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Explaining the Interrelations between Health, Education and Standards of Living in Portugal.
A Simultaneous Equation Approach

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Explaining the interrelations between health, education and standards of living in Portugal. A simultaneous equation approach.

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Abstract

The aim of this paper is to analyze the links between health status, education and economic growth in Portugal. Focus is given to the achievements made in infant mortality rate which represents the most significant reduction among the OECD countries in the last decades. While this very positive performance is a direct consequence of the investments made in the health sector, it is also important to note that it is a result of other socioeconomic factors outside the health system (mainly in the education system) that have contributed significantly to an improvement of the living conditions. So, to a complete understanding of the Portuguese infant mortality decline we must consider in our analysis the potential cumulative causation effects between health, education and per capita income growth. Having this in mind, in this paper we use a three equation model to determine simultaneously the interactions between infant mortality rate, education and per capita income growth. Our empirical evidence shows that the proposed model is adequate to highlight the potential links between these core factors.

JEL code: H51, I12, I18, C23

Keywords: health, education, standards of living, simultaneous equations system

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1. Introduction

After the seventies the Portuguese economy has registered the most significant reduction of infant mortality rate among the OECD countries. This indicator – that measures deaths per 1000 live births in the first year of life – has fallen from 55 in 1970 to 3.3 in 2008, being at present one of the lowest rates among the OECD countries (OECD, 2011). Together with the decrease of perinatal mortality rates, the significant reduction of infant mortality is a key factor to understand the increase in life expectancy at birth of the Portuguese population¹. According to the OECD (2011) data, from 1970 to 2009 life expectancy has risen 12.8 years (from 66.7 to 79.5 years), representing the highest gain among the European Union (EU) countries. Considering that life expectancy is one of the most commonly used indicators to express the health status of the population, we can assert that the Portuguese population has achieved the most significant gain in health status improvements during this period.

Although recognizing that these important health outcomes cannot be dissociated from the investment and strategies adopted in the health sector – in great part linked to the creation of the National Healthcare System (NHS) in 1979 – there are other relevant factors worth mentioning. In fact, in the past decades two main events have contributed significantly to the socioeconomic changes in Portugal: the end of the dictatorial regime in 1974 and the accession to the EU in 1986. Along with health, the Portuguese governments have assumed education as a priority and these two factors have contributed decisively in the improvements of the standards of living. In this context, we can assume that improvements in health and education are strongly related with a higher economic performance in this country through a cumulative causation mechanism with expanding properties. There should be a strong link with reciprocal tendencies between health, education and economic growth that explains the improvement in economic performance in Portugal, based on cumulative causation

¹ See Figures 1 and 2 in the Annex.
characteristics that turn the growth process self-expanding. Increasing returns to scale generated in the health and education sector (at least in the long-run) can be a stimulus to economic growth compensating for the decreasing returns of physical capital. As the endogenous growth theory states, a healthy human capital is the engine of economic growth with externality effects spread-out over the whole economy improving labor productivity and thus growth.

Having these potential cumulative causation characteristics in mind, the present study aims at analyzing the linkages between health, education and economic performance in Portugal. While there is a vast literature exploring the reverse causality between these three dimensions (Adams et al., 2003; Albert and Davia, 2007; Bloom and Canning, 2008, among others), the studies that highlight empirical evidence are scarce and, to our knowledge, there is no empirical studies focusing on the Portuguese economy. By using a simultaneous equation approach we attempt to provide empirical evidence for Portugal, highlighting and disentangling the bidirectional effects between education, health and economic growth through a simultaneous equation approach. In line with Gregory’s et al. (1972) model, we propose a model that consists on the simultaneous estimation of three main equations: (i) the health equation using infant mortality rate as the health status proxy; (ii) the human capital equation using the secondary enrolment rate as proxy for the education attainment; (iii) a standard augmented Solow-Swan growth model as a proxy of standards of living. Using annual time series data from 1972 to 2009, we estimate the model by 2sls and 3sls to efficiently evaluate the feed-back and endogeneity effects between the core variables.

To do so, we structure the paper as follows: Besides the introduction, the next section briefly analyzes historical achievements on health, education and growth performance in Portugal along the period considered. In section 3 we present the model specification and explain the data used. Section 4 explains the estimation methodology and section 5 discusses the empirical results. The final section summarizes the main conclusions of the paper.
2. **Historical trends on health, education and economic performance in Portugal.**

Since the seventies a significant effort has been made to improve the health standards of the Portuguese population. These improvements include the increase in life expectancy, the reduction in infant and perinatal mortality rates, the decrease in mortality rates for specific causes and reduction of potential years of life lost, among others. All these health achievements are well documented\(^2\) in national and international statistics, showing a clear convergence of wellbeing indicators in relation to the average of OECD countries.

This remarkable progress in the health status was due, in a great part, to the creation of the National Health System (NHS) in 1979 that assured the universality and equity in the access to health care services. As Campos (2008) notes, “more and better health infrastructures as well as more and better qualified human resources disseminated all over the country, after the creation of the NHS, were responsible for a strong equity effect on the utilization of health care services and for an improvement on their quality”.

These improvements on the health sector have necessarily implied very strong investments in several dimensions, such as infrastructures, health equipment and human resources. These investments made possible the generalized access to public healthcare services well illustrated by the evolution of several indicators: number of consultations, acute care beds or average length of stay. The number of qualified human resources had also an impressive evolution during the period under analysis expressed by a notable increase of the number of practicing physicians and nurses per million habitants (0.99 and 1.69 in 1972 to 3.8 and 5.6 in 2009, respectively)\(^3\). These investments corresponded, along the period under analysis, to

\(^2\) See, for instance, Barros and Simões (2007).

\(^3\) The evolution of these (and other) indicators is available on *OECD Health Data* (several years).
a raise of the total per capita expenditure on health from 47US$ (measured in US$ purchasing power parity) in 1972 to 2508US$ in 2008, with public expenditure having a significant role (28US$ in 1970 and 1632.6 US$ in 2008, respectively)\(^4\).

This priority on the health sector is also well reflected by the ratio of total expenditure on health in relation to GDP: in 1972 health spending was 3.2% of GDP against 10.1% in 2008\(^5\).

In fact, the successive increase in health spending is a challenge (common to other OECD countries) that policy makers have to deal with in the future. Although this problem is common to other OECD countries, the lower growth rate of the Portuguese economy during the last decade justifies an increased concern to control public finances and to assure the sustainability of the social system. Nevertheless, it is worth mentioning that (as shown in Figure 3 in the Annex) the annual average growth rate in health expenditure per capita in real terms during the past decade was 1.5% in Portugal, clearly below the 4.0% average growth rate in the OECD countries for the same period. On the other hand, in 2009 the share of private expenditure on GDP was already 3.5% in Portugal, well above the 2.7% OECD average (see Figure 4 in the Annex). Taking into account the high income and health inequalities\(^6\) that characterize the Portuguese economy, any health reform should emphasize the efficiency gains. As Campos (2008) highlights, the main challenge that health sector has to face is to control in a more efficient way the expenditures in this sector.

In spite of the importance of all the efforts and investments made in the health sector, health outcomes are also the result of other factors that simultaneously have contributed to an important improvement of the population living conditions. Among these factors, we can

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\(^4\) OECD (2011).

\(^5\) The source was OECD (2011). See also Figure 3 in the Annex.

\(^6\) Well documented by the WHO (2010).
highlight the investment in basic infrastructures, like sanitation and access to potable water, better nutrition and house conditions and, above all, the generalization of the access to education.

In fact, it was only after a democratic regime took place in 1974 that education was really assumed by the policy makers as a priority. Significant improvements in the education sector were made, being direct and indirectly linked to health outcomes. As the evidence shows, countries with high literacy levels tend to have low infant mortality. Moreover, it is important to note that the magnitude of health inequalities can be reduced by improving educational opportunities (Mackenbach et al., 2008; Rosa Dias, 2009; Cutler and Lleras-Muney, 2010). On the other hand, as Albert and Davia (2007) refer, since schooling is a causal determinant of occupation and income, the effects of education on health may also reflect its impact on the socioeconomic status.

The concern with education by the Portuguese governments was evident after the 70’s: low standards of living, high levels of illiteracy and a huge out-flow of migration were very restrictive factors to economic development that could not respond to the increasing challenges of a higher integration. Compulsory school first increased from six to nine years and in 2008 it was extended to 12 years. At the same time, the educational system was extended to include pre-primary instruction. Important reforms were also introduced in the secondary and tertiary education system in order to improve the educational standards in Portugal. Under the period of our analysis it was in the secondary education system that the highest enrolment rates’ happened. In what concerns the tertiary education system there was a very significant increase of degrees’ supply from both public and private institutions,
mainly after the eighties. The access to tertiary education was extended all over the Portuguese districts, with polytechnic institutions having a major role in this geographical distribution.

Given that secondary schooling was not generalized among a large part of the adult and working age population, other educational strategies were adopted more recently to reintegrate this population into both the secondary and higher education levels. This is at the same time a response to the increasing need of a more qualified human capital able to assimilate the new technologies. As a consequence, there was a strong demand for secondary education that contributed to increase the gross enrolment ratio. However, despite the progress that was made for a free access in the schooling system, the abandoning rate in the Portuguese educational system is of great concern not enabling to achieve higher educational levels.

In spite of all efforts made in this sector, well reflected by the share of education expenditure on GDP, more qualitative achievements in this area are somehow disappointing when compared with other countries’ results. According to the 2009 PISA report (OECD 2009), in the year 2000 the Portuguese students were among the ones with the lowest reading performance in the PISA’s assessment. However, PISA’s 2009 results evidence a turning point in the Portuguese educational performance. According to this report, Portugal was the

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7 For a detailed review and relevant statistics on the Portuguese educational system in the last 50 years, see GEPE (2010).

8 “New Opportunities” and “Over 23” (respectively) are two main examples of those measures.

9 The gross enrolment ratio (GER) provides a measure of the capacity of education systems. It is the ratio of total enrolment, irrespective of age, to the targeted population (UNESCO, 2011).

10 This share was 5.2% of GDP in 2008 (see Figure 5 in the Annex).
second country with the most important recovery/progress in sciences and the fourth in reading and math standards, cited for the first time close to the OECD average. This is a very relevant progress, especially if we take into account the low socioeconomic background of a great part of the schooling population.

The evolution of the educational and health sectors is clearly a conditioning factor of the country’s economic performance, mainly through the role human capital plays enhancing growth. St. Aubyn (2002) analyzes the efficiency of the Portuguese health and education sectors, providing evidence that can help to explain the contribution that these sectors have had on economic performance in the last decades. In what concerns the health sector, the author points out the existence of some important inefficiencies, meaning that the same expenditure level could result in a better health, or, alternatively, the same health status could be achieved by spending less resources. The same study also refers that the scarcity of some resources – general practitioners, nurses or hospital beds – and their asymmetrically distribution in geographical terms may contribute to reduce the efficiency in health care.

Concerning education, the analysis must distinguish the quantitative from the qualitative aspects. There has been a very significant investment in education that has allowed enrolment rates and school expectancy to rise, attaining the average levels of the OECD countries. Nevertheless, as the author refers, when a more qualitative approach is used the education performance in Portugal becomes much lower. These qualitative comparisons can be done both at the “stock” level, when adults are considered, and at the "formation" level, when student performance is assessed and compared internationally. Comparisons in two international assessments\(^\text{11}\) showed that the Portuguese students were amongst the worst in every category.

\(^{11}\) The author uses the Third International Mathematics and Science Study (1994-95) and PISA 2000 results in his study.
Some studies that present empirical evidence on the impact of human capital on the Portuguese economic performance in the last decades, include Freitas (2002) or Teixeira and Fortuna (2003). Freitas (2002) analyzes the evolution of economic growth in Portugal for the period 1960-2000, showing that this development was not uniform during this period. However, considering the whole period, the faster economic growth allowed the country to approach significantly to the standards of living of the OECD countries, with per capita income rising from 41.5% of the EU15 average in 1960 to 73.8% in 2000\(^\text{12}\). Freitas also points out the importance of educational attainment (measured by average years of schooling relative to four European countries\(^\text{13}\)) on the convergence process, noting that, after an expressive recovery in the 60’s and the 70’s, the more recent evolution is less satisfactory.


In a recent study based on the cumulative causation principle that covers the period 1965-2006, Antunes and Soukiazis (2011) showed that after a fast recovery of the Portuguese economy relatively to the EU partners and the OECD countries, with economic growth rates exceeding the UE and OECD averages (with an exception for the 1983-1985 period), the Portuguese economic performance has slowdown since 2002, diverging from those countries. According to the authors, the decline of growth after that period can be explained, in a great part, to the low productivity and the loss of competitiveness in external markets.

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\(^{12}\) Author’s calculations based on growth accounting methods.

\(^{13}\) The four countries are Spain, Greece, Ireland and Portugal.
3. The structural model

Literature review

It is argued in this paper that there is a mutual causation tendency between income, health and human capital with feedback and spillover effects that can give rise to a cumulative causation process, with health improvements leading to higher human capital accumulation and thus to a higher economic growth. The whole process can be described by a virtuous circle with self-expanding tendencies where increasing returns to scales are at work stemming from the health and education sectors. Health has direct effects on human capital and economic growth due to better education and higher productive efficiency. On the other hand, better education contributes to improve health conditions. In what concerns economic growth, as countries improve their economic performance they have the capacity to invest more on education and health services.

While there is a vast macroeconomic literature that investigates theoretically the several mechanisms that link health, education and growth/income, only few of the empirical studies use system equations to account for those interactions. According to Fingleton (2000), there are some difficulties associated with simultaneous equation modeling that can explain, at least partly, the lack of studies using this methodology. A major problem consists in deciding which variables should be treated as exogenous and which should be treated as endogenous. Another problem is to specify correctly a structural model that is coherent both from a theoretical and empirical point of view. Our paper aims to fill this gap and provide consistent empirical evidence considering Portugal as a case study.

One pioneer work in this area is due to Gregory et al. (1972) that developed a multi-equation model to explain birth rates in the United States. Assuming that fertility decisions depend on

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14 For a literature review see Howitt (2005), Cutler and Lleras-Muney (2006) or Albert and Davia (2007).
several socioeconomic factors\textsuperscript{15}, the authors considered four equations that describe the structural model: (i) a birth rate equation; (ii) a permanent income equation\textsuperscript{16}; (iii) an infant mortality equation and (iv) an equation for a female labour participation. Using time series data for the period 1910-1968 and 2s\textit{ls} and 3s\textit{ls} estimation methods the authors’ reported results highlighting the large negative impact of education both on infant mortality and on birth rate; a positive impact of income and a negative influence of the female participation on labour market on the birth rate. It is important to note that, in this study, although recognizing this is a critical issue, the authors opted to consider education as an exogenous variable in the fertility, permanent income and infant mortality equations. The reason to this choice is that they assume that education is essentially a policy variable controlled by the government\textsuperscript{17}.

Other more recent studies include Fielding and Torres (2005; 2005a). Fielding and Torres (2005) analyze the determinants of the cross-country variation in the level of development by modeling four dimensions – the level of material prosperity\textsuperscript{18}, educational attainment, fertility and health – simultaneously. This approach allows identifying quantitatively the impact that each of these dimensions of human development potentially has on the others.

\textsuperscript{15} Those factors are per capita income, education, female labour participation, unemployment rate and the share of non-white population.

\textsuperscript{16} Instead of per capita income, the authors estimate a per capita permanent income equation because they consider that family’s fertility decisions depend more on its average income over a period of time rather than on its current income.

\textsuperscript{17} However, this view is very restrictive since, as fertility declines, parents are more able to concentrate resources in fewer children, increasing the probability of investing more in their education and health.

\textsuperscript{18} Their measure of wealth is based on a household survey recording each household’s possessions, so it isn’t a measure at the personal level but at the household’s level. This approach also permits to avoid references to purchasing power parities (PPP).
Using data from the World Bank based on household survey for 48 countries, their empirical results show that the effects of fertility rates on the other indicators of development have the expected sign and are statistically significant, although the overall magnitude is relatively small. A more interesting finding of this study is that even small improvements in health outcomes have a large impact on wealth and education, being as important as innovations that act directly on these variables. This result emphasizes the idea that, taking into account the effects that health has on the other dimensions of life, investing in basic health is crucial for promoting growth and development. In a different work, Fielding and Torres (2005a), propose a simultaneous equation model to describe the development process. They consider four main dimensions of economic development – per capita income, education, health and inequality – to be estimated simultaneously. Using the literacy rate as a proxy for education, years of life expectancy as a measure of health and the Gini coefficient for inequality, the authors apply 3sls to cross-country data for 95 countries. Their empirical results show that there is a correlation between reductions in inequality and improvements in the economic variables mentioned above.

**Model specification**

Our model specification inspires from Gregory’s *et al.* (1972) approach, assuming three equations to estimate simultaneously: *(i)* the infant mortality rate (IMR) equation as a proxy for health, *(ii)* the secondary school real enrolment rate equation as a proxy for education, and *(iii)* the per capita income growth equation reflecting the standards of living of the Portuguese population. The three equations will be estimated simultaneously to capture the interdependence and feedback effects between health, education and income, the core variables of the model.
The infant mortality equation is specified as follows\textsuperscript{19}:
\[
\ln(\text{IMR} ) = a_0 + a_2 \gamma t + a_3 \ln(\text{HSpend}_{t-1}) + a_4 \ln(\text{Nurses}_t) + a_5 \ln(\text{Fert}_t) + a_6 \ln(\text{Edu}_t) + \epsilon_t
\]  
(1)

In this equation we assume that the main determinants of infant mortality rate (IMR) are: economic factors expressed by the annual growth rate of per capita income ($\gamma_t$)\textsuperscript{20}; the financial and human resources devoted to health care, approximated by the per capita health spending ($\text{HSpend}_{t-1}$) lagged one period\textsuperscript{21}, and the number of nurses per million habitants ($\text{Nurses}_t$), respectively; the fertility rate ($\text{Fert}_t$) and education level ($\text{Edu}_t$) (measured by the real enrolment rates on secondary school) are additional socioeconomic factors that is believed to explain infant mortality rate, too.

We expect that economic growth ensuring better standards of living has a negative impact on IMR, corroborating with existing evidence, such as Preston (1975) or Pritchett and Summers (1996). Per capita health spending and nurses reflect monetary and human investment in health expecting to reduce IMR, too. We assume that nurses, more than practicing physicians, play a critical role delivering health care services to mothers and children, mainly during pregnancy and in the first months of life\textsuperscript{22}. In what concerns fertility rate, economic literature emphasizes that, as parents have fewer children, they invest more on them,

\textsuperscript{19} All variable sources and definitions used in our model are given in the Annex.

\textsuperscript{20} Gregory \textit{et al.} (1972) use permanent income rather than per capita income. Although this criterion may be more pertinent in the IMR analysis, the lack of data enables us to use this variable in our study.

\textsuperscript{21} The lagged value of per capita health spending is justified by the fact that previous spending on health assures mother’s health thus reducing infant mortality.

\textsuperscript{22} See Younger (2001) and Ssewanyana and Younger (2007) that use similar specifications of the infant mortality regressions on a macroeconomic perspective.
providing more education and health care services. Having this in mind, we expect a positive relation between fertility rate and IMR. At last, we also consider the level of education as a determinant factor of IMR. There are many studies that link gains in education with improvements of child health\textsuperscript{23}. This may be explained by a greater consciousness (mainly by parents) of the advantages of adopting healthier behaviors, like hygienic habits or better nutrition.

In the health equation (1), the right hand variables, education and growth of per capita income are assumed as endogenous and cannot be estimated by the usual OLS method, since the estimates would be biased and inconsistent. One of the simple way to deal with the endogeneity problem of the regressors is to use instrumental variables but in this case we ignore the feedback effects of the endogenous variables and the inter-linkages between them. In order to capture the cumulative causation effects between health, education and income a system of simultaneous equations can be used defining the determinants of the endogenous variables.

Therefore, the second equation of the system is education defined as:

\[
\ln(Edu_t) = b_1 + b_2 gy_t + b_3 \ln(EduSpend_{t-1}) + b_4 \ln(Teacher_t) + \epsilon_t
\]  

(2)

The dependent variable in this equation (which appears as an edogenous regressor in equation (1)) is the secondary school real enrolment rate that depends on economic conditions like the annual growth rate of per capita income (\( gy_t \)); on financial and human resources devoted to education, proxied by the education expenditure share on GDP

\textsuperscript{23} See, for instance, Masuy-Stroobant (2001).
(EduSpend$_{t-1}$) lagged one period$^{24}$, and the ratio between the students in the secondary school and the number of teachers working in secondary schools$^{25}$ (RatioS/T$_t$). All these factors are expected to influence positively the rate of schooling with the exception of RatioS/T$_t$ that should be inversely related to secondary school real enrolment rate.

The use of real enrolment rates as a proxy for education in our study is explained mainly by the fact that this variable was available for a longer period of time. On the other hand, the choice of the “secondary school” is due to the fact of its pertinence relative to other school levels. In fact, several studies, such as Psacharopoulos and Patrinos (2002) or UNESCO (2011), are consensual in pointing out that the social returns of investing in this education level are more significant than in higher education regardless of the income level of the country. At the same time, secondary school has a crucial role in assuring the linkage to higher education and in preparing many students that go directly to the labour market. However, we should have in mind that it only represents current flows of education. As Teixeira and Fortuna (2003) note, the accumulation of these flows is an element of human capital stock that will be available in the future.

An important factor related with education is income. Secondary school was not compulsory until recently (2008), and in spite of public expenditure having a major role in financing it, there are also important costs supported by families (including transport costs, material expenses, parallel education costs, etc.) that can be seen as extra expenses for parents. This is

$^{24}$ The same argument as in the infant mortality equation can be used here, that previous spending on education will improve current enrolment rates.

$^{25}$ This variable includes teachers that teach to one class team at least and/or do support educational activities in full or partial time.
particularly true when there are strong social inequalities\(^{26}\) as in Portugal. Having this in mind, instead of income (or permanent income) we rather use per capita income growth reflecting improvements in standards of living in a dynamic sense. Public spending on education and human resources (teachers) employed in the education system are also important for improving educational standards.

In the education equation (2) (and also in the health equation (1)) the growth of per capita income is an endogenous regressor and therefore this variable has to be specified individually defining its main determinants.

Therefore the third equation of our model is a growth equation of the Solow-Swan type extended to include health and human capital which are endogenous to the system:

\[
g y_t = c_1 + c_2 \ln(y_{t-1}) + c_3 \ln(Employ_t) + c_4 \ln(K_t) + c_5 \ln(Edu_t) + c_6 \ln(IMR_t) + \varepsilon_t
\]  

(3)

In this equation, \(g y_t\) is the annual growth rate of per capita income at time \(t\); \(y_{t-1}\) is the initial per capita income lagged one period\(^{27}\); \(Employ_t\) is the employed population (in millions) at time \(t\); \(K_t\) denotes the investment share on GDP as a proxy for physical capital accumulation; \(Edu_t\) is the real secondary schooling enrolment rate, and \(IMR_t\) the infant mortality rate as defined before.

Equation (3) is the well-known growth equation which gives evidence on conditional convergence associated with the endogenous growth theory. Convergence will depend on the distance of per capita income from its steady-state value, the higher this distance the higher

\(^{26}\) Data on inequalities (Gini coefficient) was not available for a large number of years, which enable its consideration in our regression analysis.

\(^{27}\) The relation between the growth of per capita income and its initial level is known as the convergence hypothesis with \(c_2<0\) (see Barro and Sala-i-Martin, 1992).
the growth will be. According to the endogenous growth theory, there are increasing returns to scale stemming from human capital and innovation that compensate the decreasing returns of physical capital. The growth process will depend on these structural factors which are endogenous to the economic system. Having these qualifications in mind we expect that employment, physical capital and human capital (education) will have a positive impact on growth, while infant mortality (as a proxy for health status) will have a negative influence on growth.

*Estimation Methodology and data analysis*

We estimate equations (1), (2) and (3) by using 3sls assuming that health status (infant mortality rate), education (real rate of secondary enrolment) and income per capita are simultaneously determined in the system. This method of estimation controls for the endogeneity problem of the regressors and takes into account the reverse causality between the core endogenous variables of the system. It also considers the error correlation between the equations constituting the system. Therefore it is the most appropriate method to capture the cumulative causation characteristics that turn the system self-sustained. The estimation approach covers the period 1972-2009 of the Portuguese economy. When we apply 3sls to the system we need to test the validity of the instrumental variables. The Sargan statistic is used to verify the validity of instruments and the null hypothesis - that the instruments are valid, uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. However, since in the 2sls regressions we had to correct the three equations from heteroskedasticity and first error autocorrelation we report the relevant Hansen's J statistic 28.

28 To correct for heteroskedasticity and first error autocorrelation the options *bw(auto)* and *robust* were used in stata version 11. With these options Sargan's statistic becomes Hansen's J statistic, which is consistent in the
Table 2 in the Annex explains the set of variables used in the regressions and reports some elementary descriptive statistics. Some of the variables are used as external instruments in the regressions but they do not appear as regressors (i.e. consultations). Analyzing these simple descriptive statistics allows us to have an idea of the sharp differences most variables show between the years of 1972 and 2009, since minimum and maximum values correspond in most cases to the beginning or end of the period \(^{29}\). It is interesting to see the figures on secondary education and infant mortality (in the Annex) showing the remarkable improvement that has been made in these sectors.

4. Empirical results

The three equation health-education-income model is estimated by 3sls and the regression results are shown in Table 1. As we explained before this method of estimation captures the important linkages and feed-back effects between health, education and income growth that generate cumulative causation tendencies leading to higher economic growth.

\(^{29}\) The opposite is true for the variables IMR, K, and Fert.
Table 1. 3sls and 2sls regression results of the health-education-income system. Portugal 1972-2009.

### 3sls

<table>
<thead>
<tr>
<th>Equations</th>
<th>Explanatory variables</th>
<th>$R^2$</th>
<th>F-stat</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln\text{IMR}_t$</td>
<td>$\ln \text{y}<em>{t-1}$ $\ln \text{HSpend}</em>{t-1}$ $\ln \text{Nurses}_t$ $\ln \text{Edut}_t$ $\ln \text{Fert}_t$ Constant</td>
<td>0.993</td>
<td>1043</td>
<td>0.000</td>
</tr>
<tr>
<td>$\ln\text{Edut}_t$</td>
<td>$\ln \text{y}_{t-1}$ $\ln \text{Employ}_t$ $\ln \text{K}_t$ $\ln \text{Edut}_t$ $\ln \text{IMR}_t$ Constant</td>
<td>0.928</td>
<td>153.2</td>
<td>0.000</td>
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<tr>
<td>$\ln \text{y}_{t-1}$</td>
<td>$\ln \text{y}_{t-1}$ $\ln \text{Employ}_t$ $\ln \text{K}_t$ $\ln \text{Edut}_t$ $\ln \text{IMR}_t$ Constant</td>
<td>0.769</td>
<td>27.06</td>
<td>0.000</td>
</tr>
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</table>

### 2sls

<table>
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<th>Equations</th>
<th>Explanatory variables</th>
<th>$R^2$</th>
<th>AR(1) test$^{(1)}$</th>
</tr>
</thead>
<tbody>
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<td>$\ln\text{IMR}_t$</td>
<td>$\ln \text{y}<em>{t-1}$ $\ln \text{HSpend}</em>{t-1}$ $\ln \text{Nurses}_t$ $\ln \text{Edut}_t$ $\ln \text{Fert}_t$ Constant</td>
<td>0.994</td>
<td>$\chi^2=2.586$ p-value=0.2744</td>
</tr>
<tr>
<td>$\ln\text{Edut}_t$</td>
<td>$\ln \text{y}_{t-1}$ $\ln \text{Employ}_t$ $\ln \text{K}_t$ $\ln \text{Edut}_t$ $\ln \text{IMR}_t$ Constant</td>
<td>0.921</td>
<td>$\chi^2=2.787$ p-value=0.4256</td>
</tr>
<tr>
<td>$\ln \text{y}_{t-1}$</td>
<td>$\ln \text{y}_{t-1}$ $\ln \text{Employ}_t$ $\ln \text{K}_t$ $\ln \text{Edut}_t$ $\ln \text{IMR}_t$ Constant</td>
<td>0.790</td>
<td>$\chi^2=2.820$ p-value=0.7277</td>
</tr>
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</table>

Notes:

$^{(1)}$ The use of “robust” option gives Hansen test rather than the Sargan test; Estimates are efficient for arbitrary heteroskedasticity and autocorrelation and statistics are robust to heteroskedasticity and autocorrelation.

Endogenous variables: $\ln \text{y}_t$, $\ln \text{IMR}_t$, $\ln \text{Edut}_t$

Exogenous variables: $\ln \text{y}_{t-1}$, $\ln \text{Employ}_t$, $\ln \text{K}_t$, $\ln \text{HSpend}_{t-1}$, $\ln \text{Nurses}_t$, $\ln \text{Fert}_t$, $\ln \text{Edut}_{t-1}$, $\ln \text{RatioS/T}_t$, $\ln \text{Consultations}_t$

*** p<0.01, ** p<0.05, * p<0.1

The obtained results are generally quite satisfactory in terms of the goodness of fit and statistical significance of the coefficients. A more detailed analysis of each equation shows that most variables present the expected sign and are statistically significant with some exceptions.
Having a closer look at each individual equation, health (infant mortality) is mostly explained by human resources devoted to this sector (number of nurses), the education level and fertility rate. These variables are highly significant at the 1% significance level. These results collaborate with previous findings in the literature that the higher human resources employed in the health sector and the higher the level of education the lower the infant mortality will be. The impact of human resources is the one with the higher magnitude and this result corroborates with existing evidence on the role nurses usually have in health care services related to child care in the first year of life. If we consider that low rate of infant mortality creates a new more healthy generation then investing more in human resources in the health and education sectors is the right policy for improving standards of living. The fertility rate is also in line with early findings influencing positively the infant mortality. As we explained before, this result is justified by the fact that high fertility will force parents to devote less economic resources to health and education, increasing therefore infant mortality. Parents having fewer children can invest more in their health. On the other hand, it is more likely that infant mortality will increase when the fertility rate is high since there will be a higher number of new born children. Therefore it is a matter of a scale measurement.

In the health equation it was not possible to find any significant impact of the growth of per capita income or the per capita spending on health sector (lagged one period) on infant mortality. This can be taken as evidence that what matters more in the health sector are factors related to education and human resources than financial spending which does not take into account its efficiency dimension.

In the education equation the most significant impact comes from per capita spending on education and the students/teacher ratio. Our empirical results show that (the lagged) per capita education expenditure ($EduSpend$) has a positive impact on the secondary school real enrolment rate with statistical significance at the 1% level. This is an expected result since more spending on education will create better conditions in schooling increasing therefore the attendance rate. Another variable with a significant negative impact on education at the 1% level is the students/teacher ratio. This is also expectable since a lower ratio means more
human resources in the education system that may improve the teaching quality strengthening the participation level. It is also important to note the teachers’ role beyond the classroom, supporting other students’ activities. Nevertheless, the growth of per capita income has not a significant effect on schooling attendance. These results reinforce the idea that public support on education is a key factor to educational frequency at this level of basic schooling.

In the growth equation all variables have a significant impact and carry the expected sign. The negative impact of the lagged per capita income is in line with the conditional convergence hypothesis of the endogenous growth theory. In what concerns the other factors explaining economic growth, our empirical results highlight that capital investment, employment and education improvements are of extreme importance in the growth performance of Portugal, being all statistically significant at the 1% level and having their expected positive impact on growth. In what respects infant mortality, it evidences a negative and significant impact on growth at the 5% level. These are important results reflecting that capital accumulation and employment are beneficial to growth and that education (although in a quantitative perspective) is in fact one of the driving forces of economic growth, supporting the endogenous growth theory. They also evidence that better health conditions (due to the reduction in infant mortality) endorse economic growth.

Moreover, looking at the whole model we can say that the main link between health and economic growth works through education.

5. Conclusions

The main argument of this paper is that there should be a cumulative causation mechanism that explains the interdependence and feed-back effects between health, education and economic growth. To capture these important linkages a simultaneous equation approach was used defining the main determinants of the core endogenous variables of the system.

The health-education-income system was estimated by 3sls, in order to provide consistent estimates and handle the problem of the endogeneity of regressors. This method also
considers cross-equation error correlation capturing important links between the core endogenous variables. The results found fill the gap of the lack of empirical evidence on this topic and particularly focusing on an individual country, Portugal.

Regarding the health equation it is shown that human resources and education standards are important determinants explaining the remarkable progress in reducing infant mortality rate in Portugal. Fertility rate also has a significant impact on infant mortality collaborating with the idea that lower fertility allows parents to invest more on children’s health and education. Therefore, human resources and socioeconomic factors explain mostly the progress that has been made in Portugal to improve health standards.

With respect to education equation, again human resources (students/teachers ratio) and per capita spending on education are the most important factors explaining the progress that has been made in the schooling enrolment. These results reinforce the idea that public support on education is an important incentive to improve the education standards.

Physical capital accumulation, employment and education are important factors in explaining the growth performance in Portugal and this is in line with the endogenous growth theory. Health factors (measured by infant mortality) also play an important role explaining per capita income growth. We also obtain evidence favoring the well-known conditional convergence hypothesis. With respect to this, increasing returns to scales should be at work stemming from human and health capital, compensating the diminishing returns of physical capital.

In general terms our model specification and estimation technique are shown to be useful instruments explaining the important inter-linkages between health, education and economic growth in Portugal.
Annex

Figure 1. Infant mortality rates, 2008 and decline 1970-2008

Source: OECD health at a glance (2010a).
Figure 2. Life expectancy at birth, 2009 (or nearest year), and years gained since 1960

Figure 3. Annual average growth rate in health expenditure per capita in real terms, 2000-09 (or nearest year)

Source: OECD health at a glance (2011a).
**Figure 4.** Total health expenditure as a share of GDP, 2009 (or nearest year)

Source: OECD health at a glance (2011a).

**Figure 5.** Public and private expenditure on education for all levels of education (as a percentage of GDP, 2008 or latest available year)

Source: OECD (2011b).
Table 2. Descriptive statistics of the variables, 1972-2009.

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<thead>
<tr>
<th>Variables</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>IMR&lt;sub&gt;t&lt;/sub&gt;</td>
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<td>15.20</td>
<td>12.18</td>
<td>3.30</td>
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<td>34.48</td>
<td>22.69</td>
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<td>gy&lt;sub&gt;t&lt;/sub&gt;</td>
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<td>0.024</td>
<td>0.034</td>
<td>-0.086</td>
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<td><strong>Exogenous variables</strong></td>
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<td>y&lt;sub&gt;t-1&lt;/sub&gt;</td>
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<td>10679.22</td>
<td>3613.23</td>
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<td>HSpend&lt;sub&gt;t-1&lt;/sub&gt;</td>
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<td>1.30</td>
<td>5.20</td>
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<td>13.9</td>
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<td><strong>Instrumental variables</strong></td>
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<td>2.40</td>
<td>4.30</td>
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Figure 6. Infant Mortality Rate, 1972-2009.

**Figure 7.** Real secondary school enrolment rate, 1972-2009.

Source: GEPE (2009); Pordata (2011).

**Figure 8.** Annual growth rate of per capita income, 1972-2009.

### Table 3. Variable description and data source:

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<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Source</th>
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<td>IMR</td>
<td>Infant mortality rate: deaths per 1,000 live births</td>
<td>OECD Health data&lt;sup&gt;(1)&lt;/sup&gt;</td>
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<tr>
<td>Edu</td>
<td>Real secondary school enrolment rate</td>
<td>GEPE&lt;sup&gt;(2)&lt;/sup&gt;; Pordata&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>y</td>
<td>Real GDP per capita in 2006 constant prices</td>
<td>Pordata</td>
</tr>
<tr>
<td>Employ</td>
<td>Employed population (in millions)</td>
<td>Pordata</td>
</tr>
<tr>
<td>K</td>
<td>Investment share on GDP</td>
<td>PWT 7.0&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nurses</td>
<td>Practising nurses, density per 1,000 population</td>
<td>OECD Health data</td>
</tr>
<tr>
<td>Hspend</td>
<td>Total public expenditure on health (per capita)</td>
<td>Pordata</td>
</tr>
<tr>
<td>Fert&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Fertility rate: number of children that would be born to each woman at the end of her childbearing years if the likelihood of her giving birth to children at each age was the currently prevailing age-specific fertility rates</td>
<td>OECD Factbook 2008&lt;sup&gt;(5)&lt;/sup&gt;; OECD Country statistical profiles&lt;sup&gt;(6)&lt;/sup&gt;</td>
</tr>
<tr>
<td>EduSpend</td>
<td>Total public expenditure on education (as a percentage of GDP)</td>
<td>Pordata</td>
</tr>
<tr>
<td>RatioS/T</td>
<td>Number of students per teacher on secondary schools</td>
<td>Pordata</td>
</tr>
<tr>
<td>Consultations</td>
<td>Number of contacts with an ambulatory care physician divided by the population</td>
<td>OECD Health data</td>
</tr>
</tbody>
</table>

**Notes:**

<sup>(1)</sup> OECD. OECD Health Data (several years), http://www.oecd.org/health/healthdata
<sup>(3)</sup> Pordata. www.pordata.pt
<sup>(4)</sup> Heston, A.; Summers, R.; Aten, B. (2011), Penn World Table 7.0 (PWT 7.0), http://pwt.econ.upenn.edu/
<sup>(5)</sup> OECD Factbook 2008: Economic, Environmental and Social Statistics
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