Active ageing, preventive health and dependency: heterogeneous workers, differential behavior

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Abstract: In a dynamic framework, in which early health spending mitigates productivity losses in later years, we show that the labor supply of older workers and investment in preventive health go hand-in-hand: high-productivity workers are more involved in active ageing and in preventive health. As a consequence, for a delay in the legal retirement age to have the desired effect on the labor supply of the elderly, an affordable system of preventive health is required, especially among those workers with low socio-economic status. In this context, the labor supply of the elderly would expand at a faster rate than would life expectancy, thus allowing for a reduction in the dependency rate.

Keywords: Active ageing, preventive health, dependency rate

JEL codes: I1, J2

1. Introduction

Ageing is one of the primary challenges facing developed economies. Although the prospect of a longer life is undoubtedly interpreted as a sign of success in our society, it has economic implications that have turned out to be not so simple to manage. Perhaps the most important factor is the financial pressure on social security systems, arising from the increasing numbers of retirees with no parallel expansion of the working population. While those aged 65 and over currently make up about 25% of the population aged 18-65 in Europe, Eurostat (2008) projections show an increase of this ratio to around 50% by 2060. There is no doubt that an increase in the retirement age would alleviate public finances, which is why so many governments are either increasing the legal retirement age, and/or increasing the required number of years of contribution to qualify for a full pension. The purpose of this paper is to show that mandating a higher legal retirement age may not have the desired effect on the labor market participation of older workers, if it is not accompanied by effective preventive health programs.

There exists a variety of individual concerns about the willingness to extend, or not, the years of working, beyond that of simply delaying retirement, which appears to be the rationale of most policy-makers. The empirical evidence supports this heterogeneity of behaviors facing retirement. For example, using USA data, Haider and Loughran (2002) find that the labor supply of people over 65 is concentrated among the healthiest, wealthiest, and most educated individuals. Kalwij and Vermeulen (2008) find that a higher labor-participation rate of Europeans aged 50-64 is positively related to both health and level of education. In the Spanish case, the likelihood of retirement is lower for individuals with at least a high-school education, compared to those with a lower educational level (Jiménez-Martín and Sánchez-Martín, 2007). Staubli and Zweimüller (2013) find that the employment response to a delay of the early retirement age in Austria was greatest among high-wage and healthy workers, while low-wage and less healthy workers either continued to retire early, via disability or unemployment benefits. To reflect this heterogeneity within a cohort, following Ales et al. (2012), we build a framework in which individuals have different life-cycle productivity profiles, conditional on an initial productivity level. To reflect health inequalities within a cohort, we consider that each individual affects his/her own health level by devoting effort to preventive health that mitigates the health deterioration due to ageing and, hence, affects the individual decision to shorten or lengthen the working life. In this context, where individuals decide jointly whether to participate in the labor market in old age, and whether to invest in preventive health, we find that those who decide to remain longer in the labor market are also those who devote more resources to preventive health, namely, those with the highest levels of productivity. The explanation is that preventive health slows down the decline in productivity over time more effectively among the most productive and, those with the highest levels of education, and in the most human-capital-intensive sectors, will have the greatest interest in extending their working lives, relative to the general population. The reverse applies for those who are more disadvantaged.

We find that the proportion of individuals willing to extend their working life is larger, the higher the expected labor income when older, the lower the utility derived from leisure, and, more interestingly, the lower the price of preventive health strategies. A good health sector, which provides accessible health services, enhances the activity rate among the elderly, and lowers the dependency rate of the non-active population. In fact, given an increase in life expectancy, an affordable health system emerges as a necessary condition for the dependency rate to remain *in stasis*, and enhances the importance of the authorities providing preventive health programs with the goal of extending the years of work, especially those programs providing services for individuals with lower socio-economic status.

The rest of the paper is organized as follows. Section 2 provides a review of the existing studies of the relationships among health, retirement, and the labor supply of the elderly. In Section 3, individual behaviors with respect to preventive health and the retirement decision are characterized. Section 4 presents the implications of these individual behaviors at an aggregate level, focusing on two factors: the rate of activity among older workers, and the rate of dependence. Section 5 presents our conclusions.

2. A review of the current literature

Although, up to the mid-1990s, the general rule was to retire increasingly early in developed countries, the trend has reversed and the participation rate of older individuals in the labor market is now increasing in most OECD countries. This behavioral change has generated a new strand of the literature devoted explaining the mechanisms of delayed retirement. Some studies focus on the role of institutional changes toward less generous pension, tax, unemployment, and disability policies as explanatory factors, while others highlight improvements in health among potential retirees. Our research follows the line that individuals in better health tend to retire at a later age than those who are not so healthy. There is a variety of theoretical explanations of the positive effects of health in delaying the timing of retirement. Coile and Levine (2007), for example, find that older workers with health problems have a greater probability of becoming unemployed, or finding themselves constrained by poor labor conditions, in such a way that retirement comes as somewhat of a relief, while Bloom et al. (2007) maintain that the fact that individuals of all ages are generally healthier, and live longer lives, leads to an increase in the optimal retirement age. Taking a different point of view, Ferreira and Pessôa (2007) explain that individuals retire earlier because longer lives imply declining productivity, and that the link between age and productivity has a homogeneous hump shape. More recent analyses estimate age-productivity profiles that increase up to the age of 50 to 55 years, and then remain flat (Cardoso et al., 2011; Dostie, 2011; Mahlberg et al., 2013).

To find an association between health and the retirement decision, we posit that planned health investment, i.e. preventive health, affects the age-productivity profile by slowing down the decline in productivity over time, and to a greater extent among more productive individuals. Consequently, those individuals with the highest levels of productivity will have a greater interest both in extending their working life and in investing in preventive health, compared to the rest of population. This mechanism is based on four key points that are well-supported by empirical evidence. First, the connection between having a good health status at retirement age, and postponing the retirement timing; second, the long-term effects of health investments later in life; third, the positive effect of health on labor productivity; and fourth, the greater probability that a higher-income adult uses preventive care. Bringing together the first three links, we maintain that a good health status at retirement age is likely to be the result of health investments in childhood and in early adulthood which, in turn, positively affects labor productivity. In other words, preventive health slows down the age-related decline in productivity and health and, hence, makes it more attractive to delay the time of retirement. The fourth point allows us to establish that this connection between preventive health and retirement is stronger for more productive individuals.

On reviewing the relevant empirical research that supports each of these four points, we take particular note of the work of Sickles and Taubman (1986) who, using longitudinal data from the Retirement History Survey, for the period 1969 to 1977, confirm that retirement decisions are strongly affected by health status at that age. More recently, empirical studies have concentrated on correcting the problems that arise from potential endogeneity of self-rated health data. For instance, Dwyer and Mitchell (1999) exploit the 1992 Health and Retirement Study (HRS), finding that health problems have a greater influence on retirement than do economic variables. In particular, men in poor overall health retire one to two years earlier. McGarry (2004) uses data from the first two waves of HRS in 1992/93 and 1994, showing that the impact of health on labor market attachment is substantially greater than either income or wealth. With a sample from 12 waves of the British Household Panel Survey, from 1991 to 2002, Jones et al. (2010) find that negative shocks to health result in increases in the hazard of early retirement for both men and women.

With respect to the long-term effects of health investment over the life cycle, the work of Grossman (1972) is particularly relevant. He introduces the need to allocate economic resources to maintain health levels above a certain minimum, i.e. health appears to be an investment good, in such a way that individuals with higher incomes invest more in health capital when young. Almond and Currie (2011) present a recent review of empirical studies that supports the Grossman model, establishing that health investment in early life has long-term consequences for future health. Closer to our interests, Bound et al. (1999), using the first three waves of HRS in 1992/93, 1994, and 1996, find that not only poor health at retirement age, but declines in health, help explain retirement behavior. Cutler and Landrum (2011), using data from the Medicare Current Beneficiary Survey for the period 1991-2007, find that health deteriorates with age at a slower rate today than in the past, but that the rate of slowing is not the same for all.

The connection between health and productivity is reviewed by Currie and Madrian (1999), who suggest that poor health reduces the capacity to work and has substantive effects on wages and labor force participation, although the size of the effect varies from study to study. One reason may be that the link between health and labor productivity is more pronounced in developing countries. By correcting potential biases arising from the use of self-reported health measures, Leroux et al. (2012), using data from the Medical Expenditure Panel Survey in 1996, corroborate that the impact of health on labor productivity is substantial. More recently, Lundborg et al. (2014), with data on Swedish males born between 1950 and 1970, also find a strong relationship between health at age 18 and adult earnings.

Finally, regarding heterogeneity in the utilization of preventive health, Ross et al. (2007) find, among American adults 50 years of age and older, that the working poor are less likely to make use of preventive care, relative to the working non-poor. This study uses data from the 1996, 1998, and 2000 waves of HRS. More evidence is provided by Maurer (2009), who, using a German subsample from the first wave of The Survey of Health, Ageing and Retirement in Europe, shows that educational attainment and preferences towards preventive health are key demand-side factors in the determination of influenza vaccination take-up. Carrieri and Wuebker (2013) also show that, in Europe, mammography and blood tests are concentrated among higher-income individuals, despite their substantially lower diagnostic needs.

3. Individual behaviors, health investment, and labor supply

The population of any economy can, very broadly, be separated into two general categories, the young and the old. Every individual of each generation is endowed with a different productivity level θ_i, uniformly distributed along the interval [0,1]. We normalize the size of each new generation to 1, in such a way that every individual of each generation is identified with a different value of the subindex *i*, continuously distributed along the interval [0,1]. The uniform distribution of productivity in the same range allows us to identify $\theta_i = i$.

Any young individual *i* inelastically supplies θ_i units of effective labor; thus, with *w* being the wage rate, the labor income is equal to $w\theta_i$. A part of this income is spent on consumption goods, c_i^y, another part is spent on preventive health goods, h_i, and the rest is saved: $s_i = w\,\theta_i - c_i^y - qh_i$. The consumption good is considered as the numeraire good, and *q* denotes the relative price of the health good.

The longevity of an individual is uncertain, with *p* denoting the probability of remaining alive in the second period of life. As usual in the economic literature on longevity, we assume the existence of actuarially fair insurance contracts that redistribute income from those who do not survive to old age, to those who do. Through this mechanism, the surviving elderly obtain a capital income in old age of $\frac{1+r}{p}s_i$, where r denotes the interest rate. Survivors may supplement their capital income by remaining in the labor market, and thus earning an additional labor income $w\theta_i^o e_i$, where e_i denotes their labor force participation and θ_i^o captures the productivity of the individual at the later age. Any worker retains, when old, a fraction of his youth productivity given by:

$$\theta_i^o = Dh_i^\delta \theta_i \ , \tag{1}$$

with $\delta \in (0,1)$. D is a scale parameter that measures the effectiveness of health goods in the fight against productivity decline. This specification reflects the fact that the higher the level of preventive health investment when young, e.g. screening for the early detection of chronic diseases or appropriate clinical management of diseases, the lower will be the loss of productivity due to the ageing process.

Thus, the old-age consumption of individual i in period t is given by $c_i^o = \frac{1+r}{p}s_i + w\theta_i^o e_i$. As in Matsuyama (2008), we assume that the elderly agent's labor-force participation is a zero-one decision: $e_i = 0$ if he or she decides to retire, or $e_i = 1$ if he or she decides to remain in the labor market. Note that, in this framework, without unintended or intended bequests, those who decide to retire cannot borrow when young because they only have their savings to finance their old-age consumption. However, those who decide to remain in the labor market when old may borrow when young because they have labor income when old to reimburse previous credits.

Every individual derives utility from both youth and old-age consumption, conditional on survival. We assume the existence of a gain in utility due to the leisure time enjoyed when old that depends positively on preventive health investments made when young. Following Aisa et al. (2012), the expected utility of any individual i is given by:

$$EU\left(c_i^y, c_i^o, e_i\right) = \left(\frac{c_i^y}{1-\beta}\right)^{1-\beta} \left(\frac{c_i^o}{\beta}\right)^{\beta p} \left[1 + \lambda(1-e_i)\right]^p , \tag{2}$$

with λ measuring the gain in utility from the leisure time when old. The presence of p in the exponent of the terms associated with old age captures the uncertainty of remaining alive in that period. This specification generalizes the inter-temporal preferences for consumption and the retirement decision proposed by Matsuyama (2008), by incorporating the uncertainty of longevity[1]. Given the uncertainty of surviving the first period of life, the expected utility derived from consumption and leisure when old appears to be multiplied by the life expectancy p. Parameter $\beta \in (0,1)$ is related to the inter-temporal discount rate of consumption. A positive discount rate for future consumption requires $\beta/(1-\beta)<1$. Note that this specification implies that the marginal rate of substitution between consumption in two periods does not depend on the retirement decision; in other words, retirement does not affect saving by changing the inter-temporal preferences over consumption. The retirement decision does affect saving by modifying the time-profile of labor income.

According to the above assumptions, the representative individual i of the cohort born in *t-1* faces the following optimization problem:

$$\underset{c_i^y, c_i^o, h_i, e_i}{\text{Max}} \; EU = \left(\frac{c_i^y}{1-\beta}\right)^{1-\beta} \left(\frac{c_i^o}{\beta}\right)^{\beta p} \left[1+\lambda(1-e_i)\right]^p ,$$

$$\text{s. t.: } w\theta_i + \frac{p}{1+r} wDh_i^{\delta}\theta_i\, e_i = c_i^y + qh_i + \frac{p}{1+r} c_i^o , \qquad \text{(P)}$$

$$c_i^y, c_i^o > 0 \,;\; h_i \geq 0 \,;\; e_i \in 0\{0,1\} .$$

in which the constraints corresponding to young and old ages have been combined into one. Lemma 1 presents the individual optimal decisions about consumption, preventive health investment, and retirement.

Lemma 1. There is a critical value of the productivity θ_{i*} such that the optimal decisions $\forall i \ni \theta_i \leq \theta_{i*}$ are given by:

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[1] In fact, it is a monotonous transformation of a standard logarithmic utility function of the form $(1-\beta)\ln\left(\frac{c_{t-1}^y}{1-\beta}\right) + p\beta\ln\left(\frac{c_t^o}{\beta}\right) + p\ln\left[1+\lambda(1-e_{i,t})\right]$.

$$e_i = 0,$$

$$c_i^y = \frac{1-\beta}{1-\beta+p\beta}\left[w\theta_i + \frac{1-\delta}{\delta}q\left(\frac{p}{1+r}\frac{wD\delta\theta_i}{q}\right)^{\frac{1}{1-\delta}}\right], \tag{3a}$$

$$c_i^o = \frac{\beta(1+r)}{1-\beta+p\beta}\left[w\theta_i + \frac{1-\delta}{\delta}q\left(\frac{p}{1+r}\frac{wD\delta\theta_i}{q}\right)^{\frac{1}{1-\delta}}\right], \tag{4a}$$

$$h_i = \left(\frac{p}{1+r}\frac{wD\delta\theta_i}{q}\right)^{\frac{1}{1-\delta}}. \tag{5a}$$

whereas the corresponding values $\forall i \ni \theta_i > \theta_{i*}$ are:

$$e_i = 1,$$

$$c_i^y = \frac{1-\beta}{1-\beta+p\beta} w\theta_i, \tag{3b}$$

$$c_i^o = \frac{\beta(1+r)}{1-\beta+p\beta_i} w\theta_i, \tag{4b}$$

$$h_i = 0. \tag{5b}$$

Proof. See Appendix. □

According to the results in the Appendix, individuals whose young productivity exceeds the critical value

$$\theta_{i*} = \Omega \frac{q}{w}\left(\frac{1+r}{pD\delta}\right)^{1/\delta}, \tag{6}$$

where $\Omega = \left\{\frac{\delta}{1-\delta}\left[\left(1+\lambda\right)^{\frac{p}{1-\beta+p\beta}} - 1\right]\right\}^{\frac{1-\delta}{\delta}}$, will choose optimally to remain in the labor market when old $\left(e_i = 1\right)$. Conversely, individuals whose young productivity is lower than θ_{i*} will optimally choose retirement when old $\left(e_i = 0\right)$.

Expressions (3a)-(4a) show higher levels of consumption in both periods of life than (3b)-(4b), since those who remain in the labour market when old earn an additional income, w_t per unit of effective labour supplied in the second period, whereas retired individuals receive no labour income in that period and, thus, are more concerned about saving when young. Although the most productive individuals earn a higher income in the first period, which could lead to early retirement, they are also the most productive when old, which acts as an incentive to remain active. This result conforms to the bulk of the empirical evidence, that the more productive individuals and, hence, those with the highest levels of education, tend to retire later. It would also be plausible to consider that the well-educated usually work in white collar jobs that are less physically-demanding than blue- collar jobs, and this lesser physical effort becomes part of the incentive to delay retirement. This explanation is included in our model, since the more productive workers (white-collar), although experiencing a decline in productivity with age, retain levels of productivity at later ages higher than those of blue-collar workers. Thus, our model predicts that those in white-collar jobs retire later than those in blue-collar jobs. However, our specification allows us to go one step further, identifying among those with white- collar jobs who are the workers with a greater incentive to delay their retirement age. The report on active ageing by the European Commission (Special Eurobarometer 378, 2012) detects differences in the average age up to which people feel they will be capable of working in their current job, between manual and white-collar workers, and also among white-collar workers themselves. Manual workers, on average, believe they will be capable of doing their job until age 59.9, compared with an average age of 63.2 years for managers, and 61.8 for other white-collar respondents[2].

Focusing on health consumption profiles, equations (5a) and (5b) reveal that only those individuals who plan to remain in the labor market for longer find preventive health measures worth paying for. In particular, equation (5a) shows that, for a given productivity, the (preventive) health demand is positively related to life expectancy, the wage rate and, more interestingly, the effectiveness of health goods in combating productivity loss. This result is supported empirically, since the advance of health technology, providing new drugs and methods to combat illness, is the main determinant of increases in health care expenditure[3].

Moreover, calculating the fraction of income spent in preventive health goods from equation (5a):

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[2] Page 57 Special Eurobarometer 378.
[3] See, among others, Newhouse (1992).

$$\frac{qh_i}{w\theta_i} = \left(\frac{p}{1+r} D\delta\right)^{\frac{1}{1-\delta}} \left(\frac{1}{q}\right)^{\frac{\delta}{1-\delta}} \left(w\theta_i\right)^{\frac{\delta}{1-\delta}}, \tag{7}$$

it can be observed that preventive health is a luxury good; that is to say, the higher the income, the greater the fraction of income spent in preventive health goods. Hall and Jones (2007) also find that health is a luxury good, as a consequence of the specification of a non-homotheticity utility function. They consider that health spending allows individuals to extend life, which means additional periods of utility. Since the marginal utility of life extension does not decline, the health share grows along with income. However, in our case, this result is not related to the form of the utility function. The explanation is given by equation (1), which implies that the more productive a young worker, the greater the fraction of such productivity in old age that is maintained from investing in preventive health.

Finally, this particular behavior of individuals related to health expenditure has, as a consequence, an expansion of the heterogeneity among individuals in old age. Investment in preventive health exacerbates the differences in productivity (and, thus, in income) among older individuals. First, those who invest in preventive health obtain in exchange a lesser decline in productivity at a later age than those who leave the labor market and avoid health expenditures. This leads to a divergence between both groups of individuals in terms of productivity, with the former having a smoother productivity profile over time. Second, among those who invest in health, the more productive are those who devote the greater amount of their resources and, thus, who retain the larger fraction of their younger productivity. As a result, differential expenditures on health extend the differences in productivity among active older workers.

Before closing this section, we would like to clarify that this striking difference in health investment behaviours, between those who retire, with null health preventive investments, and those who continue working, with positive health preventive investments, arises from the assumption that the only effect of preventive health investments is to counterbalance the loss of productivity due to ageing, as equation (1) reflects. We could have assumed uncertainty with respect to the effectiveness of health goods in the fight against productivity decline in equation (1), which would imply a higher level of individual preventive health investments. Alternatively, an additional effect incorporated in the utility function could be considered, namely a positive relationship between preventive health investments and the enjoyment of leisure. In that case, two forces of opposite signs would emerge. The first, present in our specification, pushes individuals to prolong their active lives and, jointly, to invest in preventive health goods, since preventive health investments make the elderly more productive. A second force, absent from our specification, pushes individuals to retire and, jointly, to invest in preventive health goods, since health investments increase the gain in utility due to leisure. That it is to say, health-preventive expenditure enhances future productivity, which increase the opportunity cost of leisure and, at the same time, increases the benefits of leisure when old. If the latter force is smaller, the outcome that more productive individuals are those who prolong their working lives will be maintained. Finally, our analysis does not consider the realistic assumption that the probability of remaining alive in the second period of life, for each individual (p_i), depends positively on investments in preventive health (h_i). This link would add an incentive for preventive health investments for all individuals, independent of their retirement decision. Again, the outcome that the more productive individuals are those who prolong their working lives would be maintained if the effect of preventive health investments on future expected income (the probability of surviving to old age, and thus that of earning the associated labor income) was higher than the effect on the value of leisure (which is also more likely to be enjoyed). Undoubtedly, these modifications would have enriched the present specification, but we decided not to introduce them into the present analysis, to maintain both its tractability and its transparency.

4. Implications at an aggregate level: activity rate and dependence

Having identified the two different sets of individuals, depending on their behavior facing retirement, and having characterized their different health investment decisions, we now measure the size of both collectives through the rate of activity of those older individuals, x, that is to say, the fraction of individuals willing to remain active in their second period of life. The following proposition about the rate of activity of the elderly can be stated:

Proposition 1. The rate of activity of the elderly is higher i) the higher the expected income when old (higher life expectancy, greater productivity retained when old), ii) the lower the price of health goods, and iii) the lower the utility derived from leisure.

Proof. According to Lemma 1, active individuals in the second period of life are those born with a productivity exceeding θ_{i*} in (6). Since our assumptions about the size of the population and the distribution of productivity at birth allow us to identify $\theta_i = i$, the active in old age are those in the range (i*,1], that is to say, 1-i* in number. Thus, the rate of activity of the elderly can be written as $x = 1 - i*$. Carrying $\theta_{i*} = i*$ to (6), we have:

$$x = 1 - \Omega \frac{q}{w} \left(\frac{1+r}{pD\delta} \right)^{1/\delta}, \tag{8}$$

where it should be noted that the constant Ω is positively related to λ, which captures the utility associated with leisure time. Equation (8) indicates that, as expected, a higher valuation of leisure is in favor of an early retirement, to the detriment of an extended participation in the labor market, as is a higher interest rate because it reduces the actualized value of future income. A higher relative price of health goods q discourages investment in health and, thus, the productivity of older workers; this decreases the expected labor income when older and reduces the set of workers willing to remain in the labor market. The reverse applies when the probability of surviving to old age p is perceived as high. Finally, a high effectiveness of the preventive health investment D reduces the productivity loss in later age and, thus, increases the expected income, again increasing the activity rate. With these two sets of opposing forces in play, a non-zero activity rate of older workers requires the latter forces (those pursuing a longer active life) to be stronger than the former (those promoting an earlier retirement). Namely, the condition $\Omega \frac{q}{w} \left(\frac{1+r}{pD\delta} \right)^{1/\delta} < 1$ must hold, in order to guarantee that $x \in (0,1]$ in (8). □

Thus far, our results show that a longer life expectancy increases the willingness of workers to remain in the labor market. A greater probability of remaining alive in the second period of life increases the expected income derived from the labor supply in that period, which spurs the welfare derived from remaining in the labor market, to the detriment of the alternative option, retirement. This analysis is according to recent changes in legislation, with higher legal retirement ages justified by improvements in life expectancy. However, since the decisions about prolonging working life and about health demand are strongly inter-related, our analysis also leads us to the conclusion that a greater life expectancy modifies the dependency ratio of retired individuals over the active, depending on the extent of access of individuals to preventive health goods, as Proposition 2 states:

Proposition 2. Let d be the dependency rate, defined as the ratio of retired individuals over the active. If the price of preventive health goods is lower than a critical value $\tilde{q}$, an increase in life expectancy leads to a reduction of the dependency rate.

Proof. Since retired individuals amount to a fraction (1-x) of the surviving older generation (of size p), whereas active people are the full younger generation (of size 1) and the remaining fraction x of the older generation, the dependency rate d is given by:

$$d = \frac{(1-x)p}{1+xp}. \tag{9}$$

From equations (8) and (9), we obtain:

$$d = \left[(1+p)p^{\frac{1-\delta}{\delta}} \frac{w}{\Omega q} \left(\frac{D\delta}{1+\bar{r}} \right)^{\frac{1}{\delta}} - 1 \right]^{-1}. \tag{10}$$

Equation (10) shows an unambiguous inverse relationship between d and p for any $x \in (0,1]$ (note that for $x = 0$ the dependency ratio becomes $d = p$). In the proof of Proposition 1, we deduced the condition that guarantees that the dependency ratio lies in that range. It can be reformulated in terms of the price of health goods as $q < \tilde{q} = \frac{w}{\Omega}\left(\frac{pD\delta}{1+r}\right)^{1/\delta}$. □

That is to say, for a sufficiently low price of health goods, as life expectancy increases, the active older worker set expands in parallel with a reduction in the dependency rate. The prospect of a longer life, by itself, expands the labor supply of older workers: even without the possibility of avoiding productivity losses, a greater probability of earning labor income in the second period of life encourages a broader set of workers to remain longer in the labor market. The investment in preventive health reinforces this effect. The greater probability of enjoying the returns of the investment in health in later years promotes a greater demand for health which, in turn, increases even more the expected income from labor of older workers. As a result, the halting of productivity deterioration thanks to health investment expands even more the set of workers willing to remain active when old. Our results show that the conjunction of both forces (higher probability of earning labor income, and higher labor income due to higher productivity) increases the fraction of active older workers proportionally more than the extension of life expectancy, leading to a reduction in the proportion of retired to active individuals. Thus, active ageing will not only have a better response among more productive workers, but it will also invite a better response in those economies where the (preventive) health sector productivity is sufficiently high and, thus, offers health goods at a low price.

Note that the threshold $\tilde{q}$ increases with life expectancy. When life expectancy is low, the threshold is also low, making it more probable that the price of health exceeds $\tilde{q}$ and hence, all individuals would retire at the expected age, and the dependence ratio $d = p$) would increase with *p*. However, as life expectancy grows, the threshold $\tilde{q}$ moves up. Since the elasticity of the threshold $\tilde{q}$ to life expectancy is equal to $1/\delta$, with $\delta \in (0,1)$, $\tilde{q}$ rises more than proportionally to increased life expectancy, making it more likely that further increases in life expectancy would entail progressive reductions in the dependency ratio.

This suggests an important role for public policy in the actual context of the ageing of the population, to guarantee access to preventive health goods at a low price, either by subsidizing this activity, implementing public health insurance, or directly making public health services available for all workers. Recent empirical evidence appears to point in this direction. For instance, Finkelstein et al. (2012) show that an approximately one-year extension of access to Medicaid among a low-income, uninsured adult population in Oregon led to an increase in compliance with recommended preventive care, including blood cholesterol checks, blood tests for diabetes, mammograms, and Pap tests. Courtemanche and Zapata (2014) find that the 2006 Massachusetts health care reform, oriented to guaranteeing universal access to health care, has led to positive effects on overall health, strongest among those with low incomes. Since the current growth in the retired population, relative to the active one, leads to increasing pressure on government budgets, an early investment in preventive health could, as shown above, reduce the dependency ratio and, as a consequence, relieve the pressure on the public pensions system. This raises the question of whether the initial expenditure (either through subsidies, or direct financing of a public health system) is compensated for by the improved budget of the pensions system. Since we have not incorporated pensions, or workers contributions, our framework does not allow for an answer. However, it is plausible to consider that a very efficient health sector would make public investment in health desirable from a financial point of view.

5. Conclusions

Active ageing is not simply the participation of older individuals in the labor market; it is a much broader concept. Health advances have brought an increase in life expectancy over recent decades that has had an economic impact by increasing the labor supply, both quantitatively (people live longer, so they are available for longer in the labor market) and qualitatively (people are healthier and, thus, more productive). In developed countries, however, the quantitative has been exhausted once life expectancy exceeded the retirement age, and so the increase in longevity translates into an expansion of the retirement years, without significant changes in the labor supply. This situation, and the potential financial challenges involved, has led to a debate about the convenience and/or advisability of delaying retirement, with the result that many countries are increasing the legal retirement age. The main challenge, in fact, is not to increase life expectancy, but to extend the period of a healthy and productive life. In other words, the focus is - or should be - qualitative: on a healthy life expectancy.

With the new scenario in mind, we have developed a theoretical model that takes life expectancy as given, and focuses on the incidence of investment in the health status of the elderly. From an economic point of view, this is important because health status is a significant determinant of worker productivity and has implications both at the individual and at the aggregate levels: on the one hand, it conditions retirement decisions; on the other, it increases the labor supply and brings a halt to the broadening ratio of non-active individuals relative to the active mass. The consideration of differences in productivity between workers introduces an additional dimension to the analysis, since it can give rise to heterogeneous individual behavior facing both retirement and health demand decisions.

Our results show clearly that individual productivity is a primary determinant of the length of the active period of workers' lives. Those who are more productive stay longer in the labor market, whereas those with lower productivity retire sooner. In turn, heterogeneity in health expenditure leads to increasing differences in productivity among older workers. However, a low-productive health sector, with high prices, would eliminate this relationship, because it would prevent the whole of society from investing in health and working later. This is why we assert the importance of a good health sector providing accessible health services, to encourage individuals to consider postponing their retirement. The better the health services, the higher the activity rate among the elderly and, thus, the lower the dependency ratio (non-active over active population).

This suggests an important role for public health policy in the context of the ageing of the population. In developed economies, some public health services are available to all workers as a way of preserving their health status without incurring direct expenses. Thus, with the affordability of health services being guaranteed to at least some extent (or, alternatively, properly subsidizing access to the health goods market), the increase in life expectancy would not necessarily lead to a reduction in the dependency rate; on the contrary, if individuals were free to choose their retirement age, the labor supply of older workers could expand at a faster rate than longevity.

Appendix. Solving the equilibrium

The individual problem (P) can be solved in two stages. In the first, individuals decide on their levels of non-health consumption when young and old ($c_i^y > 0, c_i^o > 0$), and their level of health goods consumption when young ($h_i \geq 0$), which, in turn, will depend on the retirement decision. In the second stage, the decision about whether to retire ($e_i = 0$) or not ($e_i = 1$) is taken by comparing individual welfare in both situations. The Lagrangian function is given by:

$$L = \left(\frac{c_i^y}{1-\beta} \right)^{1-\beta} \left(\frac{c_i^o}{\beta} \right)^{\beta p} \left[1 + \lambda(1-e_i) \right]^p + \mu \left(w\theta_i + \frac{p}{1+r} wDh_i^\delta \theta_i \, e_i - c_i^y - qh_i - \frac{p}{1+r} c_i^o \right).$$

The optimal non-health and health consumption profiles, conditional on the retirement decision, are given by:

$$\frac{\partial L}{\partial c_i^y} = (1-\beta) \left(\frac{c_i^y}{1-\beta} \right)^{-\beta} \frac{1}{1-\beta} \left(\frac{c_i^o}{\beta} \right)^{\beta p} \left[1 + \lambda(1-e_i) \right]^p - \mu = 0, \tag{i}$$

$$\frac{\partial L}{\partial c_i^o} = \left(\frac{c_i^y}{1-\beta} \right)^{1-\beta} \beta p \left(\frac{c_i^o}{\beta} \right)^{\beta p - 1} \frac{1}{\beta} \left[1 + \lambda(1-e_i) \right]^p - \mu \frac{p}{1+r} = 0, \tag{ii}$$

$$\frac{\partial L}{\partial h_i} = \mu \left(\frac{p}{1+r} wD\delta h_i^{\delta-1} \theta_i \, e_i - q \right) = 0. \tag{iii}$$

Equations (i) and (ii) can be merged into:

$$\frac{c_i^o}{c_i^y} \frac{1-\beta}{\beta} = 1 + r \tag{iv}$$

with the marginal rate of substitution between consumption in two periods being equal to $1+r$; that is to say, the inter-temporal rate of consumption substitution is independent of e_t. However, from equation (iii), an interior solution for h_i emerges when $e_i = 1$:

$$h_i = \left(\frac{p}{1+r} \frac{wD\delta\theta_i}{q} \right)^{\frac{1}{1-\delta}}, \tag{v}$$

whereas $e_i = 0$ leads to the corner solution $h_i=0$. We assume that the condition $D < \left(\frac{1+r}{p} \frac{q}{w\delta} \right)^{\delta}$ holds that, from equations (1) and (v), guarantees that individual productivity levels fall due to ageing: $\theta_i^o < \theta_i$.

Substituting (iv) and (v) into the individual budget restriction, the optimal consumption levels when young and old, conditional on the decision to remain in the labor market when old $\left(e_i = 1\right)$, are given by (3a) and (4a). In parallel, substituting (iv) and $h_i=0$ into the individual budget restriction, the optimal consumption levels when young and old, if the individual retires when old $\left(e_i = 0\right)$, are given by (3b) and (4b).

By introducing equations (3a) and (4a) into the utility function, we obtain that the level of welfare achieved by a worker *i* who decides to remain in the labor market when old is given by:

$$EU\left(e_i = 1\right) = \left(\frac{1}{1+r} \right)^{1-\beta} \left\{ \frac{1+r}{1-\beta+p\beta} \left[w\theta_i + \frac{1-\delta}{\delta} q \left(\frac{p}{1+r} \frac{wD\delta\theta_i}{q} \right)^{\frac{1}{1-\delta}} \right] \right\}^{1-\beta+p\beta} ,$$

whereas, by using (3b) and (4b), the welfare in the case of retirement is:

$$EU\left(e_i = 0\right) = \left(\frac{1}{1+r} \right)^{1-\beta} \left(1+\lambda\right)^{p} \left[\frac{1+r}{1-\beta+p\beta} w\theta_i \right]^{1-\beta+\beta p} .$$

The individual *i* will be willing to participate in the labor market when old only when $EU\left(e_i = 1\right) \geq EU\left(e_i = 0\right)$, that is to say, when

$$\left[w\theta_i + \frac{1-\delta}{\delta} q \left(\frac{p}{1+r} \frac{wD\delta\theta_i}{q} \right)^{\frac{1}{1-\delta}} \right]^{1-\beta+p\beta} \geq \left(1+\lambda\right)^{p} \left(w\theta_i\right)^{1-\beta+\beta p} ,$$

a condition that holds for individuals whose (young) productivity exceeds the critical value given in (6):

$$\theta_i \geq \theta_{i*} = \Omega \frac{q}{w} \left(\frac{1+r}{pD\delta} \right)^{1/\delta} ,$$

where $\Omega = \left\{ \frac{\delta}{1-\delta} \left[\left(1+\lambda\right)^{\frac{p}{1-\beta+p\beta}} - 1 \right] \right\}^{\frac{1-\delta}{\delta}}$.

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