THE POLITICAL ECONOMY OF HEALTH CARE, TECHNOLOGY AND R&D

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Abstract: The first part of this article considers some relevant facts about health care R&D, technological innovation, and health care expenditures. Some of the most important facts about health care expenditures are examined and summed up. The second part reviews the literature on the determinants of health care costs with particular focus on the role of technological innovation. Technology is an important driver of health care costs. In the third part, an extension is suggested to try to make technology endogenous to R&D. An "insurance" model of the demand of health care R&D is proposed and some preliminary empirical results are shown for total and public R&D. While R&D behaves as a normal good, medical care price has a positive impact on the demand of health care R&D. This finding is inconsistent with the insurance model, which predicts a negative effect of health care price on the demand of health care R&D.

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[§]PhD Candidate. Department of Economics at George Mason University, 4400 University Dr. Fairfax, VA 22030. The presentpaper is an extract from the dissertation I'm writing as a PhD candidate at George Mason University with the tentative title "*The Public Choice of Health Care: Technological Dilemmas, Challenges and Imperatives.*" It is a draft of an ongoing project. The empirical results reported are very preliminary; please do not quote or circulate. The main objective is to open the topic to discussion by session participants of the PCS Meeting in Miami.

1. Introduction

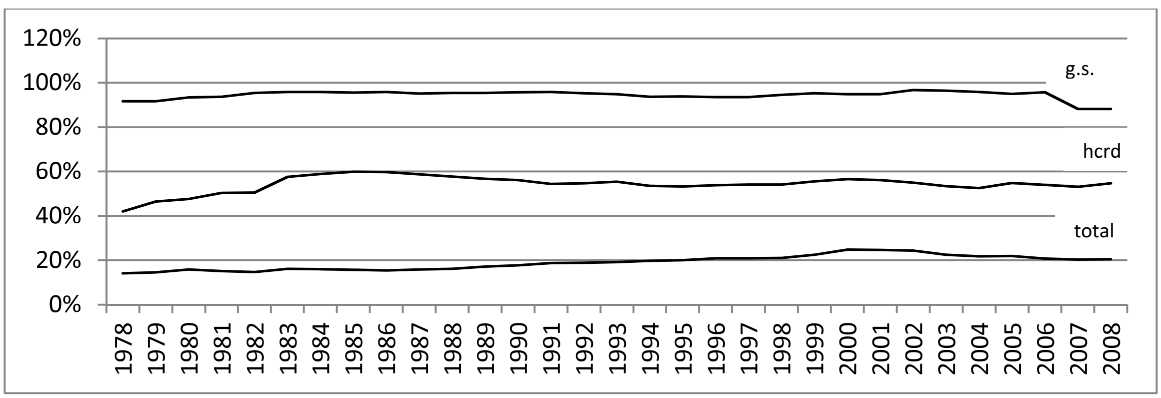
The present paper seeks to be a contribution to the debate concerning the rising costs of health care expenditures in the US. It is organized in three parts. The first part considers some relevant facts about health care R&D, technological innovation, and health care expenditures. We sum up some of the most important facts about health care expenditures.

The second part is a review of the literature about the determinants of health care costs, with particular focus on the role of technological innovation. We show that technology is an important driver of health care costs, with the majority of the empirical literature showing a cost increasing effect. In the third part, we look at technological innovation as an endogenous process driven by R&D funding and then consider some of the possible political preferences and incentives towards R&D decision making. It emerges that, especially in the health care sector, R&D is mainly a public business. We then propose an "insurance" model of the demand of health care R&D and in the last section we show some preliminary empirical results. We find that medical care price has a positive impact on the demand of health care R&D. This finding is inconsistent with the insurance model, which predicts an unambiguous negative effect of health care price on the demand of health care R&D. On the other hand, it is empirically confirmed that R&D behaves as a normal good, as predicted by the model. However, we find that it cannot be considered a luxury good as some empirical analysis on the demand of health care seems to suggest.

2. Some relevant facts on health care R&D, technological innovation, health care expenditures, and costs

R&D is undoubtedly a main driver of technological innovation and diffusion. Here we show some trends of health care R&D expenditures in the US. For example, the following chart (Chart 1) shows the ratios of public R&D and total R&D (data from the National Science Foundation). Government sponsorship of research is very important for general science subsectors (g.s. series), where almost all expenditures are from public sources. R&D is also an important, but not a dominant, source of health sector R&D (hcrd labeled line), accounting for more than half of the spending of total basic R&D and reaching the top share of 60% in 1985. However, the share of public funding participation with respect to total basic R&D is from 20 to 40% higher than the average participation in the total.

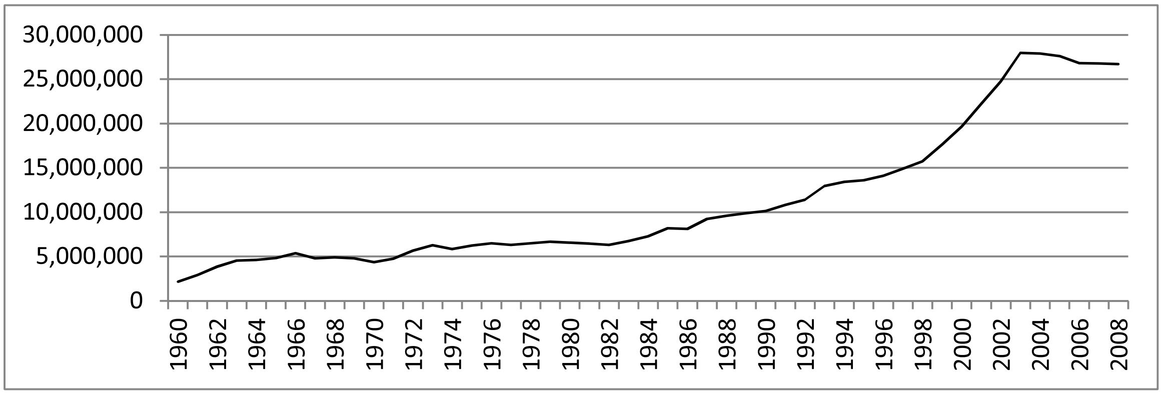
Chart 1: NSF Ratio (%) of total public R&D to basic R&D (for total R&D, health R&D, and general science subsectors)



Further evidence shows that the National Institutes of Health (NIH) appropriations for research in the healthcare/ biotech sector from 1960 until 2008 rose constantly until 2004 (Chart 2). They reached nearly 30 billion dollars in 2003; after that date, the total amount of appropriations declined.

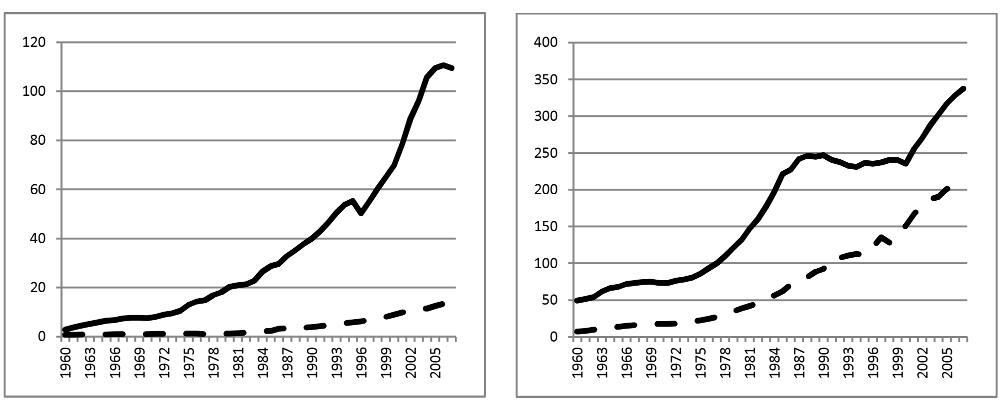
Chart 2: Total thousands $ NIH appropriations (2005=1)

Source: NIH



Charts 3a and 3b are particularly effective in showing how R&D in the US should be considered mainly a sort of public "business"; this is particularly true if we look at the series for health care R&D (source: OECD Health Data), where the wedge between public and private expenditures increases constantly for the period.

Charts 3a and 3b: Public and private R&D, Technological diffusion and innovation in the Health Care sector: charts representing R&D series.
Chart 3a: (left) per capita Health Care R&D expenditures (OECD); Chart 3b: (right) total per capita R&D expenditures – US (1960-2007), (NSF)
Federal (solid line); Private (dotted line)



The following table (Table 1) shows a comparison of the diffusion of Tomographic Scanners (TS) and Magnetic Resonance Imaging (MRI) (rates per million pop) between an unweighted average of OECD countries and the US for selected years. Data, when available for the period 1993-2007, show that the rates of diffusion in the United States are higher than the unweighted average of selected OECD countries. This observation might suggest the link between a more "technological" form of supply of healthcare and the high healthcare expenditures in the US with respect to other OECD countries (this evidence will be provided in the following charts).

Table 1: TS (Tomographic Scanners) and MRI (Magnetic Resonance Imaging):

US and OECD u.a. comparison

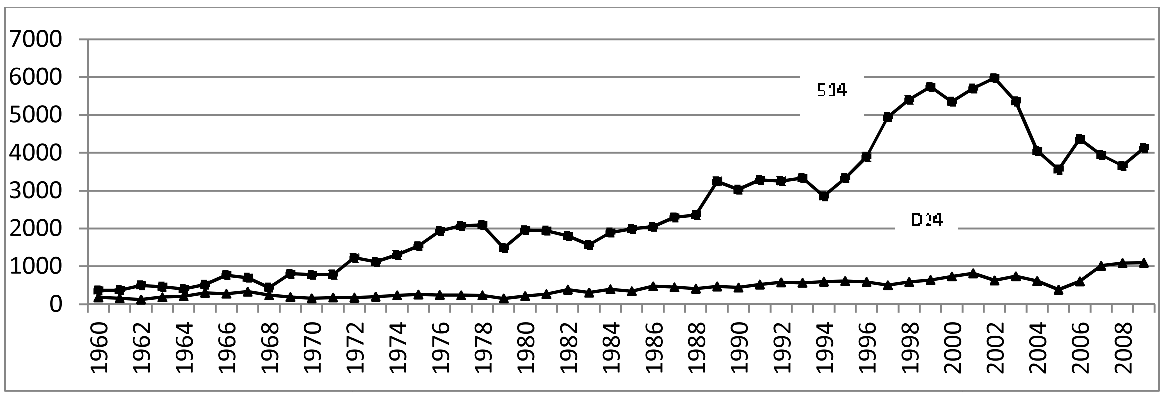
Source: OECD Health Dataset 2009

year	*Tomographic Scanners (per million pop)*		*MRI (Magnetic Resonance Imaging) (per million pop)*		*year*	*Tomographic Scanners (per million pop)*		*MRI (per million pop)*	
	United States	*OECD u.a.*	*United States*	*OECD u.a.*		*United States*	*OECD u.a.*	*United States*	*OECD u.a.*
1993	*n.a.*	*14.4*	*11.5*	*3.3*	*2000*	*n.a.*	*15.5*	*n.a.*	*5.7*
1994	*n.a.*	*11.4*	*n.a.*	*2.4*	*2001*	*28.9*	*15.7*	*20.1*	*7.0*
1995	*n.a.*	*12.1*	*12.3*	*3.9*	*2002*	*n.a.*	*19.8*	*n.a.*	*7.9*
1996	*n.a.*	*16.6*	*n.a.*	*4.4*	*2003*	*29.2*	*16.6*	*21.9*	*7.4*
1997	*24.1*	*13.8*	*13.5*	*4.6*	*2004*	*32.2*	*17.4*	*26.6*	*8.6*
1998	*n.a.*	*13.9*	*n.a.*	*4.9*	*2005*	*n.a.*	*18.7*	*n.a.*	*10.0*
1999	*25.1*	*18.6*	*15.4*	*7.6*	*2006*	*34*	*19.4*	*26.5*	*9.1*
					2007	*34.3*	*19.4*	*25.9*	*9.9*

The chart below shows the number of patents on Medical and Laboratory Equipment (class D24) and on Drugs Bio-Affecting and Body Treating Compositions (class 514) approved from 1960 to 2008 in the US. The source is the USPTO. These data should be considered a more appropriate measure[2] of applied R&D than innovation. The steady constant increase in the number of patents slowed after the year 2000.

Chart 4: Patents on drugs and medical devices in the US (1960-2008)

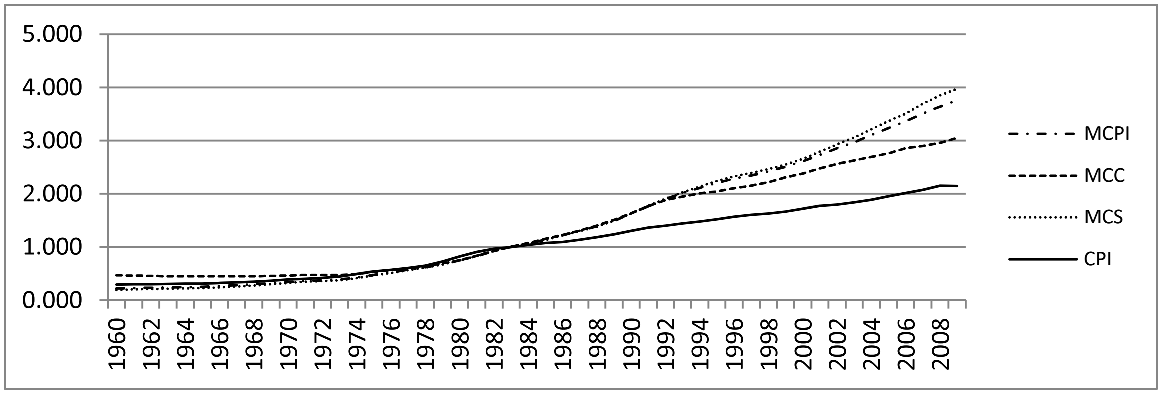
Source: USPTO http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cbcby.htm#Printing



A more detailed analysis follows. Price indexes reveal that until the mid 1980s the dynamic of prices in the medical sector (both for commodities, services and for a weighted average of both) kept the same pace with the CPI. After the mid 1980s, there was an increasing wedge between price indexes in the medical sector and general CPI. For the entire period the increase of medical care price index with respect to the CPI has been 133%.

[2] We acknowledge that this is an imperfect measure, because not all patents pass clinical and preclinical trial tests and receive the approval of the FDA. Moreover, data don't take into account citations.

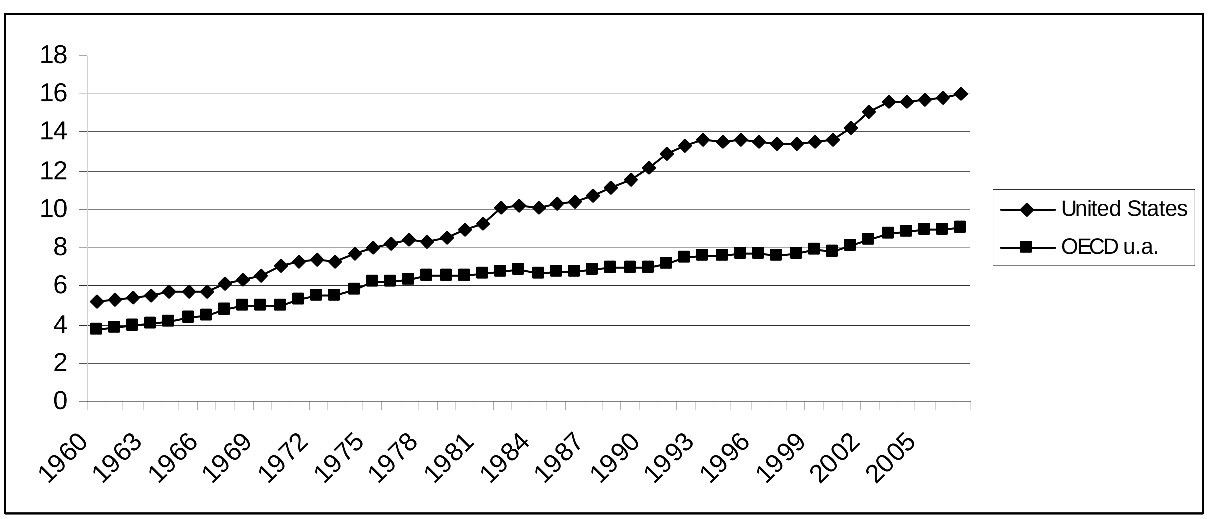
Chart 5: Price indexes
MC: medical care; MCC: medical care commodities; MCS: medical care services; CPI: general consumer price index: all data are annual averages 1982-1984 = 100.
Source: BLS



From a public finance perspective, the size of health care expenditures is increasing among the OECD countries. In the US this effect is particularly strong. For example, the first graph (Graph 1) uses data from the OECD Health Data 2009 from 1960 to 2007. Data represent the evolution of health care expenditures as percentage of GDP through the period. The steady increase of the ratio is apparent both for the unweighted average of the OECD countries and for the series of the US.

Chart 6: Total Health Care expenditures as percentage of the GDP for the period 1960-2007

Source: OECD Health Data 2009

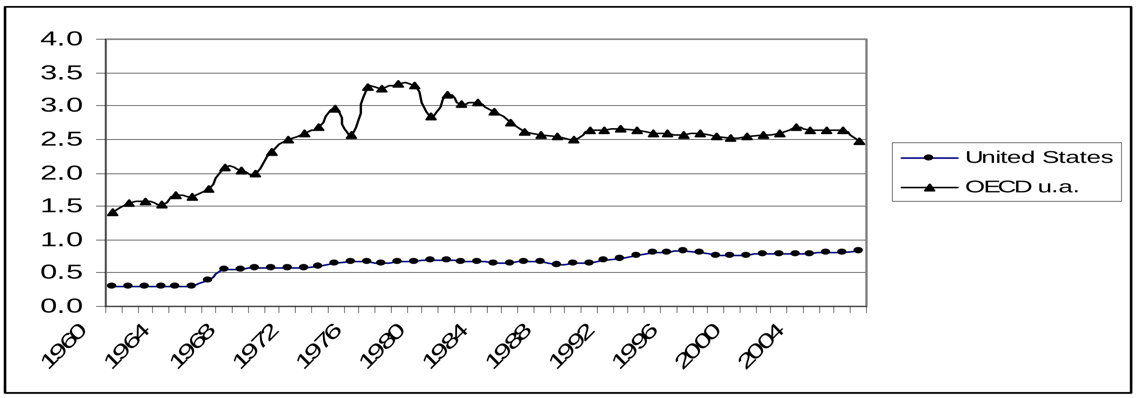


The second relevant aspect of the comparison is the increasing spread between the US and OECD series. For the whole set of the OECD countries and for the US the value was respectively 3.8% and 5.2% in 1960 while the two percentages were respectively 9.1 and 16 in 2007. The spread increased relevantly from 1.4 to 6.9%.

Chart 7 shows the ratio of public to private expenditures in health care. While the order of magnitude is higher for the OECD countries (almost all of them have a universal insurance plan), the US shows a slow but steadily increasing trend that reaches almost the one-to-one ratio (0.8) in 2007.

Chart 7: Public/Private HCE

Source: OECD

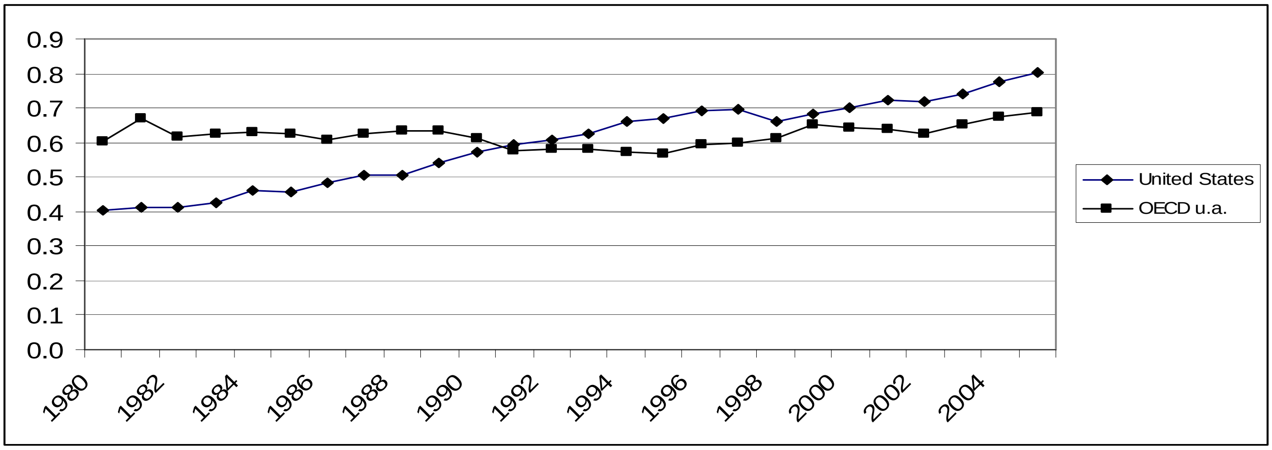


On the other hand, the OECD countries stabilized and reduced the ratio starting from the early 1980s, from a peak of 3.1 in 1981 to a 2.6 level from 1986 onward, passed slightly only in 1992 (2.7). The irregular drop (from 3.3 in 1979 to 2.8 in 1980) seems more determined more by the statistical sensitivity of the index than to structural/historical reasons. Private expenditure percentage of GDP rises from 1.5 to 1.7 while the public part falls from 5 to 4.9.

Focusing more on the public part of the health expenditure, the increasing relevance of the health sector with respect to other social insurance programs is highlighted in the following chart (Chart 8). While this index is almost constant for the period 1980-2004 in the OECD countries, the trend for the US is steadily increasing and passes the unweighted average for the OECD countries in 1991. Its value in 2006 is 0.8, not far from the one-to-one ratio.

Chart 8: Ratio of Health (%GDP) to the rest of Social Protection (without health part HCE/(Social Protection no HCE)

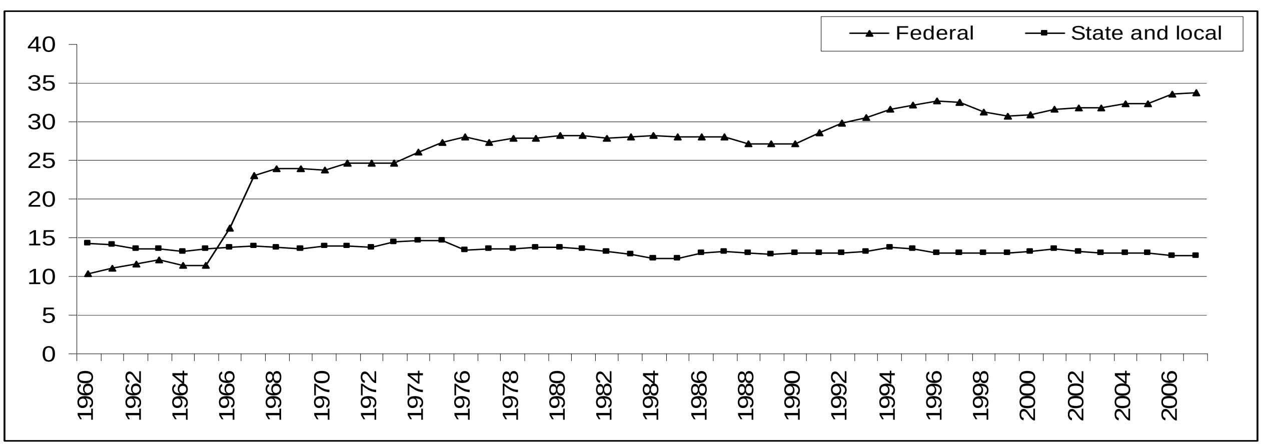
Source: OECD Health Data 2009



It is possible to achieve a more detailed focus on the US experience for the period 1960-2007 utilizing the Health Expenditure Dataset available online from the US Department of Health and Human Services – Center for Medicare and Medicaid.

Chart 9: US federal and state-local expenditures as % of total public expenditure 1960-2007

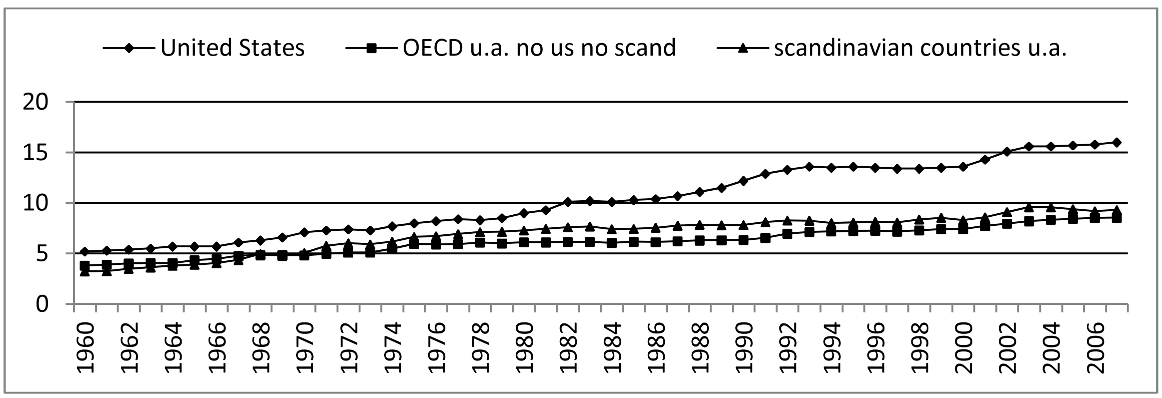
Source: US-NHE Dataset



The relevant aspect shown in this chart is the predominant role exercised by federal expenditures in the public sector. The overtaking happens in the years 1965-1966, when the Medicare program is approved. The spread between the federal and the state shares is steadily increasing and goes from 2.4% in 1966 to 21.1% in 2007. Tax-financed healthcare expenditures have been increasing among the OECD countries for most of the same period. Three factors are likely to contribute to this growth: income, the ageing of the populations in most OECD countries, and the availability of new more sophisticated medical procedures. The latter is likely to be, at least in part, a consequence of past R&D expenditures decided mainly at a public level. The chart below uses data from the OECD-Health Statistics Dataset 2009 from 1960 to 2007 that characterize healthcare expenditures as percentage of GDP through the period. The steady increase of the ratio is apparent for the unweighted average of the OECD countries, for the series of the US and for a subset of Scandinavian countries. The second relevant aspect of the comparison is the increasing spread between the US and OECD series. The increase in healthcare expenditures in the US, where many of the world's new procedures are worked out, is particularly strong.

Chart 10 *Total*

Healthcare expenditures as percentage of the GDP for the period 1960-2007Source: OECD Health Data 2009



For the whole set of the OECD countries and for the US the value was respectively 3.8% and 5.2% in 1960 while the two percentages were respectively 9.1 and 16 in 2007. The spread increased relevantly from 1.4 to 6.9%. On the other hand, the OECD countries stabilized and reduced the ratio starting from the early 1980s, from a peak of 3.1 in 1981 to a 2.6 level from 1986 onward, passed slightly only in 1992 (2.7).[3]

[3]US healthcare expenditures are, with respect to other OECD countries, i) among the highest in terms of % of GDP; ii) at least since the introduction of Medicare, total health expenditures have been steadily increasing as a % of GDP; iii) the share of public expenditures in healthcare has steadily increased with respect to the private counterpart; iv) the share of public health expenditures with respect to total public budget has been steadily increasing in the last 30 years and has become the larger "share" of the public pie; v) among public healthcare expenditures there has been an increasing role of the federal share respect to the state and local level ones.

3. Does technology drive health care costs? A Review[4]

Reviews on the determinants of healthcare expenditures have been published on a regular basis.[5] A list of the most common drivers are life expectancy, demography and mortality rates (e.g. ageing and/or proximity to death);[6] income effect;[7] Baumol's effect;[8] the role of Public/Private Insurance coverage;[9] the role of several types of institutions and healthcare delivery systems[10] or health and behavior,[11] and technology. There is neither a theoretical-unifying model, nor are unanimous empirical findings able to show that technology in the healthcare sector inevitably leads to an increase in health care costs. However, the sharp rise of healthcare expenditures (tripled as a fraction of the US GDP from 1960 to 2010) has often been explained in terms of technological advances. The majority of the findings from empirical attempts exerted in order to measure the contribution of technological development to healthcare expenditures show an important increasing effect. This effect was found to be of primary

[4] This section borrows heavily from a recent survey by van Elk, Mot and Franses (2009). The reader is encouraged to refer to this source for more detailed references on the topic.

[5] See for example, Freeland et al. (1998). Gerdtham and Jönnson (2000) provide an overview of the literature on international comparisons of healthcare expenditures. Income is the relevant factor in their empirical analysis. See also Pammolli et al. (2005); Productivity Commission, Australian Government (2005); Kaiser (2007) Foundation Report. This is a pure review article. See also van Elk et al. (2009) where the empirical part focuses on the Baumol's effect (i.e. on the effect of the increase in the relative price of healthcare with respect to other services); see also Dybczak and Przywara (2010), this is an OECD panel data analysis but the general focus is on the European experience. This paper follows a standard review of the literature like the one offered here.

[6] See for example Zweifel et al. (1999) and Raitano (2005).

[7] This is probably the most studied cause, especially in the recent literature. See for example Hall and Jones (2007).

[8] Standard reference is of course Baumol (1967), (1993) and related literature.

[9] See for example Weisbrod (1991) and Weisbrod and LaMay (1999).

[10] There is a rich review of the literature on the institutional aspect; see van Elk et al. (2009).

[11] Healthier behavior may lower the growth of healthcare expenditures over the long run, but this does not necessarily have to be the case. For example, not smoking might keep people from dying from lung cancer at a comparatively young age, with a consequence that they have a larger probability of suffering from chronic diseases associated with ageing. Taking health behavior into account is difficult with commonly available data, as lags between behavior and health effect may be very long. A person who starts smoking now may get lung cancer in 30 years from now. Christiansen et al. (2006) and Gerdtham et al. (1998) both find that tobacco consumption is associated with higher healthcare expenditures. In addition, they both find no significant effect of alcohol consumption.

importance in Newhouse (1992).[12] The empirical literature on the subject is usually divided in three families.[13]

The residual/trend approach is based on the assumption that technology is responsible for all changes not accounted for by the other quantifiable factors. In this approach, the effects of demographic changes, changes in health status, prices and income are subtracted from total increase in expenditure and the remaining part (residual) is attributed to changes in technology. Such a method avoids the difficulty of specifying the direct measure of technological progress and covers all types of technology used in the process of healthcare provision.[14] On the other hand, however, it provides only a rough, indirect and, often, overestimated measure of the effect of technological progress as the residual includes, apart from technology itself, a series of other not quantified factors, such as institutional setting, behavior, environment, education, etc. Examples of studies using the residual approach include: Newhouse (1992), Smith et al. (2009), Peden and Freeland (1998), Oliveira Martins and de la Maisonneuve (2005), Di Matteo (2005), van Elk et al. (2009)[15].

A second approach is the *proxy approach*, which uses a readily observable measure, or combination of measures, that is assumed to reflect the impact of technology. Examples include Okunade and Murthy (2002), where total R&D spending is found to be a long-run driver of per capita health care expenditures. Okunade and Murthy (2002) include both health R&D (sum of private and public) and total R&D as proxies for technological development; they find high income and "R&D" elasticities for the US. For example, Dreger and Reimers (2005) consider life expectancy, infant mortality and the share of the elderly population with respect to total population as possible proxies for medical progress. Gerdtham et al. (1998) consider the number of renal dialyses per million population

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[12] Smith et al. (2009) find a smaller effect of technology on healthcare costs. Technology accounted for around 20-30% of the total effect, rather than 40%. Okunade and Murthy (2002) find that both technology and income effects are important factors. More recent similar results can be found in Oliveira Martins and de la Maisonneuve (2005). On the other hand, Hall and Jones (2007) find that what really matters is income effect, given that healthcare can be considered a luxury good.

[13] Here we follow Kaiser (2007) and Dybczak and Przywara (2010)

[14] For a more complete critical review of the most common data problems in the literature see van Elk et al. (2009) pp. 10-14).

[15] van Elk et al. (2009, p. 17) write that "Researchers who allow for trends in real healthcare spending over time practically always find a positive trend despite the fact that gross domestic product is included as an explanatory variable [see OECD (2006)], Ariste and Carr (2003), Freeman (2003) and O'Connell (1996), where Roberts (1999) is an exception].

and find a positive significant effect. For the same set of proxies, Christiansen et al. (2006) find a positive effect also. A linear time trend is often included as well.

The case study approach analyzes the effect of a specific technology on the cost of treating a particular medical condition. These types of studies focus on the effects of specific new drugs or technologies and their contribution to the analysis of overall health care costs is thus limited. Other case studies focus on significant medical problems (usually selected according to prevalence rate, contribution to overall mortality or disability, etc.). Examples of such studies include Cutler and McClellan (2001) where the costs and benefits of introducing a new technology are compared for five selected conditions. Baker et al. (2003) compare for example ten selected technologies are to healthcare utilization and spending.

A related issue: is cost increasing technology worth?

In the first part of this section we argued that the majority of empirical studies find that technology has an important cost-increasing effect and, when added as an explicative variable, it usually reduces the explanatory power of income, transforming in some cases health care from a luxury to a more common normal good (i.e., with a decrease of income elasticity to values that are lower than 1). This phenomenon, of course, does not imply that technological change is not worthwhile. Technological innovation and diffusion are often successful and the rates of innovation and diffusion are particularly high despite the social cost that they may imply. Independently from important increases in the social benefits that many technological improvements imply and that can justify the adoption of high-cost technologies (standard reference on this point is Cutler and McClellan 2001) it seems, however, that there are important institutional arrangements that favor innovation and diffusion of new cost-increasing medical care technologies. For example, an important one is the coverage extension of new procedures and treatments by private and public insurance programs (Weisbrod 1991).

From voters' point of view, the demand for R&D can be regarded as an (indirect) demand for insurance under the moral hazard that new resulting technology will be somewhat covered through price subsidization or coverage extension. That is to say, such technologies are expected to reduce the health losses from diseases in much the same manner that other insurance does, given the expectation that such new technology will be somewhat subsidized or covered. As true of the demand for both public pensions and ordinary healthcare insurance, this demand will vary with income and age, because willingness to pay varies with income and the probability of being affected by a particular disease varies with age. If technology is such an important cost driver, then the question about what determines technological innovation and its cost-increasing/decreasing nature seems relevant. Technological progress is not an entirely random event and thus cannot be considered exogenous, but, to some extent, it is directed by R&D and by the process of accumulation of knowledge that makes possible the invention, introduction and diffusion of new drugs, medical devices and surgical procedures. Moreover, medical R&D is funded by government through subsidies and tax breaks.

4. From costs drivers to technological drivers; political concerns for quality, great expectations and technological imperatives

There are several instruments that the government can use in order to create incentives for public R&D. They may be tax incentives to particular regulations for the products of new technologies, support for universities. Research can also be managed directly by government agencies. Moreover, there are some peculiar aspects about why technology is so important in the US. For example, Noll and Cohen (1991), write about the notion of “American technological optimism” and add that “in the public sphere, technological optimism leads government officials to respond to a serious national problem by throwing technology at it” (Noll and Cohen, 1991, p. 1). More recently a narrower focus on the health care sector is Kling (2006) who writes about “premium medicine” rooted in the “American cultural expectations” (Kling, 2006, p. 11).

Noll and Cohen’s point is based on political concerns on quality and response to the public opinion great expectations from technological innovation. A more in depth and standard reference used here is Lewis Thomas (1975, 1977 and 1988). According to Thomas (1975) there are three different types of technology.

Non-Technology is supportive therapy neither aimed at influencing the underlying mechanisms of the disease nor at influencing its ex post evolution (at least in a relevant manner). It is very costly because it can be supplied only with time dedicated by doctors, other medical staff and families in order to assist patients in a disease that usually cannot be cured, but that implies high costs. The costly nature of this type of technology emerges also from a benefit analysis if we consider as a benchmark the impact of the treatment conveyed by the technology on the quality of life and its relative extension, which is usually low in those cases. Examples of non-technology are terminal cancer, severe rheumatoid arthritis, multiple sclerosis, stroke, advanced cirrhosis.

Halfway Technology is *ex post* technology adopted when it is not clear how to intervene in the process that leads to the disease; it is thus strictly related to curative medicine more that to preemptive medicine. It identifies that type of curative medical service that takes care of the illness after the symptoms are manifested. The definition used by Thomas may create some misunderstandings. It is true, this type of technology is called "high technology" in the physical sciences, but it may not be "high" in medical terms, because its results are expensive and complex, and often uncertain, on the benefit side. Thomas defines it at the same time as "highly sophisticated and profoundly primitive" (p. 38). Its use can be substituted or pre-empted by "*High technology.*" It usually attracts a great amount of public attention[16] and it is always presented as a pathbreaking problem solver. However, the reason why such technology is adopted is because a full understanding of the underlying mechanisms that lead to the disease has not yet been acquired. Moreover, "the only thing that can move medicine away from this level of technology is new information, and the only imaginable source of this information is research" (p. 39). Some examples are transplantations (heart, kidney, livers etc.), surgery procedures, etc.

The third type is "*High Technology*": this type of technology is the result of "a genuine understanding of disease mechanisms, and when it becomes available, it is relatively inexpensive, and relatively easy to deliver" (p. 40). It is the result of basic research and it allows healthcare supply to intervene in the disease at a stage where there are relatively low costs. Examples are vaccines. Thomas laments the absence of any kind of technological assessment for technology in the medical sector. Moreover, in order to contain healthcare costs, he concludes that priority must be given to basic research in biology. When there is a lack of knowledge of the mechanisms underlying the disease, the technology tends to be half-way and implies high costs.

In a related piece Thomas (1977) adds some evidence and elaborates on his previous point. This article is more a stock-taking of the results produced by R&D in the medical sector. He writes that, following the public's technological optimism, great expectations and technological imperatives, "medicine is expected to do something for each of these illnesses, to do whatever can be done in the light of today's knowledge. Because of this obligation, we have evolved "halfway" technologies, representing the best available treatment … but at a very high cost and with considerable waste resulting from overuse" (p. 303). The social and political demands imply that R&D is using on available knowledge in order to respond to the most pressing health problems of the day, though some understanding of the underlying processes of illness has not been completely reached yet. This demand leads to a shift of attention from basic to more applied R&D; using Thomas's jargon, from the

[16] Public opinion and public demand of ready-to-use technology plays, as shown later, an important role in Thomas's analysis as well.

production of high technology[17] to the production of halfway technology[18]. The shift of focus produces a shift in outcomes from preventive medicine to curative medicine. Preemptive medicine is in fact the result of basic R&D aimed at understanding the underlying mechanism of the disease. Preemptive medicine is usually both beneficial and cost effective. However, because that it is produced by basic R&D, it is more subject to longer waiting times and higher risk of failure than that of R&D. Curative medicine is aimed at recovery from an occurred illness. So it intervenes at a stage when the illness is already producing some damage on the health stock. It is not cost effective and has to be produced on the base of available knowledge. This also implies a misuse of current knowledge because it becomes essential for curative medicine to develop complementary technology that may be able to detect the illness at the very beginning. Diagnosis and other types of checks are in fact used as early warning tools only if they increase the effectiveness of available curative medical care. So we should add to the cost of curative technology also the complementary diagnostic technology that is developed to increase the efficacy of the cure.

In Thomas (1988) the author confirms the strong support for basic biomedical research as the "right" type of research that has to be done in order to increase the knowledge of the underlying mechanisms of disease and thus increasing the probability that high technology will be invented and used. So, why does half-way technology seem to be so important in medical technological innovation? The most important driver is the urge of usable results from medical research, in part conditioned by

[17] In Thomas's vision the final extent of high technology is a stage where the cumulative knowledge is able to produce effective and preventive – mainly prophylaxis medicine –- and not a curative one. Low cost and effective technology is able to intervene at early stages if not to guarantee a complete immunization of people from contracting the disease. Another point is more based on a cultural aspect and Thomas calls it the "cost of worry." It is the change of the public perception of its own well being. "The general belief these days seems to be that the body is fundamentally flawed, subject to disintegration at any moment, always on the verge of mortal disease, always in need of continual monitoring and support by health-care professionals. This is a new phenomenon in our society." (p. 312) "Underlying this pessimistic view of health is a profound dissatisfaction with the fact of death. Dying is regarded as the ultimate failure, something that could always be avoided or averted if only the health-care system functioned more efficiently. Death has been made to seem unnatural, an outrage; when people die? At whatever age we speak of them as having been "struck down," "felled." It is as though in a better world we would all go on forever." (p. 312). As soon as new techniques reveal the sources of illness and how to cope with them, people are invested by a new sense of responsibility about what can they do in order to delay as much as they can the moment of their departure from this world. People now can do much more to prevent illness and to recover from illness once it occurred, but often this awareness and the fact that "everything influences our health" implies at times an overuse of the system "swamped by expectant over demands for services that are frequently trivial or unproductive." (p. 315)

[18] Some data from the US Vital Statistics Report (10 leading causes of death in 1974) are reported in the article: the first five causes of death are: cardiovascular disease (39% of total deaths); cancer (19% of total deaths); cerebrovascular disease (11%); kidney disease (10.4%); pulmonary disease (4.5%). Non fatal diseases are also reported: acute respiratory infections; gastrointestinal infections; arthritis; neuroses and psychoses. For many of these Thomas explains that the medicine used is curative and not preventive. The reason, again, depends on the lack of explanations of the causes of those diseases.

little faith in long term biological research and on its potential to reach meaningful results in a not too far distant future. Empirical research on this aspect is quite recent. For example, Blume and Sood (2008) focus on the empirical analysis of the extension of Medicare program – part D on the R&D production process. [19] They find that coverage extension tends to shrink the R&D production process towards more applied research and development that can explain cost increasing technology, i.e. the share of clinical trials in Phase 4 of research projects increases. Given the importance of medical innovation for healthcare costs, surprisingly little research has taken place on the political economy of subsidies for medical technologies. This may be partly because the direct expenditure levels are relatively small and difficult to assess directly. However, the past few decades of technological advances have evidently increased healthcare costs far more than they have increased longevity. Dorsey et al. (2010) report that out of approximately a hundred billion dollars of expenditures on biomedical research in the US in 2007, thirty seven billion dollars of it was financed by federal, state, and local governments (taxes), with NIH accounting for about seventy percent of those expenditures. The paper analyzes the effect of subsidization on the R&D process.

Instead of high expectations and irrational optimism from the results of R&D, some authors argued that part of the cost increasing nature of technological innovation in the health care sector is induced by several types of "imperative." In particular, Lyttkens (1999) analyzes the demand for health care R&D under the restriction of a "professional imperative," according to which everybody sick should be given all possible care, regardless of the costs. This is not far from reality in a payment structure such as a third party payer mechanism. When neither the physician nor the patient bear the full costs of treatment there is an incentive to overuse medical care. This is particularly relevant in the case of retrospective payment structures, often used under public programs. A second factor is that the professional imperative is deontological in its nature (all possible care must by principle be given regardless of its outcome) rather than based on instrumental rationality. A third aspect is defensive medicine: this is particularly important in the case of supply-induced demand where professionals' utilization and supply of medical care is higher than the one they would have supplied if the information between patient and physician was symmetric. In this case, defensive medicine may be interpreted as an additional precautionary use of tests and scanning that stems from the overutilization of medical care. The physician may decide on a treatment or intervention exploiting the asymmetric information.

[19] Medicare Part D is a voluntary federal prescription drug program that provides subsidized outpatient prescription drug coverage for the elderly and disabled. This program was enacted as part of the Medicare Prescription Drug, Improvement, and Modernization Act of 2003 (MMA), and coverage began in January 2006.

Additional defensive medicine is then used in order to insure the good extent of that treatment or intervention that otherwise would not have been provided.

Second, there is a capital-biased imperative, i.e. the tendency to use too much capital in the supply of health care. This is given by the biased vision of the patient that good health care must be high tech health care. Technology is used as a proxy of good quality health care, given the insufficient information about the real quality of health care supplied. In developed countries capital dotation is often associated with higher productivity levels and thus this association is plainly translated into health care provision. High-tech health care is associated with high quality health care when the real quality cannot be directly observed; capital intensiveness is used as a proxy of good quality. Moreover, from the point of view of physicians, possessing high-tech technology and being able to use it in their daily work is a sign (and a signal) of competence, status, and skill.

Finally, there is a health imperative: the relationship between health care and welfare (in terms of standard cost benefit analysis) is biased towards health-status increasing technology versus a cost decreasing one. Would a technology that increases net benefits, but through a slight decrease of benefits associated with a more relevant decrease in costs, be adopted? It is difficult to believe that such a technology would be socially and politically acceptable and R&D would not "bet" on those types of technology (what demand would they have?), and thus it would be focused on benefit-increasing technologies. This is not only true in terms of increasing benefits for a given targeted group that may lead to an inefficient use of health care. It is also true in terms of the extension of a given new treatment to groups whose marginal benefit impact of the new treatment is lower, but still positive. In general, the health imperative deals with the use of alternative technologies implying a bias toward benefit-increasing more than cost-decreasing technologies.

Zweifel et al. (2007)[20] extend Lyttkens's model in a more micro-founded framework and take into account several types of innovations (product, process, organizational). Their basic setting is again the analysis of the trade-off between current consumption and improved health care in the next period.

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[20] There are additional "imperatives" that influence the allocation of innovative activity. One is the professional/medical imperative. Zweifel distinguishes between medical imperative at the level of objectives and medical imperative at the level of means. The first implies that $\frac{\partial u_2}{\partial H_2} \leq \bar{u}'_2$. An increase in H_2 lowers the requirements from technological innovation and calls for increases in innovation and medical expenditures. The second (medical imperative at the level of means) regards the value $\frac{\partial H_2}{\partial m_2} = (g^p g^q g^o) \frac{\partial h_2}{\partial (g^p g^o m_2)} \leq \bar{H}'_2$.

Again, the utility function is $u = u^1(c^1, H^1) + u^2(c^2, H^2)$. But now the model goes more in depth and formalizes process product and organizational innovation. We skip the technical details of optimization, and state the main results:

i) The required improvement in health in the second period produced by innovative effort will be higher the more is the loss of utility generated by foregone consumption in the first period. The required improvement is conversely less important when improvement in health status has an overriding importance in terms of increase in utility (large $\frac{\partial u_2}{\partial H_2}$).

ii) The required improvement in health status to be achieved in the second period is lower for organizational innovation than for the other two types of innovation. This is because organizational innovation has effects also in the first period.

iii) There is interdependence between the three optimal criteria.

iv) The theoretical model requires that an individual would demand the same improvement of health for each dollar spent in product or process innovation. However, Maynard (1991) shows some evidence that process innovations must usually satisfy more stringent criteria than product innovations.

v) Insurance lowers the benchmark for all three possible innovations because it reduces the loss from foregone consumption in period one. Patients do not have to pay the full cost of innovation if there is insurance. The general lowering of the requirements to be satisfied by innovation induced by insurance implies a boost in innovation. However, at the optimum, medical insurance lowers the value of expenditures for the patient and this implies higher requirements in terms of process innovation (lower r^p), but leaves constant the requirement for product innovation.

5. A simple model of the demand of R&D

We model R&D in a one period framework and consider health care exogenous. The expected utility function will be the following:

$$E(u) = (1-\pi)\, u^G(y - \Psi r, H^G) + \pi\, u^B\big(y - \gamma h - \Psi r, H^B(h, \Theta(r))\big) \qquad [1]$$

This is a state dependent utility function where G (Good) and B (Bad) indicate the two possible states of the world. With probability $(1-\pi)$ the consumer will face the good state and will incur a monetary loss identified by monetary expenditures for R&D. The actual consumption will be income y minus the monetary expenditures in R&D (r) times R&D's price, Ψ. In the bad state, which occurs with probability π, the consumer will spend money for health care consumption (h * ϒ) and for health care R&D. Note that the expenditure in health care R&D is not conditional to state occurrence. In the sick state, utility is state dependent. It depends on the health status' level $H^B < H^G$ after sickness occurred. Health status can be partially restored through health care h consumption, or through technological innovation Θ driven by health care R&D. We make standard assumptions about the concavity of utility function ($u_c > 0$ and $u_{cc} < 0$ in both states G and B) and about the effects of health care and technology driven by R&D on health status when sickness occurs. In particular the following assumptions seem quite intuitive: $H_h > 0$, $H_{hh} < 0$, $\Theta_r > 0$, $\Theta_{rr} < 0$, $H_\Theta > 0$, $H_{\Theta\Theta} < 0$, finally $H_{h\Theta} > 0$. The interpretation of the last assumptions states that an increase in technology has a positive effect on the marginal impact of additional health care consumption on the health state.

The first order condition follows:

$$F_r = \frac{\partial E(u)}{\partial r} = -\Psi\,(1-\pi)\, u_c^G(y - \Psi r) - \Psi\,\pi\, u_c^B\Big(y - \gamma h - \Psi r, H^B(h, \Theta(r))\Big) + \pi\, u_H^B\Big(y - \gamma h +$$

$$-\, \Psi r, \alpha h, \Theta r\ H\theta Bh, \Theta r\ \theta r(r) = 0 \qquad [2]$$

The FOC implicitly defines the demand for R&D $\overset{*}{r} = r(y, \pi, h;\ \Psi, \gamma)$[21]. We assume that an interior equilibrium exists. Throughout the comparative static section we avoid useless notational complexity and omit the use of whole formula derived from the application of the implicit function theorem. Given that (-SOC) is positive, the sign of the comparative static effects clearly depends on the signs of the cross derivatives that appear as numerator.

The income effect will depend on the formula

$$F_{ry} = -\Psi\,(1-\pi)\ u_{cc}^{G} - \Psi\,\pi\,u_{cc}^{B}\ +\ \pi\,u_{cH}^{B}\,H_{r}^{B} > 0 \qquad [3]$$

and it is unambiguously positive. In an insurance type model R&D is a normal good. The interpretation is that, as income increases, the marginal loss from foregoing consumption for R&D in both states decreases. This effect adds to the increase in health state implied by R&D in the sick state. As soon as the consumer becomes richer it costs her less to forego consumption for R&D and moreover R&D helps to recover my health state when I'm sick.

The morbidity's (π) sign depends on two separate effects.

$$F_{r\pi} = \ \Psi(u_{c}^{G} - u_{c}^{B}) +\ u_{H}^{B}\,H_{\theta}^{B}\theta_{r} \qquad [4]$$

The second term is unambiguously positive and shows that with increasing morbidity the benefits from R&D investment increase. However, the effect on the marginal costs from R&D is indecisive and depends on utility state-dependence. The first term may in fact be positive or negative depending on the difference between the marginal utilities in the two states. If $u_{c}^{G} -\ u_{c}^{B}\ \geq 0$ we have negative/null state dependency (i.e., the marginal utility in the healthy state is higher than the marginal utility in the sick state) and the final effect is positive. With positive and strong state-dependence, $(u_{c}^{G} < u_{c}^{B})$ the effect is negative.

The own price effect is clearly negative

$$F_{r\Psi} = \ -\left((1-\pi)\ u_{c}^{G} +\ \pi\ u_{c}^{B}\right) +\ \Psi^{2}\left((1-\pi)\ u_{cc}^{G} + \pi\ u_{cc}^{B}\right) - \Psi\,\pi\ u_{cH}^{B} < 0 \qquad [5]$$

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[21] Note that the SOC holds and it will be: $\Psi^{2}(1-\pi)u_{cc}^{G} +\ \Psi^{2}\pi\,u_{cc}^{B} -\ \Psi u_{cH}^{B}H_{r}^{B} + \pi\ [u_{cH}^{B}(-\Psi) +$ *uHHBHθBθr HθBθr+ πuHBHθθBθr+ πuHBHθBθrr<0.*

$$F_{r\gamma} = \Psi\gamma\,\pi\; u^B_{cc} - \gamma\pi u^B_{cH}\alpha_r = \pi\gamma\,(\Psi u^B_{cc} - u^B_{cH}\alpha_r) < 0 \qquad [6]$$

An increase in health care consumption has no clear sign too.

$$F_{rh} = \Psi\,\pi\;\gamma u^B_{cc} - \Psi\,\pi\gamma\, u^B_{cH}\,\alpha_h - \pi\gamma u^B_{cH}\alpha_\theta\theta_r + \pi\; u^B_{HH}\alpha_h\alpha_\theta\theta_r + \;\pi\; u^B_H\alpha_{h\theta}\theta_r \qquad [7]$$

Finally (equation [8]), the effect of an increase in health care implies that the equilibrium level of R&D is lower. This fact can be explained by recalling that in an insurance model, optimality requires a tendency towards the equalization of marginal utilities between states. The simplicity of the model defines health care and health care R&D as complements because both contribute to an increase in the marginal utility from consumption in the sick state. A rise in the price of health care implies an increase in the marginal utility from consumption in the bad state and R&D must be reduced in order to restore marginal utility at the equilibrium level. This is undoubtedly a “strong” result and an argument about the existence of some sort of substitutability can also be advanced. When health care becomes too costly then there are incentives to increase R&D to find cheaper and/or more effective solutions.

$$F_{r\gamma} = \Psi\gamma u^B_{cc} - \pi\gamma\; u^B_{cH}\alpha_\theta\theta_r < 0 \qquad [8]$$

6. Empirical Section

The empirical strategy is based on a linear specification in order to test the expected signs from the theoretical model. At this preliminary stage of the research we present some basic OLS results. The model specification is the following:

$$R\&D_{tj} = \beta_0 + \beta_1 \underbrace{INC_{tk}}_{+} + \beta_2 \underbrace{OWNPRICE_t}_{-} + \beta_3 \underbrace{MORBIDITY_t}_{+} + \beta_4 \underbrace{HCARE_t}_{+/-} + \beta_5 \underbrace{HCAREPI_t}_{-} +$$
$$+\beta_6 R\&D_{t-1j} + \beta_7\, trend + \boldsymbol{X\alpha} + \varepsilon_t \qquad [9]$$

t is a time index and j several measures for health care R&D like public/private/total or measured in terms of patents or financial expenditures. k can be average or median income. X is a matrix of additional controls. We run three different models (Results are in Tables 1 to 3) and change the dependent variable in total HC R&D, in its private component and its Federal component. We use the lagged values for each of the three aggregates in order to control for autoregressive dynamic and in each regression we took into account a common linear trend. Durbin-Watson statistics are used in order to evaluate the presence of autocorrelation and Prais-Winsten correction was applied when needed. The results change depending on the aggregate used as the dependent variable. Financial aggregates (health care and health care R&D) are log transforms of the real values per capita. So the interpretation of the coefficients are elasticities.

Table 1 shows the results obtained regressing the total amount of Health Care R&D expenditures on the various controls chosen in order to measure the magnitudes of the independent variables in the model. The income elasticity is in general lower than the one usually obtained in health care expenditures and qualify R&D as a normal good. The own price effect has the right sign, but it is never significant. The coefficient on morbidity is negative, but not significant. The other significant variable is the price index of medical care. However, we obtain the opposite sign than the one predicted by the model. Other controls added to test an institutionally augmented form are not significant. These results are really similar to the ones obtained when regressing only the public part of R&D.

Table 1 – Tot HC R&D

V Dep tot real hcrd	(1)	(1')	(2)	(2')	(3)	(4)	(5)
INC (+)	.5572732**	.4999236*	.6112739**	.5126109*	.5057527*	.4915112*	.486237*
OWNP (-)	-.230732	-.2614209	-.2590008	-.2740898	-.2639936	-.264083	-.2695444
MORB (+/-)	-.0031079** (1)	-.0027094*	-.005659 (2)	-.0043633 (2)	-.0028903(1)	-.0037051 (1)	-.0024783 (1)
HCARE (+/-)	.2877623	.221426	.1744676	.1054609	.2586194	.2696285	.1817606
HCAREPRICE (-)	.3654111**	.3440498*	.3938717	.3454147	.3493791*	.3539358*	.3454498*
Rd(-1) (+)	.6430083***	.6231242***	.6226886	.5994293	.6002808***	.595569***	.6072127 ***
Trend (linear) (+)	-.0302105**	-.0233501	-.0281796	-.0187541	-.0165517	-.0237289	-.0198839
Dep. Ratio					-.9219602		
D/R						.0017703	
mean/median							-.228093
R^2	0.9861	0.9750	0.9857	0.9715	0.9753	0.9750	0.9741
DW	1.62	1.91 (pw)	1.57	1.919041	1.909645 (pw)	1.919476 (pw)	1.904836(pw)
N	46	46	46	46	46	46	46

Table 2 – Public HC R&D

DEPVAR: real public hcrd	(10)	(11)	(12)	(12')	(13)	(14)	(15)
INC (+)	.6428634**	.5908701**	.6991799**	.6149954**	.645768**	.6920319**	.680995 **
OWNP (-)	-.3614225	-.3854195	-.3984505	-.4128986	-.3639931	-.3954728	-.4146045
MORB (+/-)	.3867081 (1)	-.0029357 (1)	-.0057057** (2)	-.0046702 (2)	-.0034222	-.0054291	-.0053033
HCARE (+/-)	.3867081	.3274707	.2607716	.2033323	.4102863	.2953634	.2153513
HCAREPRICE (-)	.4604432 **	.4414405*	.4792221**	.4433261*	.4642966**	.482276**	.4866993 **
Rd(-1) (+)	.6516984***	.6309614	.6399585***	.6130122***	.6528585***	.6256059***	.6239959***
Trend (linear) (+)	-.0344243	-.0284482	-.030614	-.0229538	-.0352142	-.0309285	-.0264338
MEDICARE	.0466272	.0450552	.0606698	.0569184	.0461753	.0609756	.0612836
Dep. Ratio					.1593917		
D/R						.0010502	
mean/median							-.352076
R^2	0.9791	0.9648	0.9785	0.9603	0.9788	0.9785	0.9786
DW	1.673004	1.899667 (pw)	1.62787	1.907589 (pw)	1.62492	1.619913	1.619095
N	46	46	46	46	46	46	46

*, **, *** represent 10, 5 and 1% significance respectively. (1) Male mortality rates used; (2) Female mortality rates; (pw) means that Prais-Winsten correction for autocorrelation has been applied. R&D (public and private HC R&D have been partialled out from the total HC expenditures).

7. Conclusion

Rising health care costs have long been an important subject of study. In this paper we reviewed some important facts about health care expenditures (total and public) and about technology and R&D in the US. Technology is widely acknowledged to be an important cost driver. However, technological change is endogenous to decisions about health care R&D. Public health care R&D funds represent an important share of the total expenditures on R&D. We reviewed some of the literature about the political incentives that direct R&D towards curative more than preemptive medicine. And, usually, curative medicine is more cost-increasing than preemptive medicine. We propose a model of demand of health care R&D in an insurance framework. While the traditional model of insurance characterizes an income stabilization mechanism that operates through income transfers between states, R&D in this context shows a similar function, but benefits in the sick state are not provided through income stabilization, but through quality improvements made possible by foregone consumption in both states. We tested this model using time series data for the US for the period 1960-2006. Preliminary results show that R&D is a normal good. While the model characterizes health care and health care R&D as complements, empirical evidence seems to suggest that they are substitutes. Augmenting the model with variables such as the age dependency ratio, the ratio of Democratic to Republican seats and the ratio of mean to median income doesn't seem to add insights. However the empirical results are very preliminary and should be considered with caution.

Data sources and descriptive statistics

VAR	Source Description
HC R&D	Data on HC R&D expenditures are from National Science Foundation and OECD health dataset
INC	Data on income are from PENN World Tables
OWNP	The own-price index is the series on the biomedical research and development price index BRDPI
MORB	Mortality rates (male and female) are from World Bank – World Development Indicators
HCARE	Health care expenditures are from the National Health Expenditure Dataset
HCAREPRICE	The Medical care price index is from the Bureau of Labor and Statistics
Dep. Ratio	The dependency ratio is calculated (0-14 pop + 65 pop)/(tot pop) and data are from OECD health dataset
D/R	Democratic to Republican Congressional Seats
mean/median	Ratio of mean to median per family incomes are from US Census

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