EDUCATION AND HEALTH IN THE OECD:

A Macroeconomic Approach

Cecilia Albert (UAH) and María A. Davia[1] (UCLM)

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Abstract

The aim of this paper is analyze the determinants of health from a macroeconomic perspective, paying particular attention to the role of education attainment in the determination of health. We construct a time-series cross-section data base with economic and non economic variables for 30 OECD countries which covers information form 1960 to 2003. We have estimated several specifications of a health production function adapting Grossman's human capital model to a macroeconomic approach. Results show that education has mainly a long-term impact on health; its effect remains in the presence of very relevant inputs in the health production function, such as income and expenditure on health, but fades away when other inputs (habits and other health resources) are present in the health production function.

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1. Introduction

Education and health are two forms of human capital. Governments are interested on how (and how much) to influence both of them in order to improve welfare. The main difference between these two types of human capital is that education increases productivity both in market and non market activities, whereas health determines both the quantity and the quality of time available for market and non market activities (Grossman, 1972). This difference may lead to the conclusion that investment on health services may be a priority versus investing on schools, since productivity may not increase if no healthy time is available. We might even say that education investments are not possible without health investments; without "healthy time" there are no possible increases in productivity. Even if this were true, it is worth wondering whether it is possible to improve health indicators in a country by increasing the educational attainment of its population. In order to answer this question we must be able to empirically demonstrate that *there is* a causal link between education and health. Several pieces of work, most of which use microeconomic databases, have tackled this problem (See Grossman, 1999 for a very interesting survey of many of them).

Papers from a macroeconomic approach are but a minority in this literature. This is, among other things, due to the lack of harmonised time series across countries of both independent indicators for health indicators and its determinants until very recently (Or, 2000). The aim of this piece of work is contributing to this strand of the literature analysing the effect of education on health from a macroeconomic perspective. Specifically, in this paper we estimate macroeconomic health production functions for 30 OECD countries since 1960 to 2003. For the sake of consistency we have estimated health using two different proxies: life expectancy and what we will call "potential years of life lost due to health problems". Our explanatory variables are

economic factors (income), public and private effort -expenditure on health- and some proxies of healthy lifestyles and, last but not least, the educational attainment indicators (school expectancy and percentage of university graduates in the adult population).

The nuance we add to previous literature is precisely the focus on educational attainment amongst the determinants of health. In order to add this variable we have merged two sources of data: we have taken education variables (school expectancy and percentage of university graduates in the adult population) from UNESCO yearbooks[2] since the sixties, and we have combined them with the OECD Health Database 2005. Merging information on education in the OECD-HD2005 offers a great opportunity to contribute to the literature on this issue, both from Economics of Education and Health Economics fields.

We have estimated an Error Correction Model (hereinafter, ECM) in order to determine the effect of education and income on health both in the short run and in the long run in the presence of several other inputs. The ECM has been complemented with the inclusion of fixed effects (a country-specific dummy variable), which allows us to control for the idiosyncratic time-invariant characteristics of every country. By estimating the ECM with fixed effects we control for non stationarity of both dependent and independent variables and unit heterogeneity. Moreover, we also control for panel heteroscedasticity and horizontal correlation by applying panel corrected standard errors (PCSE) to the OLS estimation of the model instead of the usual OLS standard errors. All these details will be fully explained in the methodological section.

This piece of research outstandingly confirms that the most important determinant of health status across countries is education, even in the presence of income and other variables, although its relevance tends to fade when other determinants, such as expenditure and (un)healthy habits are included in the model. This result remains despite the variable used to approach health (life expectancy and

[2] Data on education attainment in Canada has been obtained directly from the Canadian Censuses and only for 1981-1996 due to difficulties to link data from different yearbooks in UNESCO.

potential years of life lost) and education (school expectancy and percentage of university graduates in the adult population). This is a remarkable result and confirms evidence already obtained with microeconometric databases.

The paper goes as follows: after a review of the empirical literature and some hints about our theoretical framework we will introduce the data-set and the methodology used. Section 6 summarises the main results and section 7 concludes and points at some further work to be done in the near future.

2. Theoretical framework

The idea that activities that enhance human productivity are a way of investment coined the concept of "human capital". This concept stems from Theodore W. Schultz's speech in the 1960 annual meeting of the American Economic Association. The application of Irving Fisher's concept of capital to human beings moved Gary Becker (1962) to take ability and knowledge as a way of capital which is the result of investment in education. Ten years later Michael Grossman (1972) was a pioneer in the study of health in the framework of the already well known human capital theory. He was particularly concerned about explaining the link between both basic types of human capital: health and education. In his model, education plays a crucial role in the demand for health since it contributes to the efficiency in the self-provision of health. Grossman's point of view has a counterpoint in Victor R. Fuchs (1982), who also points to the striking correlation between number of years of schooling and mortality, in particular for the United States. Yet he would not explain this correlation on the basis of *any* human capital argument, but on the correlation between education and preference for the future.

It is important to devote some time to the different individual motivations to invest in different types of human capital: physical capital, education and health. The only reason to invest in physical

capital is economic in nature. The decision to invest in education is only partially economic in nature; a person may value education not only because it contributes to future income but also because it contributes to present enjoyment of knowledge in itself.

Having a good health status increases productivity, but this fact is not very relevant when agents make decisions about their own health or their relatives, since health is valuable in itself. Non market aspects of health are more relevant than market aspects (Weil, 2005). This feature of health is present in part of the empirical literature in human capital and economic growth. The same literature has paid attention to difficulties to made health and the externalities of investments in health.

The positive link between education and health is due to the fact that education may influence several of the individual decisions that may determine "quality of life". For instance, education may affect the selection of occupation and type of job, ability to select adequate diets and healthy habits, not to mention efficiency in the use of health care resources. The relation between education and health is endogenous, either because one determines the other or because education and health are determined by a common set of unobservable variables. This explains for the efforts devoted to seeking an instrumental variable that enables the empirical contrast of the connection between health and education. This requires paying attention to the links between health and income on the one hand and education and income on the other hand.

Beyond doubt, the link between education and health is very influenced by the relation between both variables and income. The empirical literature on economic growth considers health as one of the most important factors. This is something that Grossman (2005) has observed as an empirical generality: "Multicollinearity and autocorrelation problems in this type of studies make coefficients in key variables instable and only a few variables are always significant in the explanation of economic growth, with health being amongst them". The

well known specialists in economic growth theories Barro and Sala-i-Martín (1995) find that a 13 years increase in life expectancy would lead to a 1,4% increase in the rate of economic growth. The economic historian Robert Fogel (1994) estimated that health and nutrition improvement accounted for about 30% of Britain's income growth rate or about 1.15% per capita per annum in the 200 years from 1780 to 1990. This resulted from the confluence of two factors: an increase in both the number of available persons for work and the effort they could make. From a different point of view, Acemoglu *et al* (2001) consider that differences in income between rich and poor countries are due, amongst other things, to the institutional context that make differences in health among rich and poor countries persistent. Since institutions tend to perpetuate differences in health, even if differences in income were eradicated, poor countries would be less healthy than rich countries.

Empirical evidence in the opposite direction, i.e., with macroeconomic conditions and cultural factors being determinants of health mostly consists on studies focused on developing countries and usually linked to international institutions, such as the World Bank, the World Health Organization and the OECD. One example is Or (2000) who computes a health production function with the OECD Health Data files in the 2000 edition. He is provided with information from 1970 to 1992 for 21 OECD countries. His research objective is finding evidence on the effect of medical and non medical resources, social and economic factors and life-style indicators on health. He estimates a health production function where the dependent variable is potential years of life lost and the explanatory variables are per capita GDP, total and public expenditure, alcohol, fat and sugar intake, and consumption expenditure on tobacco. Among the inputs in the health production function he includes an indicator of labour force qualifications: the proportion of white collar workers in total workforce, which turns out to be the most significant variable in his fixed effects panel estimates. The main difference with the present piece of work lies

in our independent indicators for educational attainment; we explore the influence of two "direct" indicators of educational attainment[3] on health (the outcome of the health production function). Moreover, Or's estimations do not deal with non stationarity of dependent and independent variables, whereas we do take it into account with the applied modified version of the Error Correction Model. Finally, In using panel corrected standard errors instead of OLS we also control for horizontal heteroskedasticity.

Rhum (2002) is another piece of work adopting a macroeconomic perspective. He uses aggregate data for 23 OECD countries from 1960 to 1997. His aim is to show that, unlike the previous results in the literature, health status is countercyclical, since during economic downturns agents have more time to devote to health care. He takes several health status proxies, namely, the total mortality rate and deaths from nine leading causes as cancer, accidents or suicides. The methodology is based on weighted least squares, using the square root on national population as weights in order to control for heterogeneity. The main result of that piece of research is that economic downturns have negative effects on physical health. But, unlike the present work, it does not explicitly include any education indicator. Ruhm did include education attainment indicators in different papers (2000 and 2005), where he developed a similar strategy, but this time using U.S. databases[4], so that his results are not comparable to ours. Even though these papers are not focused on the particular impact of education on health, it is still worth mentioning Rhum obtains in them a positive impact of education on the health outcome estimated.

We try to enrich the above outlined evidence adopting the most standard approach to this problem: the human capital model or the production function of health in a reduced form of a structural model. The main contributions to this approach are based on microeconomic

[3] Namely, the proportion of university graduates among the adult population and school expectancy.

[4] He uses the *Behavioral Risk Factor Surveillance System* in 2000 and the National Health Interview in the 2005 paper.

models and evidence, and here we translate them into macroeconomic models. According to this model, health is one of the best known non monetary returns to education (see Grossman, 2005 for a review of the literature on non monetary returns to education, health-related ones included). We base our empirical contribution on this theoretical framework and try to explain health outcomes at an aggregate level by the education achievements of the population, in the presence of macroeconomic conditions (particularly income and expenditure) and other indicators. Moreover, our estimations control for unobserved individual heterogeneity, which accounts for country specificities dealing with institutional and cultural aspects that we cannot explicitly include in the specification of our model and/or are time invariant.

3. The data and some initial descriptive analysis

The OECD-HD2005 is a very interesting tool for the analysis of the relation between income, education and health. This is due to the availability of long series (the longest ones comprise from 1960 to 2003) of relevant variables[5]. We show here two health indicators life expectancy for both genders and number of years of life lost for every 1000 in habitants (under 70 years old) due to health reasons[6].

Unfortunately, the variables related to education attainment of the population are available in the OECD-HD2005 for the period 1989-2003 only. In order to get as much advantage as possible of the long series in the rest of variables, we have added two series of education attainment from UNESCO statistical yearbooks up to 1999; they are available online since then. We have withdrawn two human capital indicators from them that had been registered at censuses every decade[7] since

[5] A more detailed explanation of what is the OECD-HD2005 and its structure may be found in www.oecd.org.

[6] These are all the reasons for death except what it is called "external reasons". These are deaths due to traffic accidents and fatal accidents in general, suicides, violence and crime, secondary effects from drugs or complications during medical treatments.

[7] Since censuses are not published simultaneously in all countries, we had to look up the relevant information in all yearbooks from 1960 up to 1999. Educational attainment from censuses is available in UNESCO web page since 1999.

1961: proportion of population over 25 years old with tertiary education attainment and school expectancy (number of years expected in the education system under the current conditions, i.e., coverage levels). Given that these data were gathered every ten years, we have made use of interpolations for the years between censuses. We have in this way completed the long series we needed to perform our long-term aggregate health production functions.

In the production function we use information about national income as a control variable. We have tried two proxies for this variable: per capita GDP and labour productivity. We also include an set of indicators of resources devoted to health such as public and private expenditure on health as a percentage of the GDP, per capita (public and private) expenditure on health, number of working doctors per 1000 inhabitants, and average acute care bed days (we have chosen them because they are the most expensive ones). At last we also include information on food consumption, such as total fat intake, fruits and vegetables, total protein, sugar and alcohol intake and proportion of adult daily smokers. These are inputs that may be proxies of (un)healthy behaviour or lifestyles.

Table 1 displays the number of valid cases in the main variables of the data-base as an average over the period (1960-2003). It shows that the number of valid observations varies a lot across countries[8], which means that the more covariates we will include in the models, the more missing values will affect the quality of the estimations. The dependent variables of the models (health indicators) and the main explanatory variables (national income and the human capital indicators) have something more than 1100 observations each, and the same applies to variables relative to nutrition. As we introduce other variables, such as public and private expenditure, number of doctors and length of stay in intensive care units the samples will get smaller. Some variables are particularly incomplete: unemployment rates and proportion of smokers

[8] Abbreviations for country names in the text are official short names in English as given in ISO 3166-1.

are not available in almost any country until 1982. And there are many missing cases in average number of visits to doctors per person as well. We have interpoled missing values when valid previous and later values in the series where available at a reasonable distance.

Table 1A in the appendix table displays average values of all the variables for every country along the period 1960-2003. We will only mention here the extreme values of the key health and education indicators. Life expectancy does not vary very much across countries, with the exception of Turkey (60 years), which remains well below the rest. Japan, Norway and the Netherlands enjoy the highest life expectancy, near 76 years in average along the observation period. As for potential years of life lost due to health reasons for every hundred thousand inhabitants[9], the huge figure of Mexico (11142) is far above the rest. The second country affected by health problems is Portugal, well behind (8194). As for the healthiest country, according to this way of measuring health, Sweden holds the first position (3561 years lost per 1000 inhabitants), followed by Iceland (3704) and Norway (3793). As for the education indicators, Turkey (5.44) and Mexico (8) register the lowest school expectancies and Denmark (17) the highest. When measured through proportion of adults with higher education, we see again in Turkey the lowest values (2%), very low values as well in Italy and Portugal (around 5%) and, in the opposite extreme, Canada (29) and Denmark (24).

[9] As Or (2000) explains, for each country *i* and for each year *t*, the standardised PYLL (expressed per 100000 population) is calculated as follows:

$$PYLL_{it} = \sum_{a=0}^{l-1} (1-a)\left(\frac{d_{at}}{p_{at}}\right)\left(\frac{P_a}{P_n}\right) * 100000$$

where *a* stands for age, *l* is the upper age limit chosen for the measure (in this database, 70), *da* is the number of deaths at age *a*, *pat* refers to the number of persons aged *a* in the reference population, and *Pn* refers to the total number of persons aged 0 to *l*-1 in the reference population.

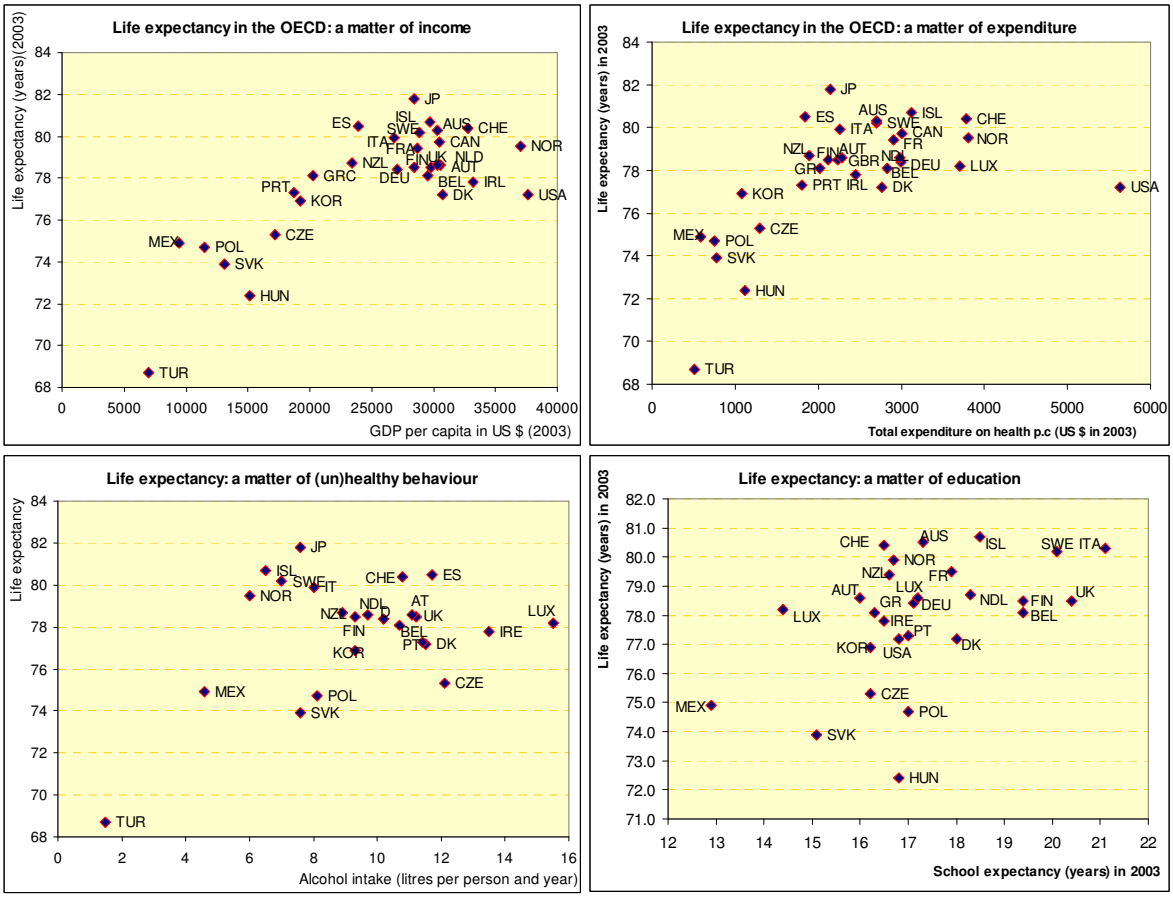
Table 1. Overall Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	Few observations in
Year	1320	1981.5	12.70324	1960	2003	
Life expectancy	***1309***	***73.02***	***4.68***	***48.3***	***81.8***	
Years lost (000)	***1137***	***5249.01***	***2307.19***	***1773***	***18431***	AUT, ITA, RCH, RSV, TUR
School expect.	***1146***	***11.39***	***4.31***	***0.7***	***21.1***	***DIN, LUX***
Higher education	***1166***	***13.08***	***9.18***	***0.1***	***48***	***DIN, LUX, TUR***
Real GDP	1142	14278.88	6281.76	1570.89	44008.5	RCH, RSV
Real GDP/worker	1108	31812.56	12675.35	4470.84	103135.5	GER, POL, RCH, RSV
PIB per capita	1187	11498.12	9065.59	498	53828	HUN, POL, RCH, RSV
Unempl. rate	600	7.33	4.24	1.2	23.9	Generalised lack of data up to 1982
Expense on health as a % of GDP	1000	6.82	1.97	1.5	15	HUN, ITA, MEX, POL, RCH, RSV
Public expend p.c.	937	738.76	624.93	9	3367	BEL,HUN,ITA,MEX,POL,RCH,RSV,CHE
Private expend p.c.	945	277.89	346.91	7	3131	BEL, HUN,MEX, POL, RCH, RSV, CHE
Doctors per 1000	1008	1.98	0.81	0.3	4.4	GER,ES,IRE,ITA,MEX,RSV
Visits to doctors	688	5.56	3.13	1	15	GER,BEL,ES,USA,HUN, IRE, ITA, NOR, NZL, RSV, CHE
Length of stay ICU	1018	17.26	10.16	4	58.1	GER, MEX, UK, RSV
Fat intake	1154	119.22	28.78	14.3	170.8	LUX, RCH, RSV
Protein intake	1154	96.87	11.50	55.7	139.7	LUX, RCH, RSV
Sugar intake	1154	41.30	11.23	1.6	71.9	LUX, RCH, RSV
Fruits and Legumes intake	1154	187.60	68.18	50.9	458	LUX, RCH, RSV
Alcohol consumpt	1207	10.11	4.02	0.8	22.6	KOR, GR, MEX, RCH
% of smokers	696	32.82	8.19	17	61	generalised lack of data up to 1980
Number of countries	30					

The remaining of the section shows a series of figures intended to reflect the relation between health and education, income and inputs in the production function (namely, health expenditure and healthy habits). Panel 1 is made of four graphs (1A, 1B, 1C, 1D) showing these links in 2003. A simple cross-section of the data may show that countries with a higher level of income and a higher expenditure on health are those with a higher life expectancy. The correlation is not so clear for the proportion of smokers. Something similar, but less clear, happens as regards our education indicator. A certain level of positive correlation between education and health is noticeable although with a significant dispersion across countries. For instance, Poland and Austria register similar school expectancies but very different life

expectancies. Hungary is a worth mentioning case for having an average school expectancy but a low life expectancy.

A similar pattern may be found for the variable "potential years lost" but it is not shown here for space reasons.

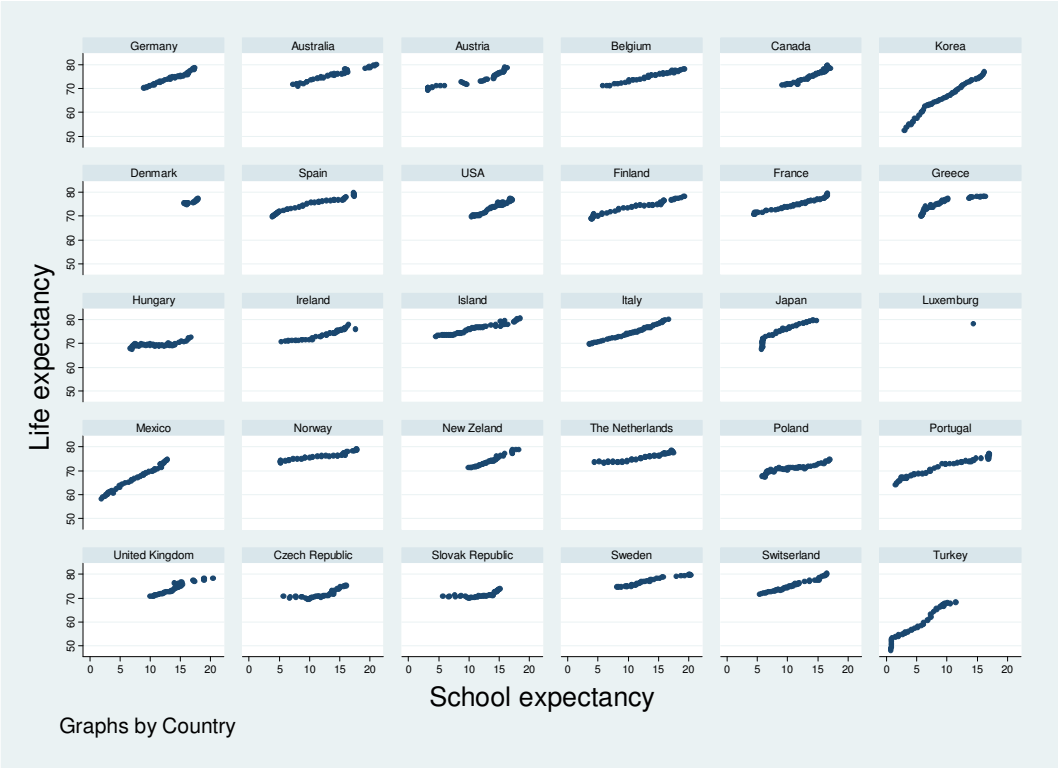


Panel 1. Scatter plots of per capita income, per capita expenditure, *per capita* consumption of alcohol and school expectancy on life expectancy.

In order to confirm different patterns across countries we have observed this relation between education and health along the observation window. Figures 2 and 3 consist on two sets of scatter plots for evolution of both education and health indicators at an aggregate level. In Figure 2 we may see that there is a positive link between health and education in all countries, although the intensity of the relation differs across countries. The correlation is particularly outstanding in Korea, Turkey and Mexico. These three countries are precisely the ones which have experienced the most pronounced advancement in their improvement in education attainment. In the

remaining, more developed, countries the relation is still positive, but smoother.

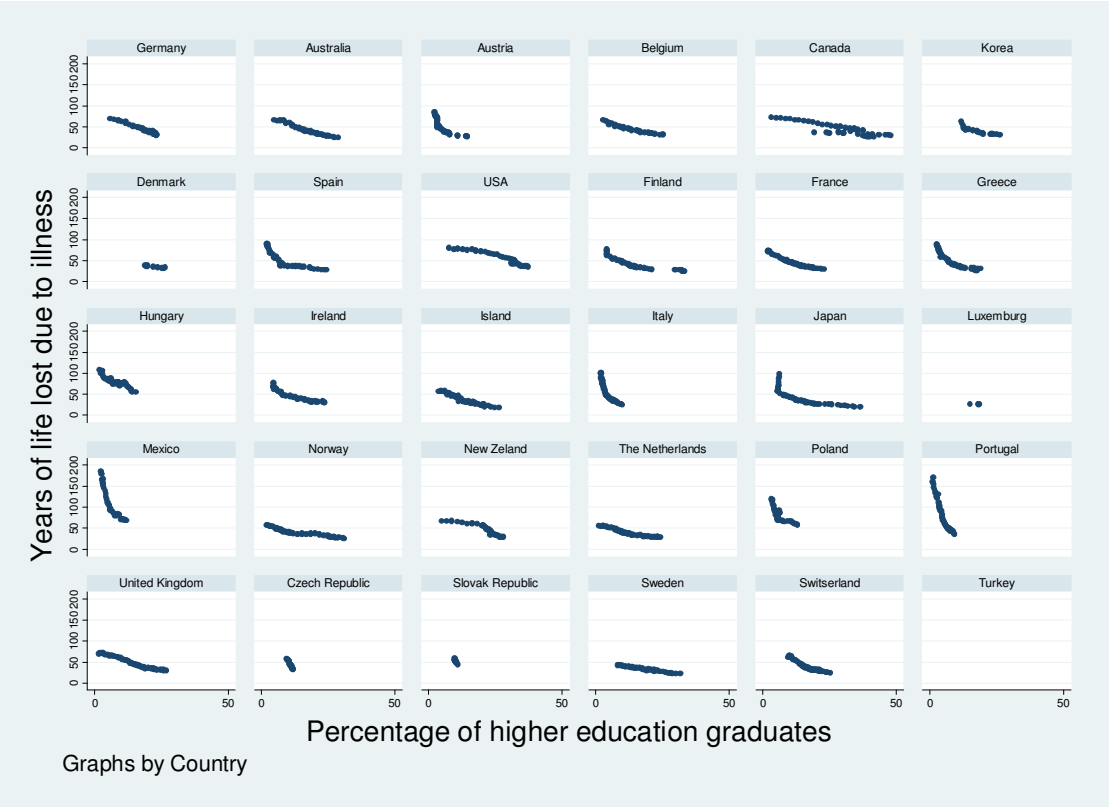
Figure 2. Scatter plot over pooling of waves, by country: school expectancy against life expectancy.



In Figure 3 we look at the same correlation, this time based on two different variables. As a health indicator we have used the number of years of life lost by every 100000 (under 70 years-old) workers due to health reasons. Education attainment is measured through the proportion of high education graduates in the country. Looking at country-specific correlations we may also perceive that the higher the percentage of higher education graduates the lower the amount of years lost due to health reasons. Moreover, it is also observed that, several countries, once beyond a given (high) percentage of university graduates, may be registering decreasing returns to education: This would be the case of Japan, Spain and Greece, among others. But, at the same time, in other countries where the proportion of university graduates is initially low, the reduction in potential years lost is quite

relevant as the proportion of graduates increases. This is the case of Mexico and Portugal.

Figure 3. Lost years of life every 100000 (under 70 years old) inhabitants and proportion of higher education graduates.



From the above shown evidence we may infer that there is a remarkable link between education and health, this link being stronger for countries that have not yet experienced a strong improvements in educational capital stocks. We may also infer from the figures diminishing returns to education in terms of health outcomes.

4. Methodology

The data set we have constructed by merging of OECD-HD2005 and UNESCO yearbooks is a time-series cross-section (TSCS) data set. This type of data is characterised by repeated observations on fixed units, such as nations. Such databases have been widely used by macreconomists, particularly in the analysis of growth. Models for TSCS

data often allow for spatial correlated errors as well as for panel heteroskedasticity (Beck and Katz, 1995). Moreover, the relevant variables are very often affected by nonstationarity. This is the case of the main variables used in our model, both dependent (life expectancy and potential years of life lost due to health problems) and independent (school expectancy, proportion of university graduates, GDP per worker, expenditure on health, and the like). This makes it impossible to estimate it via a simple OLS regression in levels, since the result can be a spurious regression (Podestà, 2006). We instead model one variant of first differences, which solve the non stationarity problem.

As Beck and Katz (1996) argue, in the presence of nonstationarity/unit root TSCS data, two different specifications appear available: the FDM (first differences model) and the ECM (Error Correction Model). Podestà (2006) explains why ECM suits very well in the type of data we are handling and the type of problem we are dealing with: first of all, in this model the dependent variable is not expressed in levels but in differences. But ECM is not just a first difference model; it represents the best pooled TSCS specification for modelling progress in health since it is able to capture long-run effects even in the presence of non stationary processes. Our ECM specification is as follows:

$$\Delta H_{it} = \beta_0 H_{it-1} + \beta_1 \Delta Y_{it} + \beta_2 Y_{it-1} + \beta_3 \Delta S_{it} + \beta_4 S_{it-1} + \Sigma \lambda^j z^j_{it} + a_i + e_{it} \qquad (1),$$

where $z^j = (E, D, L)$ and $\lambda^j = (\lambda^1, \lambda^2, \lambda^3)$ respectively. H is the health indicator, S refers to the education attainment proxy of the specification, E refers to different expenditure on health indicators, D gathers information about number of doctors and other health care measures, and L means variables related to lifestyles. The parameter for the lagged dependent variable in levels (β_1) represents equilibrium properties. The parameter φ_j for a lagged independent level variable, x_{t-1}, measures the long-term effect of that variable, at the same time as the parameter for a change variable, x_j it represents the short-term impact of x_{it} on y_{it}. We have added several variables in levels (z^j_{it}) whose

coefficients (λ) are not split into short-term and long-term impact. We had to do this as a compromise between the inclusion of inputs in the equation and degrees of freedom. Finally, fixed effects, namely, one dummy variable for every country (our unit of analysis) have been included.

Our final specification, a partial version of Error Correction Model with fixed effects estimated by OLS using panel corrected standard errors, is meant to be a compromise between the need to deal with unit heterogeneity and non stationarity without losing too many degrees of freedom. Following Podestá (2006) recommendations, we have tried to guide our model specification not only with the econometric theory, but also with the economic model we have in mind: the human capital approach to the production/demand of health. We may wonder to which extent the human capital model of health production requires being contrasted on a variable expressed in levels or in first differences. The effect of the main inputs in the production function does very likely require several years. Moreover, the original model by Grossman (1972) does explain accumulation of health upon an initial stock (adding inputs and taking into account depreciation). That is why deal with dynamics in the econometric specification since we understand that health production is a dynamic process, based on an already existing stock of health in the population, with both short-term and long-term impacts of the main inputs. Finally, we control for unobserved heterogeneity since we are aware that many country specific characteristics are unobserved in our model and may influence health, such as climate and diet, not to mention the national health institutional setups.

As for the specification, the dependent variables are life expectancy (in years) and potential number of years lost due to health reasons. The sets of explanatory variables consist on several proxies for inputs in the health production function and education. The human capital economists have tried to understand the positive link between education and health and microeconomic empirical analysis has

confirmed it once and again exploring three hypotheses[10]: productive efficiency, allocative efficiency and the time preference hypotheses. In the first hypothesis, this link is due to the fact that educated agents will be more efficient in the use of health care services and, therefore, in the production of health. In the second approach (allocative efficiency hypothesis) education is seen as a driving force (similar to a catalyst) in health related decisions. Educated individuals are more aware of the consequences of unhealthy habits and will tend to invest more time and resources on health care. In the third approach, the time preference hypothesis, those agents with a low time discount rate who prefer future consumption to present consumption tend to invest more resources on human capital and, therefore, invest more on education and health, so that the positive link between both variables is not causal (Fuch, 1982 and Farrell and Fuchs, 1982). There are many difficulties to contrast these three hypotheses, which are well documented in the literature through microdata-sets. In our case, we will take this literature into account in the interpretation of these results, although we are aware that not all issues in the microeconomic arena are easy to translate into aggregate approaches.

A final remark must be done: all our dependent and independent continuous variables are expressed in natural logarithms, so that the regression coefficients can be interpreted as constant elasticities.

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5. Results

Table 2 displays the main results of the ECM model applied to life expectancy taking school expectancy as the human education attainment. For the sake of robustness we have developed an ECM model as well, this time displayed in table 3 where the dependent variable is "potential years of life lost due to health reasons" and the education indicator is percentage of university graduates in the adult

[10] Grossman (1999 and 2005) display a very rich literature survey on these topics.

population. We have as well run specifications of these models with not control for unobserved heterogeneity. We do not include them in the body of the text since the results are not only sometimes counterintuitive but are also instable when sample diminishes and the global goodness of fit of the models is quite poor. Nevertheless, the interested reader may see these results in tables A2 and A3 in the appendix.

Broadly speaking, we may confirm that, regardless the variable we use to identify health or education, education turns to be a very relevant predictor of health, even in the presence of relevant inputs, such as income and expenditure on health. Nevertheless, as we include more and more inputs, education tends to lose explanatory power, since many of the inputs we are including in the health production function are clearly correlated with economic development and, therefore, with education attainment of the population. In all of these models the coefficient of the lagged dependent variable is negative and lower than 1 in absolute value. This may be interpreted as the presence of some (given the low values of the coefficient) cointegration between the dependent variables and the set of explanatory variables. We will proceed to comment the main results of every specification in the next paragraphs. Particular attention is due to those lagged and differenced variables (namely, income and education indicators). They must be interpreted carefully. Parameters of lagged explanatory variables reflect the long-term effect of those variables, whereas parameters in differenced explanatory variables show short-term effects of one unit change in those variables.

As explained above, Table 2 displays the ECM with fixed effects for the health production function that takes life expectancy as dependent variable. This means that positive coefficients mean that a unit change in variable x contributes to a unit change in the natural logarithm of life expectancy. As for the main explanatory variables, we observe that, when we control for fixed effects and look into within country changes, we see a clear and persistence long-run effect of education on health,

and the short-run effect is not significant any longer. This could mean that, investment in education is a long-term way of investment. Therefore, education returns at an individual and an aggregate level are only noticeable when a long observation window is considered. This is consistent with the result we already observed when comparing figure D in panel 1 with Figure 1.

The coefficient of the education indicator tends to loose explanatory power as more and more inputs are included in the health production function, particularly when unit heterogeneity is not controlled for. This may confirm the allocation efficiency hypothesis (Rosenzweig and Schultz, 1989). One of the available ways to test for this hypothesis is precisely controlling for more and more inputs and observing how the significance in the education coefficient fades away (Grossman, 2005; p 15: "To fully test the allocative efficiency hypothesis, one needs to estimate the health production function and show that the schooling coefficient is zero once all inputs are included").

The impact of education is so strong that it cancels the effect of income, which is not significant in none of the specifications, neither in the short or the long-run. This result might not be as striking as it looks like if we remember that the richest countries in the world are in our data-set. This result seems to be compatible with the income inequality hypothesis, which predicts that income inequality is correlated with health inequalities. In his seminal work, Wilkinson (1992) finds a strong negative correlation between the proportion of accumulated income by the poorest 70% of the population and life expectancy in nine of the industrialised countries of the OECD.

Some other inputs have a small but significant impact on the improvement of health. The effect of public expenditure may be read as follows: increases in public expenditure in one country explain increases in life expectancy in that precise country in a significant way, whereas private expenditure does not seem to be influential.

Some of the variables that register inputs have not a particularly clear pattern. That is the case of number of doctors and average length

of stay in acute care units. The effect, when significant, differs across specifications, probably because they are clearly correlated with expenditure on education.

As for (un)healthy habits we do also find interesting results. Those countries that have experienced increases in fat intake are as well those where life expectancy has increased most. Something similar occurs with Fruit and vegetables. Nevertheless, increases in protein intake are linked with a lower pace in the improvement of health along the observation period. As for sugar or alcohol consumption and smoking habits, we have not observed the expected negative sign. We expect this to be the result of loss of sample size when these inputs are included in the models. As a consistency check we have also run models with the smallest of the available simples across specification, namely, the available simple for specification 6. The aim of this checking was distinguishing to which extent sample size is influencing the significance of the main explanatory variables. We observed that long run effects of education on health persist despite the reduction in the sample size.

Table 2: Determinants of increases in Life expectancy. Error Correction model (controlling for unobserved unit heterogeneity – fixed effects)						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Life expectancy (in lags)	-0.050***	-0.056***	-0.055***	-0.080***	-0.073***	-0.159***
	(6.558)	(6.368)	(5.045)	(6.178)	(4.524)	(5.646)
School expectancy (differenced)	***0.005***	***0.005****	***0.005***	***0.005***	***0.004***	***0.005***
	(1.489)	***(1.701)***	***(1.550)***	***(1.382)***	***(1.039)***	***(0.826)***
School expectancy (in lags)	***0.004******	***0.004******	***0.003******	***0.002****	***0.002****	***0.004****
	(4.873)	***(5.167)***	***(3.755)***	***(2.260)***	***(1.937)***	***(1.993)***
Real GDP per worker (differenced)		0.003	0.008	0.008	0.006	0.004
		(0.584)	(1.476)	(1.433)	(0.945)	(0.571)
Real GDP per worker (lagegd)		0.001	0.002	-0.001	0.000	0.001
		(1.157)	(1.251)	(0.390)	(0.096)	(0.357)
Total expenditure on health (% of GDP)			0.000			
			(0.326)			
Public expenditure on health-per capita, US$ PPC				0.002**	0.001*	0.002*
				(2.339)	(1.867)	(1.684)
Private expenditure on health-per capita, US$ PPC				0.000	-0.000	0.001
				(0.857)	(0.497)	(1.345)
Number of active doctors per 1000 inhabitants					-0.001	
					(0.746)	
Average length of stay: acute care					-0.002*	
					(1.949)	
Total fat intake (daily grams p.c.)						0.009**
						(2.364)
Total protein intake (daily grams p.c.)						-0.015**
						(2.543)
Total sugar intake (kilos p.c.)						-0.001
						(0.837)
Fruits and vegetables (kilos p.c.)						0.008***
						(3.749)
Alcohol consumption (litres p.c.)						-0.000
						(0.033)
% of pop 15+ who are daily smokers						-0.002
						(1.220)
Intercept	0.210***	0.232***	0.225***	0.329***	0.310***	0.641***
	(6.721)	(6.575)	(5.126)	(6.250)	(4.592)	(5.403)
Observations	1114	983	819	761	573	529
Number of countries	29	29	29	28	28	27
Chi2 (all significant at 99%)	771.25	678.37	205.97	259.17	822.28	146.13
Chi2 degrees of freedom	31	32	31	29	29	32
Absolute value of t statistics in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						
Source: OECD Health 2005 database						

Table 3: Determinants of increases in potential years of life lost due to health reasons. Error Correction model (controlling for unobserved unit heterogeneity)						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Potential years of life lost (under 70) (lagged)	-0.061***	-0.076***	-0.089***	-0.121***	-0.123***	-0.184***
	(5.055)	(4.927)	(4.851)	(5.763)	(4.814)	(4.433)
Percentage of University graduates (differenced)	***-0.006***	***-0.001***	***0.005***	***-0.012***	***-0.004***	***-0.012***
	(0.253)	***(0.035)***	***(0.195)***	***(0.475)***	***(0.108)***	***(0.375)***
Percentage of University graduates (lagged)	***-0.030******	***-0.031******	***-0.029******	***-0.021******	***-0.009***	***-0.056******
	(4.791)	***(4.661)***	***(4.274)***	***(2.945)***	***(0.885)***	***(3.390)***
Real GDP per worker (differenced)		-0.010	0.022	0.034	0.085	0.148**
		(0.169)	(0.362)	(0.540)	(1.219)	(2.158)
Real GDP per worker (lagged)		-0.013	-0.007	0.031*	0.003	0.028
		(0.961)	(0.477)	(1.841)	(0.115)	(0.770)
Total expenditure on health (% of GDP)			-0.027**			
			(2.334)			
Public expenditure on health-per capita, US$ PPC				-0.020***	-0.014*	-0.004
				(2.721)	(1.715)	(0.390)
Private expenditure on health-per capita, US$ PPC				-0.010	0.001	-0.002
				(1.584)	(0.088)	(0.245)
Number of active doctors per 1000 inhabitants					-0.012	0.012
					(0.684)	(0.551)
Average length of stay: ACU					0.039***	0.028**
					(3.768)	(2.184)
Total fat intake (daily grams p.c.)						-0.147***
						(3.102)
Total protein intake (daily grams p.c.)						0.206***
						(3.037)
Total sugar intake (kilos per capita)						-0.053***
						(2.584)
Fruits and vegetables (kilos p.c.)						-0.070***
						(2.832)
Alcohol consumption (litres p.c.)						0.012
						(0.544)
% of population 15+ who are daily smokers						0.044**
						(1.972)
Intercept	0.569***	0.730***	0.832***	1.183***	1.036***	1.810***
	(5.215)	(4.584)	(4.222)	(5.325)	(3.913)	(3.674)
Observations	959	888	769	718	522	377
Number of countries	29	29	29	28	27	26
Chi2 (all significant at 99%)	756.40	404.7	759.83	5686.45	288.42	435.37
Chi2 degrees of freedom	31	31	30	30	27	27
Absolute value of t statistics in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						
Source: OECD Health 2005 database						

Results in Table 3 may well be used as a consistency check of estimations in Table 2. Here the meaning of coefficients remains but we need to remember that a negative sign in the coefficient of *x* means that increases in *x* are linked to a decrease in the number of years lost due to health problems. Therefore a negative coefficient is linked to improvements in health, unlike the estimates in table 2.

In this new set of specifications (Table 3), we observe a clear and persistent long-run relation between the presence of university graduates in the population and the lengthening of life. The coefficients decrease only in two specifications in Table 3: in specification 4, in the presence of public expenditure on health. Countries that have increased their public expenditure on health have experienced stronger improvements in their health. And in specification 5, education loses significance in the presence of average length of stay, which is a two-sided indicator of both expenditure on health and morbidity. Probably this double nature explains the positive sign in the coefficient of this variable. Those countries that have experienced longer hospital stays in acute care units may have experienced as well stronger morbidity or accidents, which explain the reduction in life expectancy. Again, in specification 6, in the presence of several other inputs, this variable retains the positive sign. Now let us finally comment other inputs, namely, habits: countries where consumption of fruits and vegetables has increased more have experienced stronger health improvements. The same happens with the consumption of sugar and fat, and all the contrary happens with protein intake. On the one hand, this result does not look very intuitive, since we are aware that sugar and fat are not healthy, but on the other it is also true that as countries develop, together with an improvement in diet habits, there is also an increase in the intake of many types of food quite rich in sugar and fat (i.e., fast food and bakery). In this specification we may clearly see how countries where the proportion of adult smokers increase are more threatened in terms of loss of average years of life.

6. Conclusions

This piece of research shows that education has a leading role in the determination of health, even in the presence of income and many other inputs. Moreover, we think that our research has showed that education acts as an efficiency factor in the production of health. We observe a persistent long-term relation between education and health, regardless the variable we use to measure both education and health. This is understandable if we keep in mind that education is a long-term investment and, therefore its potential effects are better noticed in along term perspective. Education and income are quite correlated, and given that our data-set includes rich and middle income countries, so that differences in income are not significant enough.

The available TSCS techniques have allowed us to handle heteroskedasticity and non stationarity, and we have tried to do so with our ECM specifications. Moreover we have controlled for time-invariant unit heterogeneity via the inclusion of fixed effects.

Given that we have found that both increases in education attainment and expenditure on health have a positive impact on life expectancy, we could derive several conclusions in terms of policy: both expenditure on education and on health do contribute in the long run to improvements in welfare. They play different and complementary roles: expenditure on education and habits play a direct role on health, whereas expenditure on education contributes to produce health in a more efficient way. Therefore, governments should focus on both types of expenditure in the sake of increasing levels of health and welfare in the population.

Nevertheless, we may not conclude from this idea that present expenditure on education will mean future savings in health expenditure (in line with what Groot and van den Brink (2006)). This is due to the fact that more educated individuals are more efficient in the use of health care but do demand more preventive health care as well. We might therefore expect a restructuring of health care in the future,

with an increase in the proportion of expenditure on preventive attention and a reduction of expenditure on palliative care. But what will happen with the level of expenditure as education attainment of the population increases is quite uncertain.

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Appendix

Table A1: Country-specific average values for every variable inn the data-set

	lifexp	yearl	schoolex	highered	RGDPL	RGDPw	GDPpc	Unemp	ExpPIB	publexp	privexp	doctors	visits	stays	fat	protein	sugar	fruits	alcohol	tabaco
GER	73.60	5243	13.75	18.00	17436	42677	12813	7.45	9.14	1197	327	3.12	6.46	12.66	134.35	92.70	41.28	177.26	12.37	28.38
AUS	74.80	4692	14.16	17.53	17301	37804	12379	7.46	6.72	617	311	1.79	4.69	16.19	121.16	107.20	52.28	162.31	11.06	32.30
AT	73.37	5242	10.01	5.72	15217	33382	13004	4.78	6.43	656	273	1.98	5.55	16.79	142.63	96.86	42.85	197.25	12.83	36.30
BEL	73.84	5309	13.13	15.77	15611	38831	12253	9.04	7.14			2.52	7.07	15.38	142.80	97.69	40.29	188.37	11.71	30.95
CAN	75.41	4576	13.86	28.77	18269	38978	13254	8.87	7.78	824	319	1.79	5.50	11.94	124.54	96.09	46.75	208.74	8.76	31.38
KOR	66.30	4137	9.83	11.36	6519	16094	7478	3.36	4.44	211	294	0.97	9.70	12.67	42.18	77.83	18.45	196.59	9.02	33.86
DK	74.43	4546	16.88	24.34	18608	36022	13229	6.93	8.60	1193	206	2.46	5.73	12.07	133.41	90.75	50.18	135.84	10.40	44.21
ES	75.03	5122	10.69	9.44	11473	31147	9028	16.21	5.23	440	151	2.92	8.03	13.09	115.20	95.71	28.98	256.10	14.98	34.03
USA	73.56	5606	14.12	27.18	21551	45500	15917	6.01	9.48	783	1056	1.58	9.46	11.45	130.34	103.13	60.27	210.36	9.16	29.34
FIN	73.40	4583	10.59	13.79	14958	30540	11645	8.90	6.46	641	190	2.33	3.32	20.04	126.25	95.55	41.03	109.45	7.18	24.82
FR	74.78	4749	11.22	11.88	15523	35101	12393	7.57	7.24	810	246	2.49	5.83	17.31	144.57	110.29	37.30	205.65	18.32	28.31
GR	74.69	5065	9.40	9.27	10145	26093	8030	8.75	7.69	446	386	2.61	2.46	12.60	125.75	105.39	28.63	375.72	10.77	38.90
HUN	69.71	7902	11.14	8.20	8343	17924	10639	8.27	7.53	623	179	2.45	11.08	13.38	127.95	94.19	42.13	162.43	12.32	34.44
IRE	73.12	5305	11.94	12.56	11127	28912	10048	12.16	6.30	513	170	2.20		8.08	131.55	110.18	48.46	123.21	9.40	33.44
ISL	76.59	3704	11.87	13.86	16373	32978	13384	3.55	6.52	894	167	2.25	5.16	24.09	125.78	120.30	57.43	95.82	4.44	27.27
ITA	74.80	5602	10.72	4.96	14671	37044	11713	10.28	7.89	1272	368	4.08	6.38	14.91	126.56	102.08	30.50	285.10	13.36	27.77
JP	75.96	4202	9.26	16.85	15598	24834	11985	3.11	5.77	595	172	1.39	14.22	51.47	66.83	87.01	29.72	169.39	7.02	40.72
LUX	73.16	5263	14.40	17.68	21496	51428	18084	2.02	5.69	1255	135	1.67	6.19	22.83					14.32	32.21
MEX	67.20	11142	8.01	6.79	6552	20519	4354	3.08	5.57	192	239	1.42	1.93	4.20	74.11	78.43	42.92	133.69	4.65	26.24
NOR	75.94	3973	11.17	15.51	16599	35365	13537	3.29	6.42	909	164	2.06		14.63	134.89	96.09	43.12	144.76	4.89	35.39
NZL	73.90	5192	13.76	20.69	15117	35606	11361	6.71	6.56	703	175	1.60	3.76	12.03	121.84	98.84	50.80	195.37	9.45	29.02
NDL	75.78	4083	12.57	11.48	16036	39826	12582	6.94	7.87	887	436	1.91	5.10	34.91	134.73	94.61	47.66	184.83	9.25	43.17
POL	70.97	7480	10.61	6.81	6770	14496	8422	14.53	5.91	363	138	1.80	5.36	13.44	108.67	102.91	42.87	145.33	8.19	32.83
PT	71.38	8194	9.19	5.28	9038	20835	7280	5.61	6.36	434	241	2.00	2.72	16.24	98.07	91.02	27.48	222.06	15.93	19.46
RU	74.10	4990	13.92	13.97	15007	31221	11508	8.24	5.63	595	113	1.35	5.39	11.12	139.44	93.53	44.46	148.50	9.03	37.73
RCH	71.60	4560	11.85	7.64	12966	24219	13436	6.23	6.43	809	65	2.59	11.59	14.60	112.02	92.53	45.09	146.20	11.63	24.95
RSV	71.22	5077	11.79	7.33	10589	22435	9614	15.25	5.71	565	65	3.13	12.94	10.71	108.90	81.19	37.17	140.06	11.86	24.30
SWE	76.41	3561	13.59	20.69	16995	34399	12732	4.28	8.37	1166	161	2.13	2.66	20.59	121.61	93.99	45.21	136.43	6.38	24.51
CHE	75.87	4015	11.60	17.21	21728	43370	16073	3.07	7.57	1376	1148	2.38	3.40	23.04	148.53	92.63	49.78	217.15	12.93	28.14
TUR	59.85		5.44	1.36	4668	10493	3105	8.04	3.93	130	77	0.73	1.49	7.92	79.49	95.21	24.43	298.65	1.44	41.92

Table A2: Determinants of increases in Life expectancy. Error Correction model (with no control for unobserved unit heterogeneity)						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Life expectancy (lagged)	-0.030***	-0.036***	-0.028***	-0.033***	-0.032***	-0.028***
	(8.215)	(8.421)	(5.500)	(5.286)	(4.226)	(3.312)
School expectancy (differenced)	***0.007****	***0.007****	***0.007****	***0.007****	***0.006***	***0.005***
	(2.075)	***(2.186)***	***(2.169)***	***(1.943)***	***(1.518)***	***(0.712)***
School expectancy (lagged)	***0.002*****	***0.002*****	***0.002*****	***0.001****	***0.002****	***0.000***
	(3.172)	***(3.440)***	***(4.205)***	***(1.811)***	***(1.991)***	***(0.168)***
Real GDP per worker (differenced)		0.006	0.007	0.008	0.007	-0.000
		(1.229)	(1.425)	(1.510)	(1.174)	(0.018)
Real GDP per worker (lagged)		0.001	0.000	-0.001	-0.002*	0.000
		(0.997)	(0.321)	(1.045)	(1.843)	(0.331)
Total expenditure on health (% of GDP)			-0.001			
			(1.334)			
Public expenditure on health-per capita, US$ PPC				0.000	0.001*	0.001**
				(1.201)	(1.947)	(1.977)
Private expenditure on health-per capita, US$ PPC				0.000***	0.000*	-0.000
				(2.641)	(1.717)	(0.667)
Number of active doctors per 1000 inhabitants					-0.001*	
					(1.949)	
Average length of stay: acute care					0.001*	
					(1.932)	
Total fat intake (daily grams p.c.)						-0.004***
						(3.192)
Total protein intake (daily grams p.c.)						-0.001
						(0.585)
Total sugar intake (kilos per capita)						-0.000
						(0.122)
Fruits and vegetables (kilos p.c.)						0.001
						(1.278)
Alcohol consumption (litres p.c.)						0.001***
						(2.595)
% of population 15+ who are daily smokers						-0.001
						(1.183)
Intercept	0.127***	0.151***	0.120***	0.140***	0.132***	0.139***
	(8.648)	(8.933)	(5.732)	(5.449)	(4.339)	(3.905)
Observations	1114	983	819	761	573	529
Number of countries	29	29	29	28	28	27
Chi 2 (all of them significant at 99%)	105.32	125.58	54.07	49.89	54.67	73.06
Chi2 degrees of freedom	3	5	6	7	9	13
Absolute value of t statistics in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						
Source: OECD Health 2005 database						

Table A3: Determinants of increases in potential years of life lost due to health reasons. Error Correction model (with no control for unobserved unit heterogeneity)						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Potential years of life lost (under 70) (lagged)	-0.012**	-0.015**	-0.013*	-0.018*	-0.009	-0.018
	(2.313)	(2.197)	(1.669)	(1.819)	(0.755)	(1.079)
Percentage of University graduates (differenced)	***0.038****	***0.049****	***0.054****	***0.039***	***0.040***	***0.002***
	(1.971)	***(2.442)***	***(2.499)***	***(1.610)***	***(1.207)***	***(0.046)***
Percentage of University graduates (lagged)	***-0.002***	***-0.000***	***-0.003***	***-0.002***	***0.002***	***0.005***
	(0.732)	***(0.115)***	***(1.062)***	***(0.644)***	***(0.592)***	***(0.799)***
Real GDP per worker (differenced)		-0.028	0.035	0.013	0.039	0.110
		(0.487)	(0.616)	(0.224)	(0.624)	(1.607)
Real GDP per worker (lagged)		-0.005	0.007	0.013**	0.020**	-0.015*
		(0.727)	(1.078)	(1.972)	(1.976)	(1.699)
Total expenditure on health (% of GDP)			0.000			
			(0.035)			
Public expenditure on health-per capita, US$ PPC				-0.004	-0.006	-0.007
				(1.190)	(1.326)	(1.281)
Private expenditure on health-per capita, US$ PPC				-0.001	-0.001	0.005
				(0.472)	(0.383)	(1.642)
Number of active doctors per 1000 inhabitants					0.011	-0.005
					(1.526)	(0.525)
Average length of stay: acute care					-0.000	0.005
					(0.089)	(1.204)
Total fat intake (daily grams p.c.)						0.036**
						(2.376)
Total protein intake (daily grams p.c.)						0.022
						(0.657)
Total sugar intake (kilos per capita)						-0.000
						(0.021)
Fruits and vegetables (kilos per capita)						-0.018*
						(1.870)
Alcohol consumption (litres per capita)						-0.003
						(0.398)
% of population 15+ who are daily smokers						-0.002
						(0.243)
Intercept	0.077	0.111	0.066	0.124	0.023	-0.009
	(1.626)	(1.614)	(0.852)	(1.204)	(0.185)	(0.048)
Observations	959	888	769	718	522	377
Number of country	29	29	29	28	27	26
Chi 2: only specification (6) is significant at 99%	9.84	12.62	16.18	15.54	19.74	46.11
Chi2 degrees of freedom	3	5	6	7	9	15
Absolute value of t statistics in parentheses						
* significant at 10%; ** significant at 5%; *** significant at 1%						
Source: OECD Health 2005 database						