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Human Capital and Ageing population in a macroeconomic overlapping generation model*

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Abstract

In this paper we consider two fundamental factors explaining economic growth: the human capital and the demographic structure of a population.

Both aspects are analyzed in an overlapping generation model that has been developed by Prometeia to reproduce the path of the Italian economy. This model is a general equilibrium system for long term scenarios with endogenous determination of real wages, interest rates and tax rates, at this stage of development, in a closed economy.
The consumption side is a life cycle model with rational agents that maximize a utility function for consumption and leisure for all lifetime paths, without any bequest motive.
The production side of the model comprises an estimated production function defined in terms of effective labour units, capital stock and the GDP of the Italian economy. The public sector is very simple. It consists only of the social security and education systems, and its revenue comes from the exact amount of payroll taxes required to finance current benefit claims under the prevailing rules.

Human capital is the accumulation of all past improvements in the quality of labour. We highlight how the effects of the accumulation of human capital and its impact on production are very similar to those related to physical capital, since both human and physical capital are production inputs and explanatory elements describing economic differences across countries. Hence public investments in human capital help to increase the growth rate of a country and to balance the negative effects of other economic variables, for example ageing.

There are two basic forms of human capital: human capital in the form of physical health and human capital in the form of education. In this paper we consider the latter. Indeed, in developed economies, intellectual ability is more important than physical ability in determining individual wages. As a consequence, investments in education have become the most important form of investment in human capital.

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However, calculating the returns to human capital is more complicated than calculating the returns to physical capital because human capital is always attached to its owner. To mitigate this problem we infer the returns to human capital from the different productivity time paths of the agents, hence from different levels of wages.

The dynamics of the demographic structure is another factor crucial for the long run path of an economy. Demographic structures change at different paces and with different degrees of intensity in the developed countries of the world. Ageing is already having significant effects in Italy, Japan and Germany. By the middle of this century the ratio of people of working age to those of retirement age will change dramatically. The dynamics related to ageing could have a powerful impact upon saving behaviour in both the public and private sectors; it also could affect capital formation, labour supply, tax rates, real wages, public pension systems and GDP growth.

We mimic the ageing demographic structure of Italy with overlapping generations; as a qualifying assumption we highlight that generations differ not only in terms of age but also in terms of education level (graduate or post graduate, certificate, qualified, secondary and primary schooling), and assume that different levels of schooling produce different lifetime productivity profiles.

This double characterization of the behaviour of microeconomic agents is necessary to develop the long run relationship between public expenditure on education and the evolution of human capital. Indeed, public investment in education, which increases the quality of human capital, is a tangible economic policy instrument that could be used to contrast the negative effects of an ageing population.

We provide a detailed description of the model and the age structure of the population and assess the impact of increasing investment in education as a support for reforms to the pension system, to highlight the negative effects of ageing.

1. Introduction

The demographic structure of populations is changing at different paces and different degrees of intensity in the developed countries of the world. Ageing is affecting many of today's societies, but is especially prominent in the industrialized countries, which have been feeling effect for a considerable period and where the effects are forecast to become even more pronounced over the next four decades, at the end of which a peak in the proportion of the elderly in the population is likely to be reached. In Italy, Japan and Germany the effects of ageing are already becoming, significant. In the United States and Canada this type of demographic change is forecast to emerge in the second decade of this century and in other developing economies after various time lags.

An ageing society is characterized by a growing proportion of retired to active working population. Societies age because fertility rates have declined so that fewer children are being born, or longevity has increased, or both.

Such ageing dynamics could have a powerful impact upon some of the more important macroeconomic variables such as saving behaviour in both the public and the private sectors; they could also affect capital formation, labour supply, tax rates, real wages, public pension systems and GDP growth. All these changes could have important political consequences. The level of aggregate savings and investment is forecast to fall significantly and government budgets will come under increasing pressure: social security systems will undergo increasing difficulties to balance public expenses and tax revenues. This aspect is particularly relevant because in most of continental Europe, unfunded public retirement pension systems constitute the largest part of government budgets.

In the industrialized countries, public schemes for providing for retirement are predominantly the pay-as-you-go (PAYG) type, which typically provide comprehensive coverage, but which are frequently supplemented by funded schemes, mostly operated by the private sector. A standard PAYG system levies payroll taxes on the working population, while paying benefits to the retired, but usually without the close person-based relationship between individual contributions and benefits that characterizes fully funded schemes. In the early stages of a PAYG system, fairly low contribution rates are sufficient to cover the claims of a relatively small number of beneficiaries, but as the scheme matures, the benefits paid out tend to exceed the contributions, requiring increases in payroll taxes or budget transfers. Considerable additional fiscal stress is likely to emerge under a PAYG system, as the proportion of the retired elderly rises. And if, as typically occurs, the PAYG scheme also involves various redistributive elements, there is further potential for fiscal stress, and especially as the population ages. A failure to address these fiscal stresses could inflict serious macroeconomic and structural damage on the domestic economy and, in the case of large industrial countries, through international linkages, on the world economy.

The simplest solution to decreasing the pressure on the economic system is the introduction of more restrictive pension rules. If no corrections are made to the social rules to decrease substitution rates the retirement system may eventually collapse. Policy makers, for example, could introduce in the pension system parametric adjustments to its structural characteristics, such as contribution rate, retirement age, and pension benefit indexation formulas, perhaps in combination with a building up of greater financial reserves. Another possible solution might be the introduction of systematic reforms to develop a significant, contribution-defined, fully funded pillar either within or in addition to the existing public pension scheme. Government could undertake broad fiscal adjustments including raising taxes and cutting expenditures not related to public pensions.

In addition, the macroeconomic profile of the economic system could be modified by changes to such aspects as the size of the labour force by, perhaps, encouraging greater labour force participation, or immigration.

To estimate the reforms to be applied to the retirement system it is important to have reliable estimates of the impacts of ageing populations on the most relevant macroeconomic variables, and the changes to the time paths of these variables as determined by more restrictive pensions rules. A computed general equilibrium model is the instrument to be used in this case to estimate adequately the effects of social reforms.

There are several economic models within economic theory that have been proposed to estimate the effects of the exchange of retirement and labour market rules on the GDP time path[1].

Another possible way of avoiding a collapse of the retirement system, which has received less attention in the economic literature within the general equilibrium model framework, is the development of the human capital. Countries that incentivize the development of human capital on the production side tend to emphasize their industrial sectors, which require more skilled workers and, in general, are high tech sectors. There is a lot of empirical work demonstrating that

[1] De Nardi, Imrohoroglu and Sargent (2001) study in detail saving and pension reforms in the context of general equilibrium models. In particular, they present quantitative results from some policy experiments previously computed in the literature in a contest of ageing population.

differences in the quality of workers are one explanation for differences in GDP growth among countries[2].

Economic theory considers two basic forms of human capital: human capital in the form of physical health and human capital in the form of education.

As a country develops economically, the average health of its population improves. This improvement in health is direct evidence of the population's better quality of life. In other words, health is something that people value for itself. But health also has a productive side: healthier people can work harder and for longer; they can also think more clearly. Healthier students learn better. Thus, better health levels raise countries' income levels.

In this paper we consider the education aspects of human capital. In developed economies, intellectual ability is more important than physical ability in determining individual wages. As a consequence, investments in education have become the most important form of investment in human capital.

Calculating the returns to human capital is more complicated than calculating the returns to physical capital because human capital is always attached to its owner. To solve this problem we infer the returns to human capital from the different productivity time paths of agents, and hence the different levels of wages.

In our model human capital is stylized as the accumulation of past improvements in the quality of labour. The effects of the accumulation of human capital and its impact on production are very similar to those of physical capital, since both human and physical capital are inputs of production and explanatory elements of the economic differences across countries. Hence, public investments in human capital help to increase a country's growth rate and to balance the negative effects of other economic variables. In our model the increasing use of human capital balances the negative effects of ageing. In particular, we show that a positive shock in human capital stock of a country can support GDP growth rates and aggregate savings rates, and decrease fiscal pressures on the retirement system. Thus, if government offers incentives to its citizens to invest in education this could mitigate the problems associated with ageing without the need for excessively restrictive pension and labour rules.

The effects of the ageing population and human capital development are analysed in this work in an overlapping generation model (OLG). The first OLG framework was proposed by Samuelson (1958) and amended by Diamond (1965) for a growing economy, with production, capital accumulation and government debt. This classical model was used by Feldstein (1974) to analyse the effects of an unfunded PAYG system on capital accumulation in a deterministic context.

Over the years, these theoretical frameworks have inspired applied developments used to study the prospects of national pension schemes in large scale OLG models. However, many such studies, starting with the pioneering work of Auerbach and Kotlikoff (1987) on the US economy, exploit a deterministic, 55-cohort OLG model to achieve a more accurate analysis of the effects of PAYG on macroeconomic variables and to accommodate the well forecast demographic baby boom, also referred to as the baby bust shock. Subsequent works modified Auerbach and Kotlikoff's model, adding extra features to make it more realistic. The most important among these is Miles's (1999) study, which considers representative agents with longer lifetime paths and within a detailed macroeconomic contest.

[2] Benhabib and Spiegel (2005) consider human capital and technological diffusion as elements explaining economic growth. They also present some empirical articles distinguishing between education as a factor of production and/or a factor that facilities technology diffusion. Furthermore, see also Manuelli and Seshadri (2005) or Hall and Charles (1999).

Another important strand of studies has incorporated various sources of uncertainty, heterogeneity and market imperfections in computable OLG models[3]. Some authors have developed tractable stochastic OLG models applied in environments with aggregate technological as well as birth rate shocks, to analyse the effect of social security rules on risk-sharing between generations (Bohn 1998, Diamond 1997, Chateau 2003), on equity premium (Abel 1999a) on stock prices (Abel 1999b) and even on the broad efficiency of the system (Demange and Laroque 1999).

This paper takes the first theoretical mainstream as a benchmark. Our overlapping generation structure has been developed to reproduce the path of the Italian economy. It is a general equilibrium system for long term scenarios with endogenous determination of real wages, interest rates and tax rates in a closed economy. The model is a life cycle model with rational agents that maximize a utility function for consumption and leisure in their lifetime, without any bequest motive. The peculiarity of this work is related to the development of human capital at the microeconomic level and not just as a macroeconomic variable, and to its use as an instrument to balance the negative effects of ageing. Human capital is introduced in the production function as an additional macroeconomic variable while at the microeconomic level we introduce differences in generations for age and also for schooling (graduate level, certificate level, qualifications, secondary schooling, primary schooling), under the assumption that agents with different levels of schooling have different lifetime productivity profiles.

The productive side of the model builds on an estimated production function defined in terms of effective labour units, capital stock and the GDP of the Italian economy. Total factor productivity (TFP) grows endogenously in terms of capital stock[4]. The public sector is very simple; it consists only of the social security and education systems: its revenue is the exact amount of payroll taxes required to finance the current benefit claims under the rules of the time period we are examining.

The paper is organized as follows. In Section 2 we describe the analytical aspects of our model: the equations introduced allow us to study the impact of the dynamic population structure on the equilibrium. Section 3 considers the parameterization process and the microeconomic and macroeconomic results within a basic scenario. The last sub-section of Section 3 proposes an alternative scenario with positive human capital shock to allow us to compare results with the basic scenario. Section 4 concludes.

2 . Brief introduction to the model

Our forecasting tool is a calibrated model of the Italian economy designed to asses the impact on savings, interest rates, tax rates, labour supply, wages and capital stock of the demographic changes forecast to take place over the next 50 years. At every period the model has many generations living, differing in age and schooling; the relative numbers of people in different cohorts are adjusted to match the ISTAT (Italian National Institute of Statistics) population projections for the Italian Economy and the data from the ISTAT labour force survey.

In addition to consumers, we consider two other agents: a representative production sector and an infinitely existing government. As we said in the previous section, in our model government is reduced to the social security and education departments; thus we abstract from government purchases and taxes that will not be equal to the retirement contribution or the schooling rate. We

[3] For a discussion of the various issues related to large scale OLG methods see De Nardi, Imrohoroglu and Sargent's (2001) survey; for formal presentations of various models of this type see the survey by Imrohoroglu, Imrohoroglu and Joines (1998).

[4] For analogous definitions see Jorgenson and Griliches (1967), Griliches (1979), Romer (1986).

also assume a closed economy-framework. The time period set is one year. All variables are in real terms; thus, money is not considered.
If we consider the overlapping generation structure, this model is an alternative and more complex version of the framework developed by Miles (1999) for the UK, which is itself a variant of Auerbach and Kotlikoff's (1987) model. Our model differs from Miles in that: 1) we consider generations that differ in terms of age and schooling levels; 2) we take account of social security and education departments (with retirement contributions and education taxes endogenously determined); and 3) we introduce a more complex production function that is not homogenous at degree one (but which considers increasing returns to scale and an endogenous TFP) estimated for the Italian economy. Another extension is the more realistic demographic structure on which our model is based with 113 different age cohorts. In particular we consider agents that entered the economic system at the age of 15 between 1938 and 2050, i.e. those that were born between 1924 and 2036) and include 4 schooling cohorts for a total of 452 generations.
The forecast period is 2007 to 2050 and the time path from 1938 to 2119. In 2050 there will be agents who will live to 2119, and 2007 includes agents "born" (i.e. entered the economic system at the age of 15) in 1938. Therefore we have to solve the model from 1938 to 2119.

The model is solved sequentially. First, based on historical data and ISTAT population projections and the labour force survey, we estimate the size of age cohorts to construct a series from 1938 to 2050 for the relative number of people aged between 15 and 84, alive at each point. In each year for each age we will have four generations that differ in their level of schooling: primary and secondary school (which starts working aged 15), qualified (which starts working aged 18), certificated (which starts working aged 20), and graduate (which starts working aged 25).
We make an initial guess about real interest rates and wages based on their long run average values. Similarly, values for schooling tax and contribution rates are based on the average values for the period 1938 to 2006.
Based on these initial estimates for interest rates, wages and tax rates, we solve the dynamic programming problem for every agent alive in every period, and with different levels of schooling, to determine optimal labour supply, optimal consumption, optimal savings and optimal wealth. The total stock of wealth and the aggregate supply of labour – computed as the initial conjecture related to interest rates, wages, schooling tax rates and contribution rates - generate a new time series for the capital to labour ratio, which implies a new pattern of interest rates, wages, and tax and contribution rates. These new values are the start values for the second iteration.
The procedure is repeated until a fixed point is reached; at that stage the actions of every agent alive at any point between 1938 and 2050 are optimal given the time series of interest rates and post tax and contribution real wages they face over their lives. How those interest rates and post tax wages evolve is consistent with the decisions of all individuals. The model in our last version was programmed in Matlab.

2.1 Demographics

In this general equilibrium model, agents plan labour supply and consumption choices in each period from their entry into the economic system (i.e. at age 15) to the year of their death (i.e. 84). Thus, we have a context in which each agent knows the length of his lifetime path. The economy then is populated by overlapping generations of unisex agent that lives for 70 years and that differs in terms of both age and education level which might be equal to: PS (primary and secondary schooling), QD (qualified), CD (certificated), GD (graduate).

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In this model we assume that people with primary and secondary schooling start working at 15, i.e. when they enter the economic system, qualified people start working at 18 (i.e. 3 years after entry), certificated people start work at 20 (that is 5 years after entry) and graduates at 25 (that is 10 years after entry). Students are supported by government which draws financial resources from the active labour force by means of an education tax.

The number of people born in year *t-a* - that is of age *a* in year *t* - and with a schooling level equal to *i* is denoted by $L_{t-a}^{i}(t)$. By assumption, $a \in [15, \quad 84]$.
The total number of people aged *a* in year *t* will be equal to $L_{t-a}(t) = \sum_{i} L_{t-a}^{i}(t)$ with $i \in \{PS, \quad QD, \quad CD, \quad GD\}$.
The total number of "births" (that is new entries) in year *t* is denoted by $L_{t-15}(t)$ while the total number of people in time *t* will be equal to $L(t) = \sum_{a=15}^{84} \sum_{i} L_{t-a}^{i}(t)$ with $i \in \{PS, \quad QD, \quad CD, \quad GD\}$.

In our model, for each age in a particular year on the temporal axis, there are four different representative consumer choices: one for graduates, one for certificated, one for qualified and one for primary and secondary school agents.
For instance, if we consider the generic choice variable *x* for an agent aged *a* in year *t*, we achieve the four configurations: $x_{t-a}^{PS}(t), \quad x_{t-a}^{QD}(t), \quad x_{t-a}^{CD}(t), \quad x_{t-a}^{GD}(t)$. Starting from these four variables:

1. the aggregate level of x for people aged *a* in year *t* is equal to a weighted mean, which takes as its weights the data projections from *ISTAT labour force survey*: in particular we consider the expected values of the relative frequencies of population of age *a* in year *t* and with *i* schooling: $q_{t-a}^{i}(t)$ with $i \in \{PS, \quad QD, \quad CD, \quad GD\}$; $\sum_{i} q_{t-a}^{i}(t) = 1$,

$$q_{t-a}^{i}(t) = \frac{L_{t-a}^{i}(t)}{L_{t-a}(t)} \tag{1}$$

So $x_{t-a}(t) = \sum_{i} x_{t-a}^{i}(t) \cdot q_{t-a}^{i}(t)$ (2)

2. the aggregate level of x in year *t* is equal to a weighted mean that takes as its weights the *ISTAT projections for the Italian population*: in particular we consider the expected values of the relative frequencies of population of age *a* in year *t*: $f_{t-a}(t)$ with $a \in [15, \quad 84]$;

$$\sum_{a=15}^{84} f_{t-a}(t) = 1, \quad f_{t-a}(t) = \frac{L_{t-a}(t)}{L(t)} \tag{3}$$

So $x(t) = \sum_{a=15}^{84} x_{t-a}(t) \cdot f_{t-a}(t)$ (4).

2.1.1 Data sources

As described in the previous section, in our analysis we use two data sources: the *ISTAT labour force survey* and the *ISTAT projections on Italian population*. ISTAT conducts its annual labour force survey quarterly. The principal purpose of this inferential analysis is to estimate the main aggregates of the labour force. The contents, the methodologies and the organization of this survey can be found on the ISTAT web site. ISTAT uses a two-stage sample, respectively municipality and household, with stratification of first stage unities. In each quarter ISTAT interviews 175.000 people in 1.246 municipalities in Italy.
In our work we consider only a two-way table of relative frequencies for the total population equal to or older than 15, $q_{t-a}^{i}(t)$, not the aggregate labour force, such that $\sum_{i} q_{t-a}^{i}(t) = 1$.

We start with data for the last five years, i.e. 2001 to 2006, and construct fitted values for the relative frequencies from 2007 to 2050 using the procedure implemented by Prometeia[5].

The other data source for our analysis is the *ISTAT projections for the Italian population*. ISTAT has established the central setting for the estimated projections for the period 2000 to 2050 for Italy, its regions and the self-governing provinces of Trento and Bolzano. The population used as the baseline for processing is the regional valuations for 1 January 2000. Estimated projections relate to the resident population and, for the first 20 years, include an evaluation for the foreigners regularly living in Italy.
In the short and medium term, this considers the more likely Italian population development based on recent trends in the main demographic components. In the long term, the number and the importance of the factors that will produce a divergence in the demographic components from the projected trajectory are progressively increased. The error margin connected to these assumptions becomes wider, and the estimates projections progressively lose their power to predict a "likely future" and become scenarios whose only purpose is to illustrate the possible implications of certain demographic situations in the long run. In order to render explicit the uncertainty accompanying the forecasting of a long time period, from 2030 onwards all parameters used in the estimates projections are kept steady. In our analysis we consider only people between 14 and 85 years of age.

2.2 The model in more detail

In the next sections we analyse how the key parameters of the model are set. Before this we need to consider all the elements that could influence the development in the quality of inputs (i.e. labour and capital stock), at both microeconomic and a macroeconomic levels, that are introduced in our model.
Labour and capital factors evolve at the macroeconomic level through two channels:

1. *TFP*. In this case the literature defines a total scale factor not as constant but as evolving in accordance with an established rule. In this model we consider TFP as endogenously predetermined and depending on aggregate capital stock[6].
2. *Effective labour and capital units* (macroeconomic quality of human and physical capital). In this case the effective labour and/or capital units are introduced as independent variables within the production function - not aggregate labour supply and/or the capital stock. Thus, the same stock of workers or capital will be able to

[5] For presentations of this methodology see Prometeia (2004).
[6] For analogous definitions see Jorgenson and Griliches (1967), Griliches (1979), Romer (1986).

generate an higher value of effective labour or capital units as time goes by. In our model we consider only the aggregate evolution of labour units, as aggregate human capital effects.

At the microeconomic level we could consider two other developments that influence labour input, which could be introduced only in a general equilibrium model with overlapping generations.

3. *Development of the quality of the representative worker's endowment* (effective labour units for each cohort). In this case we need to define a labour productivity rule for each cohort (time related factor), which includes an age-invariant factor that increases the efficiency of younger cohorts (i.e. a worker aged 40 born in 1980 will be more productive than a worker of the same age from an earlier cohort, e.g. born in 1960). To include this variable in the model economic theory[7] considers the sum of increments in output per head of the economy from the past to the current time. This allows technological progress to influence labour according to a dynamic (which considers the age structure of the labour force) and not a static (which considers the labour force as a whole) evolution. In this model we consider this latter aspect. We also consider differences in years of schooling (schooling related factor) such that a graduate will always be more productive than, for example, a primary or secondary level agent.
4. *The age related element that explains the growth of the labour endowment*. In this case the productivity of each cohort is a concave function w.r.t age. This feature of the model is useful to highlight that younger workers are more productive than older ones, regardless of cohort and birth year.

In Sections 2.3 to 2.5 we describe all the aspects of the model and the consideration of these four channels will become clearer.

2.3 The household sector

2.3.1 Human capital at the microeconomic level and total endowment of effective units of labour

As highlighted in the introduction, the model considers human capital in the form of education. This has many similarities to physical capital: both require investment for their creation, and once created, both have economic value. In the case of human capital as education, however, calculating returns is more complicated because human capital is always attached to its owner. We cannot separate the person's education from the rest of him or her to see how much it can be rented for. This makes measuring the returns to human capital more difficult than in the case of physical capital.

To get round this problem, we could infer the returns to human capital from data on wages. That people with higher levels of education receive higher wages can be taken as evidence of the market value of their human capital. We define the return to education as the increase in wages that a worker would receive if he or she had one more year of schooling. To be more specific, suppose we find the return to a particular year of schooling—say, seventh grade—to be 10%. This implies that if we compared two otherwise identical workers, one of whom had sixth-grade education and one of whom had seventh-grade education, we would expect the more educated worker to earn 1.10 times

[7] For analogous definition see Miles (1999).

more than the less educated worker. Hall and Jones (1999) show that the returns to education are 13.4% per year for the first four years of schooling (grades 1–4), 10.1% per year for the next four years (grades 5–8), and 6.8% per year for education beyond eight years. The fact that the earlier years of education produce higher returns is not surprising, because these are the years when the most important skills, notably reading and writing, are taught.
We will consider these percentages to describe schooling-related productivity. In particular we consider the differences in number of years of schooling among primary and secondary level educated agents, and the others. We analyse more than eight years of education; thus, the percentage that we apply is 6.8

The labour income for the workers in each cohort will be equal to:

$$y_{t-a}^{i}(t) = \frac{w}{p}(t) \cdot l_{t-a}^{i}(t) \cdot h_{t-a}^{i}(t) \cdot (1 - \tau_1(t) - \tau_2(t)) \qquad (5)$$

where: $\frac{w}{p}(t)$ is the real wage in year t; $l_{t-a}^{i}(t)$ is the labour supply in year t for an agent that was born in year *t-a* with schooling *i*; $h_{t-a}^{i}(t)$ is the total endowment of effective unit of labour in year t for an agent that was born in the year *t-a* with schooling *i*; $\tau_1(t)$ and $\tau_2(t)$ are respectively the endogenous contribution rate and the endogenous schooling tax rate.

We highlight that $h_{t-a}^{i}(t)$ evolves reflecting the age specific productivity, the schooling–related productivity and the time-related productivity as described in the points 3 and 4 of Section 2.2[8].

2.3.2 Consumers' choices

Agents maximize a utility function that depends on the present value of consumption and leisure available in each period of their lifetime; the model is a classic life cycle model without a bequest motive. Further, we assume that consumers have an intertemporal substitution elasticity defined in terms of consumption and leisure. The time path of the agent's consumption and labour supply choices depends on the interest rates, expected future real wages and labour productivity path vary according to age. Moreover, agents have to satisfy a lifetime budget constraint that equals the present value of their lifetime consumption and that of their post-taxation lifetime work and pension income. Obviously, agents will choose to save during their working lifetime and not in retirement. The optimal choices will persist to death because we are in a certainty contest in which individuals know how many years they are going to live and there are no uncertainties related to income. Then the only motive for saving is voluntary retirement saving.

We also need to highlight that PS agents start working at the age of 15, when they enter the economic system while QD agents start at age 18 (i.e. they study 3 years more than PS agents), CD agents at 20 (i.e. they study 5 years more than PS agents) and GD agents at 25 (i.e. they study for 10 years more than PS agents). Students' consumption is supported by the government through revenues obtained from taxes on the active labour force through the education tax system. During years of study then, we will assume that utility depends only on consumption -not on labour supply-

[8] The total endowment of effective unit of labour is implemented following the framework adopted by Miles (1999). For a more detailed description please contact the author.

and that agents are rule-of-thumb consumers: that is they consume the whole current income, which is equal to the state scholarship. Finally after pension age agents cannot work.
To be more precise, each agent will maximize a lifetime utility function which depends on the consumption of goods and leisure in each working period and on consumption only in study and retirement periods. We assume an additive and separable form of the agent's utility function so that lifetime utility for the cohort that enters the economic system in year *s* (that was born in year *s-15*) and with schooling i -denoted U_s^i - is:

$$U_s^i = \begin{array}{l} \sum_{t=s}^{t=s+\Delta_i-1}\left(\frac{\left\{u\left[\tilde{c}_{s-15}^i(t)\right]\right\}^{(1-1/\xi)}}{(1-1/\xi)}\right)\cdot\left(\frac{1}{(1+\rho)^{t-s}}\right)+ \\ +\sum_{t=s+\Delta_i}^{t=s+r_s(t)-1}\left(\frac{\left\{u\left[c_{s-15}^i(t),\left(1-l_{s-15}^i(t)\right)\right]\right\}^{(1-1/\xi)}}{(1-1/\xi)}\right)\cdot\left(\frac{1}{(1+\rho)^{t-s}}\right)+\sum_{t=s+r_s(t)}^{t=s+T}\left(\frac{\left\{u\left[c_{s-15}^i(t)\right]\right\}^{(1-1/\xi)}}{(1-1/\xi)}\right)\cdot\left(\frac{1}{(1+\rho)^{t-s}}\right)\end{array} \qquad (6)$$

where Δ_i is the schooling year differential for individuals with a schooling degree *i* and primary and secondary school agents. Then Δ_i is equal to 0 for PS agents, 3 for QD agents, 5 for CD agents and 10 for graduated agents.
If we consider primary and secondary school agents only then the first part of equation (6) would be missing. This is because we assume that these agents will start working in the year of entry into the economic system. For the other agents the entire formula (6) applies – assuming rule of thumb consumption[9].
T is the length of life (70 adult years for all agents).
$r_s(t)$ is the number of contribution years required for the generation born in year *s* to obtain the pension.
ρ is the rate of time preference (cohort invariant).
ξ is the intertemporal elasticity of substitution, i.e. a parameter that determines the degree of intertemporal substitutability of consumption and leisure (cohort invariant).
$c_{s-15}^i(t)$ is the consumption of a cohort with schooling *i*, born in the period *s-15* (that enters in the economic system in year s) in year *t*. $\tilde{c}_{s-15}^i(t)$ -during years of education- indicates the rule of thumb consumption always equal to the current income.
$l_{s-15}^i(t)$ is the normalized labour supply.
$1-l_{s-15}^i(t)$ is consumption of leisure ($0 \le l_{s-15}^i(t) \le 1$).

The within period utility functions $u\left[c_{s-15}^i(t)\right]$ and $u\left[c_{s-15}^i(t),\left(1-l_{s-15}^i(t)\right)\right]$ are assumed to be of the constant elasticity substitution type:

$$u\left(c_{s-15}^i(t)\right)=\left[c_{s-15}^i(t)^{(1-1/\varepsilon)}\right]^{1/(1-1/\varepsilon)} \qquad (7)$$

$$u\left(c_{s-15}^i(t),\left(1-l_{s-15}^i(t)\right)\right)=\left[c_{s-15}^i(t)^{(1-1/\varepsilon)}+\alpha\left(1-l_{s-15}^i(t)\right)^{(1-1/\varepsilon)}\right]^{1/(1-1/\varepsilon)} \qquad (8)$$

where α is a parameter that determines the intensity of preference for leisure relative to consumption and ε determines the substitutability of consumption and leisure. α will be set to

[9] We follow the analytical framework advocated by Campbell and Mankiw (1989).

match the average supply of labour of an agent over its life. ε determines how the supply varies over time in response to the changing opportunity costs of labour over the agent's life cycle.

The period to period budget constraint is:

$$w_{s-15}^{i}(t)=(1+r(t))\cdot w_{s-15}^{i}(t-1)+y_{s-15}^{i}(t)-c_{s-15}^{i}(t)+p_{s-15}^{i}(t) \qquad (9)$$

where $w_{s-15}^{i}(t)$ is the wealth of the cohort with schooling *i*, born in the period *s-15* (and enters the economic system in year s) in year *t*. *r(t)* is the interest rate in year t. $y_{s-15}^{i}(t)$ is the post tax labour income for the cohort with schooling *i*, born in the period *s-15* in year *t*. $p_{s-15}^{i}(t)$ is the state pension for the cohort with schooling *i*, born in the period *s-15* in year *t*.

The post tax labour income $y_{s-15}^{i}(t)$ is determined starting from formula (5). The lifetime budget constraint for the generation with schooling *i* born in the period s-15 is:

$$\sum_{t=s}^{s+T}\left[\frac{c_{s-15}^{i}(t)}{\prod_{t=s}^{s+T}(1+r(t-s))}\right]=\sum_{t=s}^{s+T}\left[\frac{y_{s-15}^{i}(t)+p_{s-15}^{i}(t)}{\prod_{t=s}^{s+T}(1+r(t-s))}\right] \qquad (10)$$

The optimal choices during the working years determine two sets of first order conditions. The sets of first order conditions in conjunction with the lifetime budget constraint -formula (10)- give the optimal decisions relating to consumption and leisure for all representative agents' lifetime paths.

2.3.3 Consumers' Parameterization

In our simulations we set the rate of time preference (ρ) equal to 0.0101. The rate of time preference is similar to that used by Miles (1999) and Auerbach and Kotlikoff (1987). The value of the intertemporal elasticity of substitution (ξ) is equal to 0.99. In the literature, the value attached to this variable is more controversial. Miles (1999) uses a value equal to 0.75 while Cooley and Prescott (1995) use unity and Auerbach and Kotlikoff (1987) use 0.25. Empirical work by Hansen and Singleton (1993) and Mankiw et al. (1985) suggests values a little over unity while Mankiw (1985) and Hall (1980) found values between 0 and 0.4.
Finally, we set α, the relative weight of leisure against consumption, to a value lower than that used by Miles (1999) – that is 0.33. Miles's value is in line with the UK English labour market, which involves a 40 hour working week and a typical working year of 48 weeks. Considering that in the Italian labour market the typical working year is 47 weeks and many individuals work less than 40 hours a week, we consider a value for α equal to 0.299 to be more appropriate.

2.4 Aggregate Labour and Physical Capital

We calculated savings, wealth and labour supply for all representative members in each generation to determine aggregate savings, wealth and labour supply. The determination of aggregate variables is trivial. We followed a procedure similar to that described in Section 2.1.

Total labour supply N(t) is equal to[10]:

$$N(t) = \sum_{a=15}^{25+r_a(t)} l_{t-a}(t) \cdot f_{t-a}(t) \qquad (11)$$

$$l_{t-a}(t) = \sum_i l_{t-a}^i(t) \cdot q_{t-a}^i(t) \qquad (12)$$

where $r_a(t)$ are the contribution years required in year *t* to obtain the pension.

Similarly, aggregate wealth W(t) of families in year t is equal to:

$$W(t) = \sum_{a=15}^{84} w_{t-a}(t) \cdot f_{t-a}(t) \qquad (13)$$

$$w_{t-a}(t) = \sum_i w_{t-a}^i(t) \cdot q_{t-a}^i(t) \qquad (14)$$

where $w_{t-a}^i(t)$ is the individual wealth that each agent of schooling *i* and age *a* has accumulated in year *t*.

The capital stock, *K(t)*, used in domestic production is simply:

$$K(t) = W(t) \qquad (15).$$

2.5 The production sector

As highlighted in Section 2.2, at the macroeconomic level we consider two different channels to explain development in the quality of inputs: technology change and aggregate human capital.

The recent literature[11] provides several measures that can be used to specify aggregate human capital as education. Many of these measures use imperfect proxies for the true stock of human capital. The main reason for the use of poor proxies for human capital stock is that most empirical growth studies do not focus on human capital depending much more on the data available. To solve the problem of data availability we employ a very simple proxy. Human capital stock (i.e. the variable *H(t)*) is calculated as a Törnqvist index[12].

The correction for quality in labour input is one of the channels used to express technological progress. However, this does not capture all technological progress effects. Therefore, we also looked at TFP. In particular, we introduced an estimated production function for the Italian

[10] In this model we implicitly assume that there is always full employment and only voluntary unemployment. Then the aggregate labour supply will be always equal to the aggregate labour demand and both will coincide with the labour input introduced in the production function.

[11] For a survey of the different specifications of aggregate human capital as education see Wöbmann (2004).

[12] The total endowment of effective unit of labour is implemented following the framework adopted by Rossi (2003). For a more detailed description please contact the author.

Economy[13] in which TFP, as highlighted in Section 2.2, grows endogenously in term of capital stock.

The profit-maximizing behaviour of the representative firm gives first order conditions which determine the endogenous real rate of return to capital, net of depreciation, and the endogenous real wage rate. As described in Section 2, the vectors of these two endogenous variables are crucial for determining the equilibrium of the model.

2.6 The public sector

As argued in the previous sections, in our system the public sector is very simple, consisting of only the social security and education departments: its current revenue is the exact amount of payroll taxes required to finance the current benefit claims under the rules of the time period being considered. Since we consider only two departments, we decided to introduce two corresponding and distinct taxation systems: education tax and retirement contributions. Both taxation systems are endogenously determined, meaning that the two fiscal rates are obtained by considering two distinct public budget constraints that correspond to public expenditure and related fiscal revenues. Further, in our scheme we assume that in each year the education and retirement departments are balanced and thus the current deficit is equal to 0. This is a restrictive implication that could be removed with further developments to our model; however, endogenous predetermination of the two rates is useful to study the impact of ageing on the retirement department and the effects of increasing the use of human capital to reduce fiscal pressures (and not only to increase GDP growth). This demonstrates that the modelling tools in our model (in this case the government sector) are a direct expression of our research aims.

The model considers two endogenous rates as equilibrium variables for the public sector:

1. the first is the fiscal revenue used to support the education department's current public expenditure on schooling (i.e. state scholarships and other expenses that the public schooling is responsible for, e.g. teachers' wages, costs of managing the public infrastructures, etc.);
2. the second is applied to balance current pensions with the contributions from payroll taxes paid by the active labour force according to the rules of the Italian PAYG system.

In Sections 2.6.1 to 2.6.4 we describe how these two endogenous rates were determined.

2.6.1 The schooling structure

In our model, for each age in a particular year, on the temporal axis, there are four different representative consumer choices: one for graduates, one for certificated, one for qualified and one for primary and secondary schooling. Individuals with only primary and secondary school education -PS- start working at the age of 15, when they enter in the economic system. Qualified

[13] This function was estimated based on aggregate data on the Italian economy using the Johansen (1988) and Stock-Watson (1988) methodologies. We developed a VECM analysis with four endogenous variables, i.e. GDP, physical capital, Labour*Human capital, value added of saleable services sector to industry sector ratio. We found only one cointegration vector that coincided with the long term production function. For a detailed description of the econometric analysis and TFP specification of our model see Prometeia (2004) or contact the author.

people -QD- start working at the age of 18 (i.e. three years entry to the economic system), certificated people -CD- start work at 20 (that is five years after entry to the system) and graduated people -CD- start at 25 (that is 10 years after entry to the economic system). Students' consumption is supported by government drawing on financial resources from the active labour force through the education tax.
Thus, the representative agent with primary or secondary level schooling starts working the same year of entry to the economic system, while the others continue to improve their skills, starting work at the end of their particular studies. During their period of study they do not receive work income, but receive resources from government. As described in Section 2.3.2- students are rule of thumb consumers: that is they consume their entire current income, the value of the state scholarship.
The public sector will finance the state scholarships with the schooling tax revenue. Then in each year of the forecasting period the schooling department will collect resources from the active labour force to distribute them among the students. Thus, if we consider a generic year t in the forecasting period there are four new representative agents (each 15 years old) that will enter in the system: a primary and secondary school level agent, a qualified agent, a certificated agent and a graduate. The PS agent will start working in year t, the QD agent in year t+3, the CD agent in year t+5 and the GD in year t+10. Therefore, in year t government has to finance:

1. the consumption of QD agents of 15, 16, and 17 years of age ;
2. the consumption of CD agents of 15, 16, 17, 18, and 19 years of age;
3. the consumption of graduates of 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24 years of age.

The total amount of public expenditure on education will be equal to the weighted sum of the three previous elements:

$$SG(t) = \phi(t) \cdot \left[\sum_{a=15}^{17} c_{t-a}^{QD}(t) \cdot \frac{q_{t-a}^{QD}(t)}{q_{t-a}^{QD}(t) + q_{t-a}^{CD}(t) + q_{t-a}^{GD}(t)} + \sum_{a=15}^{19} c_{t-a}^{CD}(t) \cdot \frac{q_{t-a}^{CD}(t)}{q_{t-a}^{QD}(t) + q_{t-a}^{CD}(t) + q_{t-a}^{GD}(t)} + \sum_{a=15}^{24} c_{t-a}^{GD}(t) \cdot \frac{q_{t-a}^{GD}(t)}{q_{t-a}^{QD}(t) + q_{t-a}^{CD}(t) + q_{t-a}^{GD}(t)} \right] \tag{16}$$

where: *SG(t)* is the total amount of schooling public expenditure in year t; $c_{t-a}^{i}(t)$ is the consumption of an agent born in year t-a with schooling level i; $\phi(t)$ is an exogenous scale factor. It is higher than 1 because it takes account not only of students' consumption, but also the other expenses of the public schooling sector (e.g. teachers' wages, the costs of managing the public education infrastructures, etc.).

Government will support this expenditure through the revenue from the education tax that is levied on the active labour force. We assume that in each year the education department balances its accounts; thus government does not have to finance any debt using this public expenditure.
The endogenous schooling tax rate is thus equal to the ratio of public education expenditure to education tax yields. That is:

$$\tau_2(t) = \frac{SG(t)}{N(t) \cdot \frac{w}{p}(t)} \tag{17}$$

where *N(t)* is the total active labour force equal to the total labour supply.

2.6.2 The Italian pension system

Italy stands out among the countries of the EU in terms of its ageing population and the level of its public pension expenditure. In a framework of high public deficit and debt, it comes as no surprise that the legal-institutional framework of the Italian public pension system has undergone major reform since the 1990s. Four major reforms have been implemented, Legislative Decree 503/92 – the Amato reform in 1992, Law 335/95 – the Dini reform in 1995, Law 449/97 – the Prodi reform in 1997 and delegated legislation 243/2004 – the Maroni reform in 2004, which are part of a process towards a new regime - a "contributions based regime"[14].

The main features of the Amato reform were an increase in the retirement age and a gradual reduction in pension benefits, although the existing method of calculation still applied, i.e. earnings related in which pension benefits were calculated as a proportion of pensionable earnings. The minimum retirement age was raised from 60 to 65 years for men and from 55 to 60 for women. The reference period for computing pensionable earnings was gradually extended to be based on the last 10 years for private and public employees, the last 15 years for the self-employed and to the entire working life for those entering the labour force after 1 January 1993. Prior to this reform, pensionable earnings were computed as an average of the last 5 years' salary for private employees, 10 years for self employed and the last year for public employees. Also, pension benefits were indexed to prices rather than wages.

The Dini reform, a few years later, introduced a new method of calculation: the contribution based method based on "transformation coefficients"[15], a key input that determines an individual's pension based on the full amount of social security contributions. Unlike the existing method, the contribution based method takes account of the amount of contributions paid throughout an individual's working life (capitalized at the rate of nominal GDP) and the life expectancy of the pensioner at retirement age (and the number of years that any beneficiary (widow or widower) will continue to draw benefit) based on actuarial equivalences. This related benefits directly to retirement age - the lower the age, the lower the pension, and vice versa. This reform also identified three groups of workers: 1) those that at the end of 1995 had already contributed to the system for at least 18 years; 2) those that had contributed for fewer years; 3) and those that started working in or after 1996.
One significant feature of this reform is that it maintained most of the generous provisions of the pre-1992 regime for relatively old workers, that is workers in the first group. For these people the earnings related method continued to be applied. The earnings related method persisted but, for the contribution years after 1992, the number of years of annual earnings involved in the benefit calculation was gradually increased to the last 15 years for self employed workers, and the last 10 years for others. For workers with less than 18 years of contributions at the end of 1995 (the second group), a so-called pro-rata, mixed regime was applied. For them, the pension was obtained from the sum of two components: the first, related to the contribution years before 1995, is calculated following the earnings related method with reference wages for the contribution years between 1993 and 1995 gradually extended to the entire career; the second is calculated according to the contribution based method. For the youngest group of workers, that is the third group, only the contribution based method was applied.

[14] In addition, there was a disability pension reform approved in 1984 (Law 222/84), which significantly reduced the number of newly awarded pensions, and is still having effects in terms of a reduction in the outstanding stock of pensions. Brugiavini (1999), Brugiavini and Peracchi (2005) and Baldini, Mazzaferro and Onofri (2002) provide details on the specific features of the sequence of Italian pension reforms since the 1990s.

[15] Transformation coefficients are the instruments that convert the total amount of contributions (in all working time paths) in the annual pension. In practice, these coefficients not only take into account pensioners' life expectancy, but also the probability and life expectancy of survivors, as well as a positive internal return rate. Because of the expected increase in life expectancy, the Dini reform provides for ten-year revisions to this coefficients.

This reform highlights the development of a supplementary pillar. Indeed one of the goals of all these reforms was to boost the development of private pension funds. One of the main strands in the pensions Italian debate since the early 1990s has been that the shortfall in unitary benefits produced by the pension reforms needed to be tackled through the introduction of a mixed system, in which retired people receive income from PAYG public system and a fully-funded supplementary pillar.

Social security legislation was further refined in December of 1997 in the shape of the Prodi reform, which abolished seniority pensions for everyone who started working after 1995 and raised the minimum number contribution years for pension eligibility for all categories of workers.

Finally, the Maroni reform introduced: 1) an increase of three years in the retirement age for workers due to retire after 2008 whether in the contribution based system or in the earnings related system; 2) the diversion with a silence-consent form- of employees' TFR[16] to supplementary and private pension funds.

2.6.3 The aspects of the Italian pension system introduced in the model

We have outlined the principal aspects of the pension reforms that have taken place in the last two decades, some of which have been introduced in our macroeconomic system. In particular we have considered the different methods of calculation that could be used to determine annual pensions, and the increasing retirement ages.

Then, in our model there are the three different groups of workers -as the Dini Reform decrees- and we also take into account all changes in the retirement age up to those decreed by the Maroni Reform[17].
Obviously the pension rules applying to agents with a similar levels of schooling will be the same. The differences will relate to : 1) the contribution seniority in a particular year; and 2) the retirement age which depends upon the age in the first working year.

2.6.3.1 Methods of pension calculation

In our economic system we have used three calculation methods[18].

1. *The earnings related method*. The reference period for computing pensionable earnings can be related to the work incomes for the last 5 (before end December 1992, i.e. before the

[16] TFR is a type of deferred wage that applies to private employees. Each year, firms accumulate, as book reserves, about a month's worth of salary for each worker (6.91% of payroll on average), which is returned to the workers at the end of the employment relationship (due to retirement, resignation or layoff), and which can be borrowed against to fund extraordinary expenses (usually house purchase). The employer pays a rather low return on the TFR funds (1.5% per year plus .75 of the inflation rate). TFR is often regarded as a severance pay, but it is not severance pay in its strict sense, because it is not compensation for layoff, although in the case of redundancies for the worker it constitutes a useful cushion during the period of unemployment, especially as in the Italian system unemployment benefit is very small.
[17] We assume in our economic system that there is full employment. Thus, a worker will never have been out of work. E.g., if we consider a primary and/or secondary school agent that was born in the 2006, he starts to work just after he enters the economic system, i.e. in 2021, and will be in employment until retirement age. Also, in our model, everyone will receive a seniority pension and not an old age pension because all agents start working at a young age and never suffer unemployment. Moreover for simplification, we consider only private sector workers.
[18] For a more detailed description of the three different methods of calculation in the model, please contact the author.

Amato reform was implemented) or 10 years' (after end December 1992 when the Amato reform was implemented), as described in the tables. This method was applied to all workers that had contributed to the system for at least 18 years at the end of 1995.

2. *The mixed regime*. For some contribution years we apply the earnings related method, but, starting from 1 January 1996 the contribution based method applies. This refers to all agents who have been working before the end of 1995 but whose years of contribution are less than 18.

3. *The contribution based method*. This method applies only to young workers, i.e. those that entered into employment after the end of 1995.

2.6.4 The pension structure

The pensions department in our model plays a key role in the dynamic equilibrium of the model in supporting the principal burdens of the ageing population. The department reflects a standard PAYG system that levies payroll taxes on the working population and pays benefits to the retired, but usually without the relationship between individual contributions and benefits that characterizes fully funded schemes. The contribution rate in a generic year of the forecasting time path is endogenously predetermined to balance pensions paid to the pensioners that year with taxes collected from the active labour force in the same time period. As described in the previous sections, for simplicity we consider only private sector workers and only seniority pensions.

The total amount of retirement public expenditure will be equal to

$$RG(t) = \sum_{a=15+r_a(t)}^{84} p_{t-a}(t) \cdot f_{t-a}(t) \tag{18}$$

where: *RG(t)* is the total amount of retirement public expenditure in year t; $p_{t-a}(t)$ is the annual pension of an agent that was born in year t-a.

The variable $p_{t-a}(t)$ is equal to:

$$p_{t-a}(t) = \sum_{i} p^{i}_{t-a}(t) \cdot q^{i}_{t-a}(t) \quad \text{with } i \in \{PS, \quad QD, \quad CD, \quad GD\} \tag{19}$$

where $p^{i}_{t-a}(t)$ is the annual pension of an agent that was born in year t-a and with i level schooling.

The government will support *RG(t)* with taxes paid by the active labour force. We assume in our model that each year the retirement department is balanced and thus government is not required to finance debt with this public money. The endogenous contribution rate, therefore, will be equal to the ratio of the total amount of retirement public expenditure to the contribution yield. That is:

$$\tau_1(t) = \frac{RG(t)}{N(t) \cdot \frac{w}{p}(t)} \qquad (20).$$

3 Parameterization and simulations

All parameters of the utility function were described in Section 2.3.3. The other exogenous variable considered in our model is the scale factor of the total amount of public expenditure on education (i.e. the parameter $\phi(t)$ in equation (16)). This factor, as already pointed out, is higher than 1 because it considers not only students' consumption, but also the other public expenditure that the education department is responsible for. In our simulation this factor is equal to 2. Indeed this value, in the first years of the forecasting period, generates an endogenous education tax rate that is in line with the historical data for Italy.
With regard to the simulations we begin by describing the basic scenario in which all values for relative schooling frequencies $q_{t-a}^{i}(t)$ along the forecast time path (i.e. from 2007 to 2050) are equal to the fitted values implemented by Prometeia, based on historical data from the ISTAT labour force surveys, as described in Section 2.1.1.
After consideration of an alternative scenario, in which the values of relative frequencies for graduated and certificated students increase by 25% every year of the forecasting period, we conjecture that individuals that chose to go on to higher education in the form of a certificated course or graduate degree, are in the majority compared to the basic case (consequently the number of primary, secondary school, and qualified people in each year and for each age, will decrease in order to satisfy the basic constraint on relative frequencies: $\sum_{i} q_{t-a}^{i}(t) = 1$).
An alternative case is obtained as a result of economic policy schemes that incentivize the young to continue their studies. Apart from the instruments that policy makers can apply to increase the ratios of certificated and graduate students, in this work we want to study the possible results of such a policy. In the next two sections we present the results for the basic case and those for the case with the positive shock in human capital. We compare the results for the aggregate variables in the two cases.

3.1 The basic case

In this section we describe the results for the basic case based on the data sources described in Section 2.1.1: i.e. the *ISTAT labour force survey* and *ISTAT projections for the Italian population*.
Figures 1-6- describe the individual variables for a specific age-related cohort (we focus on the 1980 cohort in which agents are assumed to be 15 years old), but in each graph we highlight education differences. We then describe the aggregate variables. We decided to consider only one age cohort because the patterns for individual variables are similar for the other age cohorts. The differences concern only the level of endogenous real wages, which increases over time, the level of interest rates, which decreases over time- and the time related factor for individual labour productivity which increases the efficiency of younger cohorts. Consequently, the life cycle patterns for labour supply and wealth with respect to age, are similar for different generations. However, the average number of hours worked by each cohort over its working life decreases significantly over time (see Figure 13) while the average level of wealth increases (see Figure 9).

We should highlight that the individual variables for the basic and the alternative cases do not change substantially. This is because the representative agent is the same: what changes is the number of certificated (CD) and graduate (GD) agents compared to primary and secondary school (PS) and qualified (QD) agents. We consider the individual variables in this section only, to avoid unnecessary repetition of similar cases.

Figure 1 depicts the total endowment of effective units of labour. The profile of this variable is concave and similar to that in Miles (1999). In our model, though, we differentiate the schooling related element so that the microeconomic productivity for qualified, certificated and graduate agents is higher than that for primary and secondary school agents. Furthermore, in our model we consider agents that do not work after the retirement age (because we only consider dependent workers and not self employed workers who might decide to go on working after retirement age): therefore the lower part of the function -from 70 to 80 years of age in the Miles's model - is not considered in our work. We note that this variable - as it is the case with the one related to the working period - is different from 0 only in the working time period –that is from 15 to 55 for PS agents, from 18 to 58 for QD agents, from 20 to 60 for CD agents and from 25 to 65 for GD agents. Consequently: 1) the individual labour supply –as shown in Figure 2- does not decrease in the last years of the working life at a marked negative rate; 2) and the total income in Figure 3 shows marked discontinuity in the first year of retirement (indeed the total income will be only equal to the pension after the retirement age) and this discontinuity will become increasingly evident as time goes by due to the effects of more restrictive pension rules and the decreasing substitution rate. We also highlight that the effect of education does not have substantial consequences for the labour supply but is relevant to total income: graduates will be more productive than other agents and thus their income will be higher even though they start working later.

Figure 4 reports the time evolution of the substitution rate with respect to retirement year and education. The X-axis finishes in 2053 simply because after that year values are roughly constant. We highlight that from 2030-2035 replacement rates are much lower than in previous years: indeed in those years the contribution based method fully applies and all restrictive effects on the pensions rules also do apply.

Figure 5 depicts the optimal pattern of lifetime saving rates at equilibrium for each level of education; again we focus on the cohort starting work in 1980 (though the pattern is similar for other age cohorts). As described by the life cycle theory, savings rates will be positive throughout the working years, and negative and increasing in absolute value during the retirement years. We should highlight that poorer savings attitudes are related to lower levels of schooling; this is because we assume that agents with higher education receive higher incomes. Further, we note that savings rates are equal to zero until the age of 18 for QD agents, until 20 for CD agents and until 25 for GD agents; indeed at that age they are students and rule of thumb consumers of state benefits.

Figure 6 illustrates the profile of individual wealth. As highlighted in previous sections, this follows a classical life-cycle profile. It reaches a peak at retirement and falls steadily to reach zero at death. The rate of accumulation and decumulation are cohort specific –wages and interest rates are moving through time- and once again we show the profile for a specific age cohort (whose agents begin to work in 1980). As for the other individual variables, in this figure we consider four different types of agents based on level of education. The higher income capability of skilled agents provides them with greater wealth than those with lower levels of schooling. It can also be seen that wealth is equal to 0 until the age of 18 for QD agents, 20 for CD agents and 25 for GD agents.

Figure 7 shows the dynamic evolution of the endogenous contribution rate. Here we present the model solution along the forecasting period. As highlighted in the notes to Figure 4, from 2030-2035 the contribution based method fully applies. In the previous years we can see a decreasing contribution rate because the more and more restrictive rules generate decreasing public expenditure for the pensions department. After 2030-2035 the marginal benefits of the more restrictive pension rules are lower because the pension system will have stabilized after 2030, and the negative effects of ageing become more pronounced so that the contribution rate starts to increase. Even if the more restrictive pension rules were to decrease the pressure on the economic system and the substitution rates for future cohorts, this would not be sufficient to avoid a collapse of the PAYG system.

Fig. 1

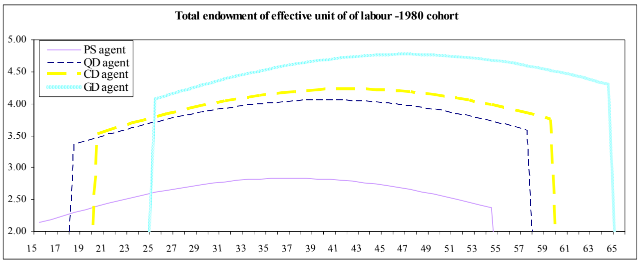

Fig. 2

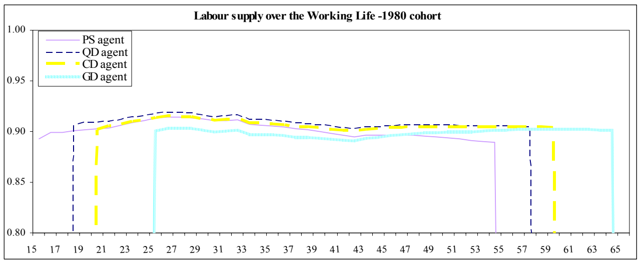

Fig. 3

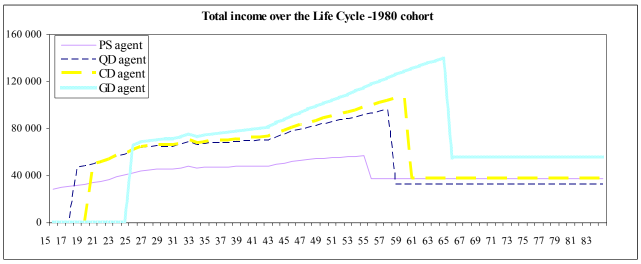

Fig. 4

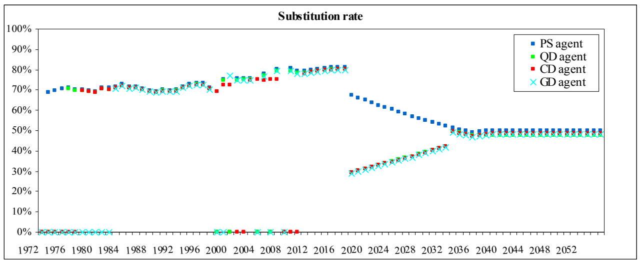

Fig. 5

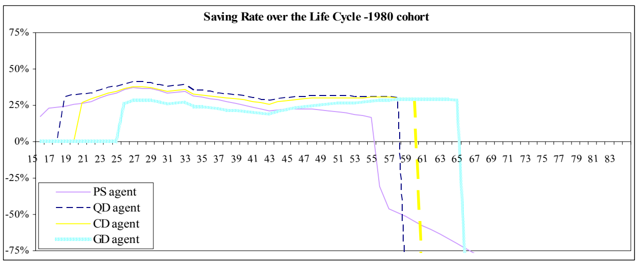

Fig. 6

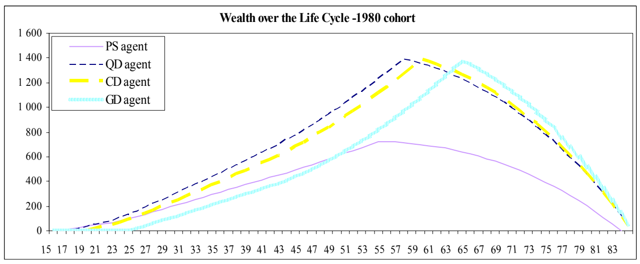

Figure 8 shows the dynamic evolution of the education tax rate, which is cyclical and virtually constant in the long run because the effect of ageing (i.e. the decreasing number of students and thus, ceteris paribus, the lower public expenditure on education) is balanced by the increasing cost of living (which results in a higher unitary state scholarship).

The rise in the relative numbers of people with a high stock of wealth and low savings rates (i.e. the elderly) and reduction in the number of people of working age, generate an increasing capital to labour ratio. This is caused by demographic changes due to ageing. If the population structure were unchanging the wealth income ratio and the capital to labour ratio in our model would be constant. The same factors that push the savings rate down - a rise in the number of people aged over 65 that have lower savings rates (negatives as highlighted in the Figure 5) and, on average, a high ratio of wealth to income (because these agents have accumulated wealth throughout their lifetimes while current incomes are low and equal to pensions) are responsible for driving up the wealth income and capital labour ratios. Figures 9 and 10 show the scale of these effects: indeed they reproduce the time path of capital labour and wealth income ratios. An increasing capital labour ratio determines an increasing labour shortage with respect to capital; then wages increase (as shown in Figure 11) and interest rates decrease (as shown in Figure 12).

Figure 13 shows another effect of ageing: decreasing aggregate labour supply. In fact as the population ages there are more pensioners who do not work and fewer young people who constitute the core of the active labour force.

Figures 14 and 15 report the evolution of GDP in terms respectively of levels and variation rates. The decreasing GDP growth rate, highlighted in the Figure 15, is the final effect considered of ageing on our economic system.

3.2 Positive shock in human capital compared with the base case

In this section we describe an alternative to the base model scenario in which the principal innovation is the use of human capital as an instrument to balance the negative effects of ageing on economic growth whether in terms of fiscal pressure on the economic system and on the PAYG system or in terms of GDP growth. We show that human capital is a crucial policy variable to balance the negative effects that all industrialized countries will face in future years. These arguments are particularly relevant for Italy, one of the industrialized countries whose investment in education and research is insufficient. More intensive use of human capital is one of the instruments that Italy might usefully employ.

In terms of the nature of this shock –as described in the Section 3- we decided to consider an alternative scenario in which there is a permanent and one-off shock on the relative frequencies for graduates and certificated students: these figures will increase by 25% for each year in the forecasting period (i.e. from 2007 to 2050) compared to the base case. This is only one of the comparative statistic exercises that could be applied (e.g. we could consider a temporary and casual shock on relative frequencies). In this work we do not explain how government might obtain these new relative frequencies; we concentrate only on the results of the shocks and not on how to promote them[19].

We present the results for the alternative scenario and compare them with those for the base case. We focus only on the aggregate variables because there are no substantial differences for individual behaviours.

Figure 16 shows the lifetime path of the aggregate human capital. Obviously the increasing frequencies of higher educated individuals determine the increase in the average number of years of schooling in the economic system and a high level of aggregate human capital.
The effects of human capital are positive on both endogenous taxation rates. Figure 17 shows that the fiscal pressure on the PAYG system is lower, and even after 2030-2035 when the marginal benefits of the contribution based method are lower than negative effects of ageing, the contribution rate is maintained at a lower level. Also, the differences between the basic and the alternative scenarios will become more pronounced over time. Figure 18 shows the evolution of the education tax rate along the forecasting period: also, in this case, the differences between the basic and the alternative scenario will become more pronounced over time.

[19] Certainly policy makers could apply various economic policies to permanently increase the frequencies of certificated individuals and graduates (e.g. by providing bigger state scholarships and other economic incentives to encourage the entry of young graduates and other more educated individual into the labour market, etc.). The links between these policies and the increment of mean schooling level could be an important area for research.

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Fig. 7

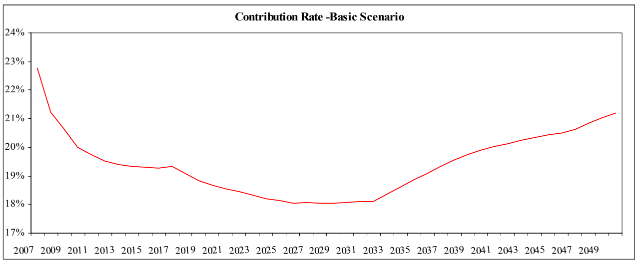


Fig. 8

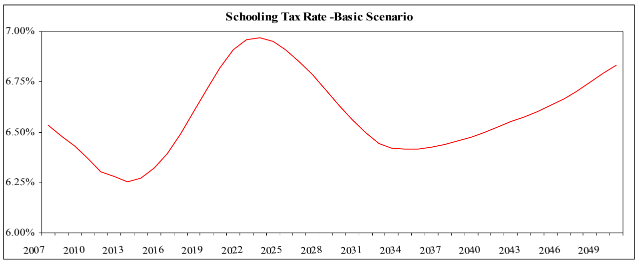


Fig. 9

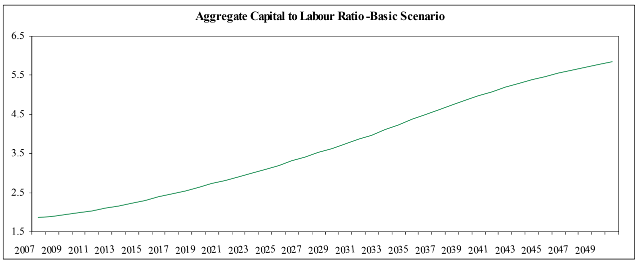


Fig. 10

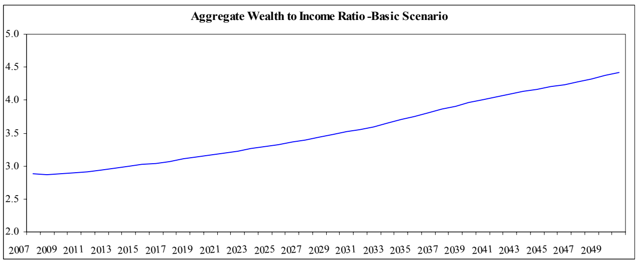


Fig. 11

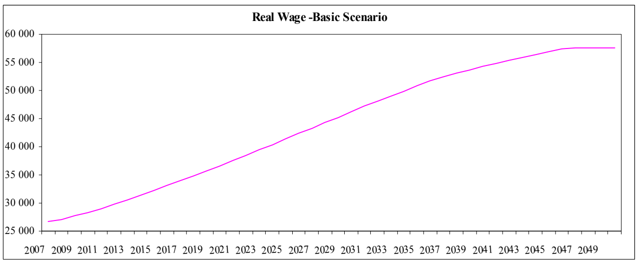


Fig. 12

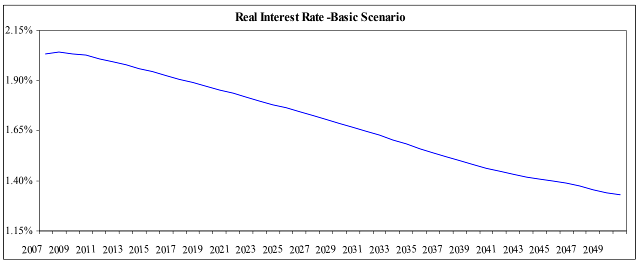


Fig. 13

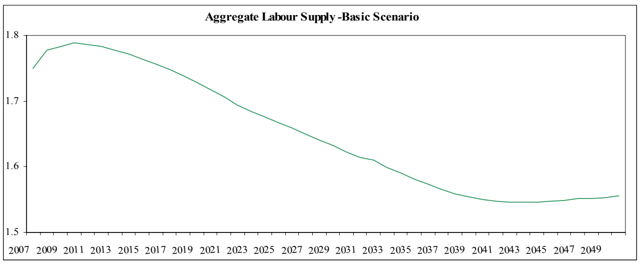


Fig. 14

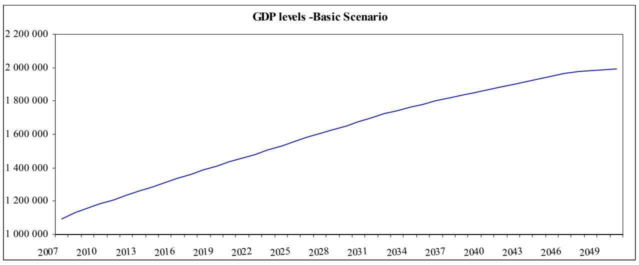
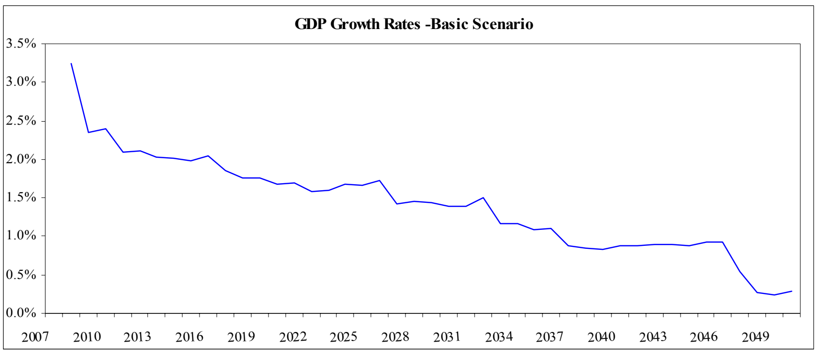


Fig. 15



If we consider the capital to labour ratio (Figure 19) we can see that there are no substantial differences between the base and the alternative scenarios: this clearly demonstrates that the shock in relative frequencies does not determine the changes in microeconomic optimal choices.

Even if the capital to labour ratio does not change, the increase in the level of aggregate human capital increases the level of real wages and interest rates as described in Figures 20 and 21, and also the aggregate labour supply as shown in Figure 22. The increment in the level of aggregate labour supply is tied, in a bidirectional way, to the decrement in endogenous tax rates: higher labour supply means a higher contributive basis and lower unitary fiscal pressure. On the other hand, if taxation rates decrease individuals will choose ceteris paribus to supply increasing levels of labour and the corresponding aggregate labour supply will rise.

The increments in the aggregate level of human capital and aggregate labour supply (the latter increase is balanced by an almost equal rise in the level of aggregate physical capital because as already highlighted the capital to labour ratio does not undergo substantial changes) determine a rise in the level of GDP higher than that in aggregate wealth such that the wealth to income ratio is lower than in the base scenario, see Figure 23. At the same time the GDP in the alternative scenario grows at a rate higher than before so that –as described in Figures 24 and 25- even the negative effects of ageing on economic growth will be partially balanced by the increment in the level of human capital.

In other words, the results of our model show that a positive and one-off shock in the level of human capital is a powerful instrument to contrast the negative effects of ageing on both economic growth and the pressure on fiscal and pension systems. A positive shock in the quality of human capital generates lower contribution and schooling tax rates and GDP growth that decreases less strongly than in the base scenario.

4 Conclusions

The dynamics of demographic structures are a crucial factor in the long run paths of developed countries. The demographic structure is showing that ageing is occurring at different paces and different degrees of intensity in the developed countries of the world. Significant ageing is already underway in Italy, Japan and Germany. An ageing society is characterized by a growing proportion of retired to active working individuals. Societies age when fertility rates decline so that fewer children are born, or when life expectancy increases, or both. Ageing has important macroeconomic effects on the growth of a country: it generates a decrease in aggregate savings rates, an increase in capital to labour ratios and capital to income ratios, a decrease in the aggregate labour supply and GDP growth rates, a decrease in real interest rates and a collapse of the pensions system with a consequent increase in fiscal pressure on the economic system. The effects of an ageing Italian population in this work were analysed within an OLG highlighting the dynamics mentioned above.

The Italian government is adopting various economic policies to try to avoid a collapse of the pensions system and decrease the fiscal pressures on its citizens. A simple solution would be to introduce more restrictive pension rules and a dynamic decrease in the level of substitution rates. Government could also undertake broader fiscal adjustments, such as raising taxes and cutting expenditures, not related to public pensions. But such policies would involve many redistributive effects, e.g. the transfer of wealth from the young to the elderly that would damage the long term growth of the country.

Fig. 16

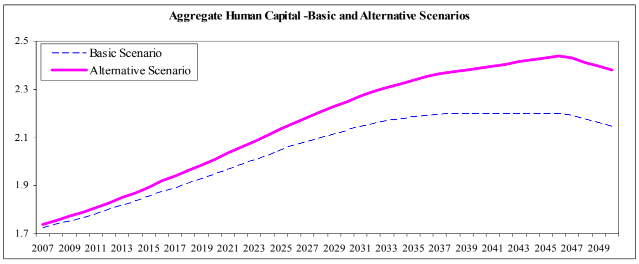


Fig. 17

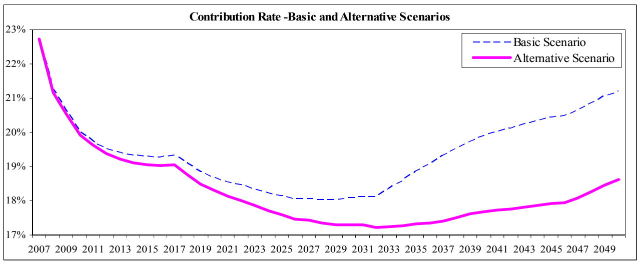


Fig. 18

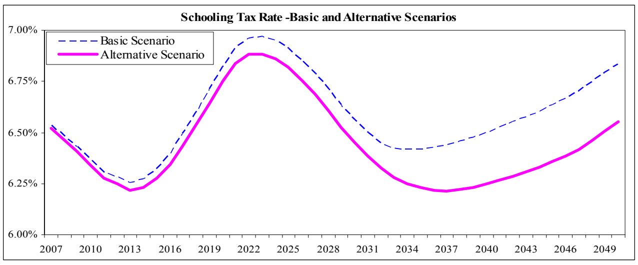


Fig. 19

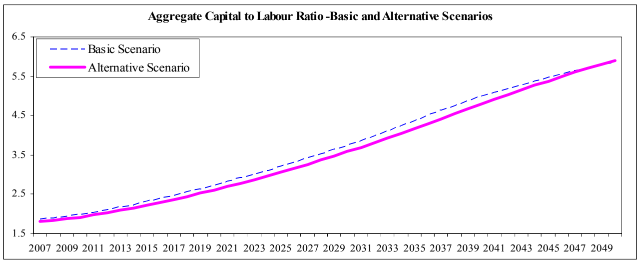


Fig. 20

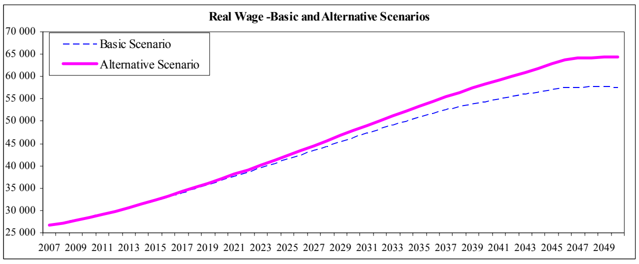


Fig. 21

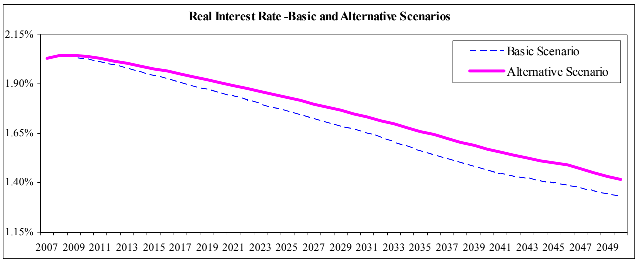


Fig. 22

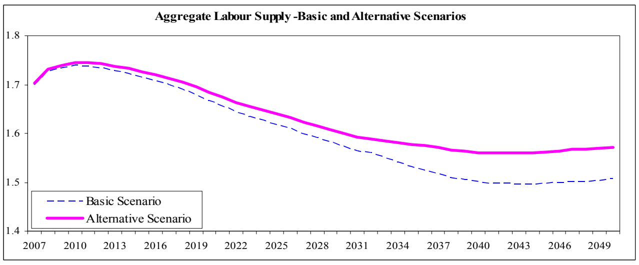


Fig. 23

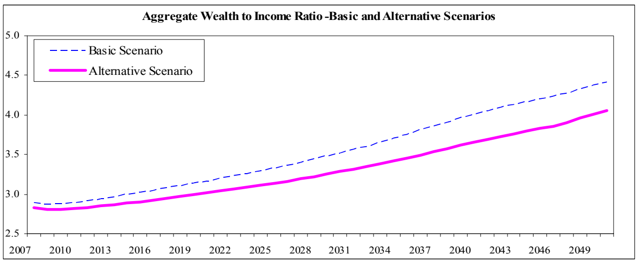


Fig. 24

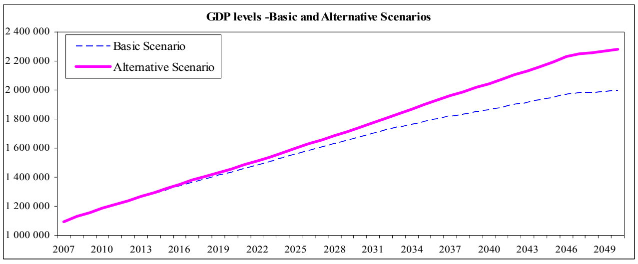
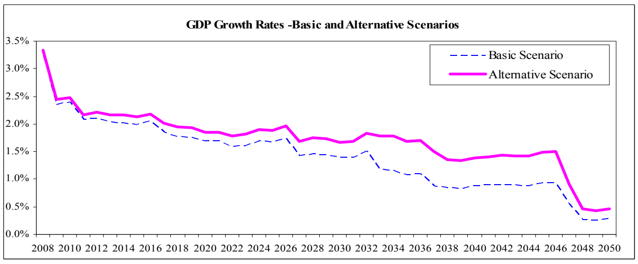


Fig. 25



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Another possible solution to avoid the collapse of the pensions system and which has received less attention from policy makers and economic theorists is the development of human capital. Highlighting and providing incentives for the development of human capital on the production side enables a country to emphasize the industrial sectors that require more skilled workers - generally, the high tech sectors. The introduction of human capital in a dynamic demographic structure, is the principal innovation of our work: in particular we take human capital as the crucial policy variable to balance the negative effects of ageing on economic growth whether in terms of fiscal pressure on the economic system and on the PAYG system or in terms of GDP growth. We constructed two alternative scenarios to study the effects of human capital on the aggregate variables: a basic scenario in which all values for relative schooling frequencies along the forecast time path (i.e. 2007 to 2050) are equal to the fitted values implemented, based on historical data from the ISTAT labour force survey, and an alternate scenario in which we consider a permanent and positive shock on the relative frequencies for graduate and certificated students.

The results of our model show that the shock in the level of human capital contrasts with the negative effects of ageing. Indeed the alternate scenario generates GDP growth rate that decreases less strongly than in the basic scenario and decreasing fiscal pressure in terms of lower contributions and education taxes. Further, even if the capital to labour ratio does not change the increase in the wealth to income ratio is less pronounced and the aggregate labour supply is higher than in the base case. We should point out that our work presents the effects only of a higher level of human capital and does not consider the economic policies that government could apply to permanently increase the frequencies of certificated individuals and graduates and more especially does not consider the links between these policies and the increment in mean schooling levels.

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