EC (Risk scenario)	OECD (Cost-containment scenario)	OECD (Cost-pressure scenario)	IMF
	Econometric model (regression in first differences)	Econometric model (regression in first differences)	Accounting framework	Accounting framework & econometric model (regression in first differences)			Econometric model (regression in first differences)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Health ageing	Effect of two demographic variables (younger than 16 and older than 64)	Effect of two demographic variables (younger than 16 and older than 64)	1 year gain in life expectancy= 1/2 year in good health	1 year gain in life expectancy= 1/2 year in good health	1 year gain in life expectancy= 1 year in good health	1 year gain in life expectancy= 1 year in good health	1 year gain in life expectancy= 1/2 year in good health
Income elasticity	0.96	0.96	1.1 in 2010 → 1 in 2060 (incudes other non-	1.3 in 2010 → 1 in 2060 (incudes other non-demographic factors)	0.8	0.8	0.3
Price elasticity	-0.48	-0.48	---	---	---	---	---
Time drift / Residual growth	Common time drift 0.59% in 2010 → 1%*0.59% in 2060	Common time drift 0.59% kept constant over the projection period	---	---	Common residual 1.7% in 2010 → 0% in 2060	Common residual 1.7% kept constant over the projection period	Country specific residual kept constant over the projection period
Results	in pp of GDP change 2060-2010 (in parenthesis pp change from 2050-2010)						in pp of GDP change 2050-2010
(Selected EU countries)	values after the bar "/" have been adjusted for base year (2010) projection bias						
France	2.9 (2.5)	6.1 (4.8)	1.4/2.4 (1.4/2.3)	2.1/3.1 (2.0/3.0)	2.2	6.1	2.6
Germany	3.1 (2.5)	6.3 (4.7)	1.4/2.3 (1.5/2.4)	2.0/2.9 (2.1/3.0)	2.3	6.2	1.5
Italy	2.3 (1.9)	4.8 (3.7)	0.6/1.4 (0.7/1.5)	1.0/1.9 (1.1/1.9)	2.6	6.4	1.1
Netherlands	2.7 (2.3)	5.4 (4.2)	1.1/1.5 (1.2/1.6)	1.6/2.0 (1.7/2.1)	2.4	6.3	4.9
Spain	2.3 (2.0)	4.9 (3.7)	1.3/1.9 (1.2/1.8)	1.9/2.4 (1.8/2.3)	2.8	6.7	3.5
United Kingdom	3.5 (2.9)	6.6 (5.0)	1.1/1.9 (1.1/1.9)	1.8/2.6 (1.7/2.5)	2.0	5.9	8.2
EU15 a)	2.8 (2.4)	5.6 (4.3)	1.0/1.8 (1.0/1.8)	1.5/2.3 (1.5/2.3)	2.4	6.2	4.5
EU27 a)	2.8 (2.3)	5.2 (4.0)	1.1/1.7 (1.1/1.6)	1.7/2.2 (1.7/2.2)	---	---	---

a) non-weighted average

Source: Table 4.3 from Maisonneuve and Martins (2013), with a few adaptations.

5. Testing Baumol's "unbalanced growth model"

In this section, Hartwig's (2008) methodology is used to test empirically the main implication of Baumol's "unbalanced growth model", namely that current total (public and private) HE is driven by wage increases in excess of productivity growth in the whole economy.[56]

Current instead of total (current and capital) HE is used, because the difference between the two – capital investment – does not play a role in Baumol's model. Also note that here we are using both public and private expenditure, whereas in the estimation of price and income elasticities and in the projection sections, the dependent variable is total public HE. The different focus reflects the fact that total public expenditure is used to make projections, whereas now we are discussing expenditure drivers from a more theoretical perspective.

Baumol (1967) developed a simple neo-classical growth model that can be used to rationalise the rapid and persistent rise in current total (public and private) HE in recent decades and assess future developments. The main implication of Baumol's model is that current total expenditure is driven by wage increases in excess of productivity growth. Using variables expressed in growth rates,[57] current total (public and private) HE is regressed on real per capita income and a variable which is the difference between wage and productivity growth for the whole economy (the so called "Baumol" variable).

The "unbalanced growth model" divides the economy into "progressive" and "stagnant" sectors. The essential assumption is that regular growth in labour productivity occurs only in "progressive" sectors, because "stagnant" sectors comprise activities which by their nature permit only sporadic increases in productivity. Regular labour productivity growth results from the introduction of capital goods (i.e. capital deepening), which automate production processes and are labour saving. In service industries, such as education and health services, physical capital cannot be employed on a large scale substituting (specialised) labour. Education and health services industries are expected to remain highly labour intensive activities and therefore belong to the "stagnant" sector of the economy. The "stagnant" sector of the economy is affected by "endemic" supply-side constraints as the rise in costs and prices outruns sluggish productivity growth.

A simplified description of Baumol's (1967) "unbalanced growth model", together with a derivation of the type of equation to be tested, based on supply-side considerations, is presented in Box 3.[58] Specifically, following the empirical test proposed by Hartwig (2008), we will show that Baumol's model strongly suggests that current total HE should rise approximately in line with wage increases in excess of labour productivity growth for the whole economy. In the remaining of this section, we will test this statement empirically.[59]

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[56] Cutler et al. (1998), Triplett and Bosworth (2003) and others have emphasised that the measurement of price deflators in services, including health care, is problematic as increases in quality or quantity can easily be mistaken for price rises. Newhouse (1992) seems to doubt the feasibility to calculate price deflators for health care expenditure, and therefore the possibility to test Baumol's cost disease hypothesis. Hartwig (2008) avoids the shortcomings of calculating health care price indices by introducing the so-called "Baumol" variable (the excess of wage increases over productivity growth of the whole economy) to test the validity of Baumol's cost disease in the health sector.

[57] Thereby avoiding the risk of running spurious regressions as no researcher has suggested that HE are I(2) or higher.

[58] This derivation is made under the restrictive assumption that the ratio of employment in the stagnant sector over total employment tends to one. Colombier (2012) provides a more general derivation, leading to a "Baumol" variable that is divided by the fraction of employment in the stagnant sector over total employment.

[59] Applying Colombier's (2012) extension to Hartwig's "Baumol" test, and using a panel data set of US states over the period from 1980 to 2009, and controlling for other factors affecting the growth of health care costs, such as income, the structure of the population and various socioeconomic variables, Bates and Santerre (2013) also find that HE grows more rapidly when economic-wide wage increases exceed productivity gains.

Data on current total HE is taken from the OECD Health Database. The panel is unbalanced, covering 22 European countries from 1960 to 2011.[60] Data on all other variables: wages and salaries per employee in the whole economy; labour productivity (real GDP per employee) in the whole economy; real GDP; the GDP price deflator; and total population are all taken from the European Commission's AMECO Database.

Baumol's "unbalanced growth model" would be consistent with a statistical significant coefficient of around one for the "Baumol" regressor: $(\widehat{W_t} - \widehat{lp_t})$, which is the difference between the growth rates of nominal wages per employee and labour productivity for the whole economy (Hartwig, 2008), respectively.[61]

The following "type" of linear regression is estimated (for a derivation see Box 3):

$$\widehat{H_{i,t}} = a * \left(\widehat{W_{i,t}} - \widehat{lp_{i,t}}\right) + b * \widehat{y_{i,t}} + \varepsilon_{i,t} \qquad (18)$$

where a hat over a variable means a growth rate (i.e. first difference of the logarithm); $\widehat{H_{i,t}}$ is the growth rate of nominal current per capita HE; $\widehat{W_{i,t}}$ is the growth rate of nominal wages per employee; $\widehat{lp_{i,t}}$ is the growth rate of labour productivity in the whole economy; $\widehat{y_{i,t}}$ denotes the growth rate of real per capita GDP; and $\varepsilon_{i,t}$ is a stochastic variable.

Use of panel data allow the estimation of models with country- and time-specific effects. The Hausman test was applied to choose between fixed- and random-effects models. In our estimates – and contrary to Hartwig (2008) – this test tends to reject the null hypothesis that random effects are uncorrelated with explanatory variables (at 5%) so we prefer to use the fixed-effects estimator.

Table 15 summarises the results using the "Baumol variable" split into two separate variables, namely wage growth per employee, and labour productivity growth. In line with our discussion in Box 3 and following the general-to-specific approach adopted in Hartwig (2008), we first estimate the effect of these two variables separately in order to test whether the sum of their coefficients adds to one. Although in the cross-section fixed-effects model we cannot reject the null hypothesis only at 1%, our interpretation of the set of Wald tests suggests that the two variables can be pooled. Hereafter, we will present results only using the pooled "Baumol" variable.

[60] AT, BE, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IE, IT, LU, NL, NO, PL, PT, SE, SI, SK, and the UK. The total number of observations amounts to just over 600.

[61] This basically assumes that relative outputs between "stagnant" and "progressive" sectors are constant, and that over time employment moves entirely to the "stagnant" sector (see Box 3). Colombier (2012) shows that the latter assumption is not essential to obtain highly significant regression coefficients for an (adjusted) Baumol variable.

Table 15 – The "Baumol" variable split as regressors of the growth rate of nominal per capita HE (log differences)

Regressions	OLS	Cross-section fixed-effects	Time period fixed-effects
Variables	(9)	(10)	(11)
Constant	0.02196***	0.02539***	0.02580***
dlog(wspe)	1.04534***	0.99692***	0.98813***
dlog(prod)	-0.15941*	-0.15900*	-0.14768
Number of observations	607	607	607
R squared adjusted	0.68281	0.59532	0.54233
Root mean squared error	0.03967	0.03921	0.03845
Wald test (p-value) a)	0.1143	0.039*	0.0651
legend: * p<0.05; ** p<0.01; *** p<0.001			

Sources: OECD Heath Database and AMECO Database.
Note: dlog(wspe)= log difference of wages and salaries per employee in the whole economy, and dlog(prod)= log difference of labour productivity (real GDP per employee) in the whole economy.
a) Tests the null hypothesis that the sum of the two coefficients (wspe and prod) is one.

Table 16 summarises the results using as regressor the "Baumol" variable unsplit. Similarly to Hartwig (2008), we find strong support in the data for the Baumol's "unbalanced growth model". As predicted (see Box 3), the value of the estimated coefficient is close to one, remaining largely stable across specifications. Alone, the "Baumol" variable explains between 45% to 60% of the total variation in the dependent variable.

Table 16 – The "Baumol" variable unsplit as a regressor of the growth rate of nominal per capita HE (log differences)

Regressions	OLS	Cross-section fixed-effects	Time period fixed-effects
Variable	(12)	(13)	(14)
Constant	0.04080***	0.04522***	0.04445***
Baumol var.= dlog(wspe)-dlog(prod)	1.01981***	0.93378***	0.94880***
Number of observations	607	607	607
R squared adjusted	0.60423	0.51672	0.46497
Root mean squared error	0.04431	0.04285	0.04157
Wald test (p-value) a)	0.5546	0.0669	0.1952
legend: * p<0.05; ** p<0.01; *** p<0.001			

Sources: OECD Heath Database and AMECO Database.
Note: dlog(wspe)= log difference of wages and salaries per employee in the whole economy, and dlog(prod)= log difference of labour productivity (real GDP per employee) in the whole economy.
a) Tests the null hypothesis that the coefficient of the "Baumol" variable is one.

Table 17 includes per capita real GDP as an explanatory variable. Recall that in the literature, GDP has emerged as the only uncontroversial explanatory variable of HE (Gerdtham and Jönsson, 2000). Results show that real per capita GDP is an important determinant of current per capita HE growth.[62] Note that the coefficient of the "Baumol" variable remains statistically close to one, according to Wald tests.

[62] Note that in Box 3, both the Baumol and the per capita GDP variables enter in equation (xi).

Table 17 – The "Baumol" variable unsplit and per capita real GDP as drivers of the nominal growth rate of current per capita HE (log differences)

Regressions	OLS	Cross-section fixed-effects	Time period fixed-effects
Variables	(14)	(15)	(16)
Constant	0.02356***	0.02770***	0.02370***
Baumol var.= dlog(wspe)-dlog(prod)	1.04048***	0.98814***	0.96907***
dlog(GDPrpc)	0.68223***	0.62080***	0.83058***
Number of observations	607	607	607
R squared adjusted	0.67878	0.59139	0.56109
Root mean squared error	0.03992	0.0394	0.03765
Wald test (p-value) a)	0.1812	0.7241	0.388

legend: * p<0.05; ** p<0.01; *** p<0.001

Sources: OECD Health Database and Ameco Database.
Note: dlog(wspe)= log difference of wages and salaries per employee in the whole economy, dlog(prod)= log difference of labour productivity (real GDP per employee) in the whole economy, and dlog(GDPrpc) = log difference of real per capita GDP.
a) Tests the null hypothesis that the coefficient of the "Baumol" variable is one.

Box 3: A simplified version of Baumol's "unbalanced growth model"

Following Baumol (1967) and Hartwig (2008), let us assume that labour productivity in the "stagnant" sector (i) stays constant, while it grows at the constant rate *r* in the "progressive" sector (ii).[a)]

$$Y_{1t} = aL_{1t} \qquad \text{(i)}$$

$$Y_{2t} = bL_{2t}e^{rt} \qquad \text{(ii)}$$

where Y_{1t} and Y_{2t} are output levels in the two sectors at time *t*, L_{1t} and L_{2t} are the quantities of labour employed, and *a* and *b* are constants.

Wages are equal across the two sectors and grow in line with labour productivity in the "progressive" sector:

$$W_t = We^{rt} \qquad \text{(iii)}$$

with *W* being some constant.

Relative costs per unit of output (the "stagnant" over the "progressive" sectors) is given by:

$$\frac{C_1}{C_2} \equiv \frac{\frac{W_t L_{1t}}{Y_{1t}}}{\frac{W_t L_{2t}}{Y_{2t}}} = \frac{\frac{W_t L_{1t}}{aL_{1t}}}{\frac{W_t L_{2t}}{bL_{2t}e^{rt}}} = \frac{be^{rt}}{a} \qquad \text{(iv)}$$

where C_1 and C_2 represent costs per unit of output.

Over time ($t \to \infty$), relative costs (iv) tend to infinity. Consequently, under "normal" circumstances (i.e. prices set as a mark-up over costs), and with an elastic demand, *there is a tendency for outputs of the "stagnant" sector to decline and perhaps, ultimately, to vanish* (Baumol, 1967, p. 418).

However, parts of the "stagnant" sector produce necessities, such as education and health services, for which the price elasticity is very low.

As an illustration, Baumol (1967) considers the case where despite the change in their relative costs and prices, the magnitude of the relative outputs of the two sectors are kept constant (e.g. through government subsidies):

$$\left(\frac{b}{a}\right)\frac{Y_{1t}}{Y_{2t}} = \frac{L_{1t}}{L_{2t}e^{rt}} = K \qquad \text{(v)}$$

with K being some constant.

Let $L_t = L_{1t} + L_{2t}$ be total employment, then it follows:

$$L_{1t} = (L_t - L_{1t})Ke^{rt} \quad \leftrightarrow \quad L_{1t} = \frac{L_t Ke^{rt}}{1+Ke^{rt}} \qquad \text{(vi)}$$

$$L_{2t} = L_t - L_{1t} = \frac{L_t}{1+Ke^{rt}} \qquad \text{(vii)}$$

According to (vi) and (vii), over time ($t \to \infty$), L_{1t} tends to L_t, and L_{2t} to zero.

In the "unbalanced growth model", if the ratio of outputs of the two sectors is kept constant, an ever larger share of labour must move to the "stagnant" sector, while the amount of labour in the "progressive" sector will gradually tend to zero.

a) For a more general derivation of the regression equation see Colombier (2012).

Box 3: A simplified version of Baumol's "unbalanced growth model" (continuation)

A GDP index can be calculated as a weighted average of the value added of the two sectors:

$$GDP_t = B_1 Y_{1t} + B_2 Y_{t2} = B_1 a L_{1t} + B_2 b L_{2t} e^{rt} \quad \text{(viii)}$$

Replacing (vi) and (vii) into (viii), we obtain the growth rate of GDP as:

$$\widehat{GDP_t} \equiv \frac{\frac{dGDP_t}{dt}}{GDP_t} = r - r\frac{Ke^{rt}}{1+Ke^{rt}} + \widehat{L_t} \quad \text{(ix)}$$

where a hat over a variable means a growth rate.

(ix) can be re—rewritten as labour productivity:

$$\widehat{GDP_t} - \widehat{L_t} = r - r\frac{Ke^{rt}}{1+Ke^{rt}} \quad \text{(ixa)}$$

In the "unbalanced growth model", the growth rate of labour productivity declines asymptotically to zero over time ($t \to \infty$).

After presenting a simplified version of Baumol's "unbalanced growth model", we will now derive an expression for the nominal growth rate of current total per capita HE, which can be tested in a regression.

Using a supply-side approach, (i) and (iii) can be used to express nominal current total HE as:

$$HE_t = \gamma W_t L_{1t} \quad \text{(x)}$$

with γ being the mark-up of prices over costs. Equation (x) can be re-arranged as:

$$H_t \equiv \frac{HE_t}{P_t} = \gamma \frac{W_t}{\frac{GDP_t/P_y}{L_t}} \frac{GDP_t/P_y}{P_t} \frac{L_{1t}}{L_t} = \gamma \frac{W_t}{lp_t} y_t \frac{L_{1t}}{L_t} \quad \text{(xa)}$$

with H_t being nominal current total per capita HE; P_t population; GDP_t nominal GDP; P_y the GDP deflator; $lp_t \equiv \frac{GDP_t/P_y}{L_t}$ labour productivity; and $y_t \equiv \frac{GDP_t/P_y}{P_t}$ real per capita GDP.

Differentiating the logarithm of (xa):

$$dlog(H_t) = dlog(W_t) - dlog(lp_t) + dlog(y_t) + dlog(L_{1t}) - dlog(L_t) \quad \text{(xb)}$$

Or expressed in growth rates:

$$\widehat{H_t} = \widehat{W_t} - \widehat{lp_t} + \widehat{y_t} + \widehat{L_{1t}} - \widehat{L_t} \quad \text{(xc)}$$

According to (vi), over time ($t \to \infty$), L_{1t} tends to L_t, thereby $\widehat{L_{1t}} \approx \widehat{L_t}$.

Consequently, equation (xc) can be approximated as:

$$\widehat{H_t} \approx \widehat{W_t} - \widehat{lp_t} + \widehat{y_t} \quad \text{(xi)}$$

Equation (xi) suggests that the growth rate of nominal current total per capita HE can be approximately broken down into the sum of the Baumol variable ($\widehat{W_t} - \widehat{lp_t}$), where $\widehat{W_t}$ and $\widehat{lp_t}$ represent the nominal growth rate in wages per employee and productivity growth in the whole economy, respectively, and the growth rate of real per capita income ($\widehat{y_t}$).

> **Box 3: A simplified version of Baumol's "unbalanced growth model" (continuation)**
>
> However, an important point should be made here. Note that per capita GDP (y_t) and labour productivity (lp_t) are linked by the identity:
>
> $$y_t \equiv lp_t * (1 - ur_t) * ar_t \quad \text{(xii)}$$
>
> where labour market variables, respectively, the unemployment (ur) and the activity (ar) rates are present.
>
> Taking the first difference of the logarithm, equation (xii) can be expressed in growth rates as:
>
> $$\widehat{y_t} - \widehat{lp_t} \approx \widehat{ar_t} - \Delta ur_t \quad \text{(xiii)}$$
>
> Identity (xiii) implies that regression (xi) can be estimated only if the term $\widehat{ar_t} - \Delta ur_t$ changes over time.

As in Hartwig (2008), in order to check that the "Baumol" variable is not only picking up monetary changes,[63] we deflate all variables using the GDP price deflator and allow the latter to enter the regression as a separate regressor (Table 18).

Table 18 – The "Baumol" variable unsplit, per capita real GDP and the GDP deflator as drivers of the real growth rate of current per capita HE (log differences)

Regressions	OLS	Cross-section fixed-effects	Time period fixed-effects
Variables	(17)	(18)	(19)
Constant	0.02265***	0.02661***	0.02142***
Real Baumol var.= dlog(rwspe)-dlog(prod)	0.87017***	0.84996***	0.66649***
dlog(GDPrpc)	0.63337***	0.58104***	0.77220***
dlog(GDPp)	0.08275*	0.02951	0.04384
Number of observations	607	607	607
R squared adjusted	0.28619	0.23379	0.16466
Root mean squared error	0.03968	0.03925	0.03687
Wald test (p-value) a)	0.042	0.0198	0
legend: * p<0.05; ** p<0.01; *** p<0.001			

Sources: OECD Health Database and Ameco Database.
Note: dlog(rwspe)= log difference of wages and salaries per employee in the whole economy, deflated using the GDP deflator; dlog(prod)= log difference of labour productivity (real GDP per employee) in the whole economy; dlog(GDPrpc) = log difference of real per capita GDP; and dlog(GDPp) log difference of the GDP price deflator.
a) Tests the null hypothesis that the coefficient of the "Baumol" variable is one.

When all nominal variables are deflated, the coefficient of the real "Baumol" variable is lowered and Wald tests reject the null hypothesis that the coefficient is equal to one at 5%. However, the coefficient of per capita real GDP is between 0.6 to 0.8, which is comparable to the income elasticity estimates reported in Table 12.

Overall, we conclude that developments in current total HE in European countries since 1960s are in line with Baumol's theory of "unbalanced growth". Wage increases in excess of productivity growth are a statistical significant explanatory variable for per capita HE growth (together with per capita income). As predicted by the theory, the "Baumol" coefficient is close to one. This finding is robust to the addition of real GDP as an explanatory variable.

Summarising, the three major results derived from the econometric analysis are: i) in a historical perspective, breakdowns of public HE growth using stylised values (derived from

[63] Recall that in Baumol's "unbalanced growth model" variables are expressed in nominal terms.

the empirical literature) for the income and price elasticities show that demographic factors played a minor role in explaining total growth; ii) the strong rise in relative prices of health services in the past half century is linked to lower or stagnant productivity growth in that sector; and iii) combined with a relatively inelastic demand, a rise in relative prices of health services generates a trend increase in the HE-to-GDP ratio.

6. Conclusions

This paper gives empirical support to the thesis that the major explanatory factors of the growth of public HE in recent decades are non-demographic drivers, such as income, the rise in the relative prices of health services, and technological progress in the medical sector. In particular, supply-side constraints seem to have a pivotal role in driving up costs and prices in low productivity labour intensive sectors of the economy, such as health services. We find strong evidence that increases in relative prices of health services lead to rises in expenditure shares because demand is inelastic.

Using panel data for 27 EU Member States and Norway in the period from 1985 to 2010, the estimated weighted average of excess cost growth is calculated between 1 and 1½% which is in line with results reported in the literature (Clements et al., 2012). Income elasticity estimates mostly below 1 are also in line with recent empirical results (Acemoglu et al., 2009), although these estimates may still be affected by omitted-variable bias, inter alia, because HE regressions do not include a technology/quality variable and policy variables.

Given the evidence on the "cost-price" disease affecting low productivity sectors of the economy, such as the health care sector, inclusion of a health price index even if as a "proxy" variable built from macroeconomic variables, seems to be an important step potentially improving the quality of HE estimations.

The specification used to estimate HE fits well with the EPC-EC methodology to project long term age related costs (DG ECFIN-EPC(AWG), 2012), because the macroeconomic variables needed to project future HE are available in the long term age related projections, namely real GDP, GDP prices, wages, labour productivity, and demographic variables. However, it should be recognised that projections depend crucially on the assumption made on the future evolution of a time drift.

Ultimately, we decided to make HE-to-GDP projections using regressions in growth rates for mainly two reasons: i) panel co-integration tests were inconclusive; and ii) assuming co-integration has the unpalatable implication that the HE-to-GDP ratio does not appear to converge to a steady-state. Furthermore, Gerdtham and Jönsson (2000) recommend that variables be specified as growth rates when conducting regression analysis because of the possible presence of unit roots in the data.

We present a few projection scenarios for the HE-to-GDP ratio up to 2060. Results suggest a minimum increase of 3 p.p. of GDP between 2010 and 2060 for the EU27. Overall, projected expenditure rises are in line with OECD's (Maisonneuve and Martins, 2013), but are considerably above those obtained using the EPC-EC methodology.

As a whole, projections of HE represent an acute reminder of the need to proceed with the efforts to curb expenditure growth and improve the efficiency of health systems. In fact, in the absence of additional control measures (i.e. in the "cost-pressure" scenario), projection outcomes suggest on average a near doubling of the HE-to-GDP ratio across the EU between 2010 and 2060.

In future work, we plan to follow Bates and Santerre's (2013) approach, which is based on Colombier's (2012) extension of Hartwig's (2008) model, to estimate panel regressions of HE expenditure, using a variety of aggregate socioeconomic indicators as explanatory variables, including an adjusted "Baumol" variable. This line of research could provide a useful alternative methodology for projecting future HE.

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