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Abstract

In this paper we model an OLG-economy where labour supply is endogenously determined and where we assume that there are two pension systems, namely, a pay-as-you-go system and a funded system. The main question is whether there is an equilibrium involving an old-age pensions system, partly financed by PAYG and partly by a capital reserve system, and what will be the size and the composition of the pension income. We also look at the consequences of increasing preference for leisure on the design of the pension system. We assume the population growth rate and the technological growth rate to be endogenous; they are assumed to be correlated with the labour supply. Negative population growth is admitted for by the model. The main conclusion is that there is in any economy an equilibrium, but that the numerical outcomes heavily depend on the attitude towards leisure and the capital production elasticity.

Keywords: ageing, labour supply, old-age pensions, pay-as-you-go.

JEL Code: D91, H55, J14, J22, J26.

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1 Introduction

A major concern of the developed world is the ageing problem. Birth rates and age-specific mortality rates are falling. The result is that the world is confronted for the first time with the fact that the retired part of populations is becoming quite substantial. The ratio of retired to workers, the dependency ratio, is increasing to 1:3 or even more. It is sometimes thought that this is a transitory phenomenon and that the ratio will tend to normal values again if we reach a new equilibrium. However, it is easy to show that this is only partially true. In a stationary demography the average age is a decreasing function of the birth rate; similarly it is increasing with rising life expectancy. In all probability we have entered into a demographic situation where the population growth rate hovers at zero or even becomes negative, say minus 1% per year, while life expectancy tends to eighty years or more. Given this new situation the question how the retired have to be supported becomes an urgent question. In most economies the retirement pension is generated from two sources or 'pillars'. The first pillar is a compulsory pension insurance system, based on compulsory savings, where workers save for their old age pension. This is a major source for capital investments. The second pillar is a state pension, which is financed by compulsory contributions from the workers to a pay - as- you - go system (PAYG). The PAYG - system does not generate capital investments. In practice in each country we find a mixture of both systems, but the mix varies widely between and within countries countries. In the U.K. and The Netherlands the funding system is quite important but, e.g., in France, Germany and Italy the bulk of pensions stems from a PAYG system.

In this paper we shall consider the question whether there is a relation between the demographic parameters, i.e. the birth rate, and the probable mix between the two pension systems and what we may expect for the total level of retirement pensions, if the demographic parameters change. This paper builds on Van Praag and Cardoso (2002), but we introduce some important new elements.

In most of the literature it is assumed that labor supply per individual is exogenously fixed. In this paper we shall assume that labor supply, that is the number of working hours per week, is determined by the worker. Hence labor supply is assumed to be endogenous. However, this free choice comes at a price. If a worker works less than a full-time working week of 40 hours, but e.g. only for half-time, then in most cases the worker will be less productive per hour than when working full-time. Empirical evidence that compensation per hour is lower in part-time jobs than in full-time jobs has been found[1]. Both employers and employees are aware of it. It may be explained by two things. First, a working task requires training and permanent schooling on the job. This implies an investment for the employer in terms of training costs and productive hours lost, which are used for learning by the worker instead of for direct production with negative consequences for labor productivity. The rentability of such investments decreases if the worker makes shorter hours. It follows that the employer will invest less in the part-time worker than in the full - time worker. A second reason is that a job may be split up in productive hours and in a number of activities and costs, which are comparable to fixed set up costs, e.g. the tools and clothing of a blue-collar worker or the time for meetings and transfer of tasks for a white-collar worker. As the fixed costs are the same, irrespective of the number of hours in employment, the hourly production becomes less for part-time workers. It follows that productivity will depend non-linearly on hours worked. We assume that the worker is aware of the fact that his hourly wage depends in a negative way on the length of his working week when determining his labor supply. We shall also assume that the growth rate of labor productivity is endogenous. This rate depends on the size of labor - augmenting investments and technological research. For the same reasons as given above we assume that employers are more inclined to invest in labor-augmenting innovations if workers are working full-time than when they are working part-time. We assume that individual workers are unaware of this relationship and decide

[1] See, e.g., Lettau (1997)

about their labor supply as if the technological growth rate does not depend on the length of the working week. It is a macro - phenomenon on which the worker as an individual has no influence.

There is some evidence in practice and in literature that such relationships between the length of the working week and both the level and the growth rate of labor productivity exist, but we recognize that the question whether such relations hold is not scientifically beyond debate. Moreover, the socio-political content of this debate is evident and this makes objective non-prejudiced research on this subject difficult. Finally, we are sharply aware of the fact that in reality there is a strong heterogeneity between individuals, which makes it hard to come to generally valid statements. Nevertheless, we shall ignore such subtleties in line with the abstraction level of this paper. In this paper we postulate a monotonically increasing relation between working hours and productivity, but this choice might be replaced by any other functional specification as well. For instance, in the framework of the nineteenth century 70 hours working week, it might quite well be that a reduction of the working week would lead to more productivity and a faster productivity growth instead of less. The major point is that the labor-augmenting growth rate becomes endogenous as well.

Finally, we observe in most countries a correlation between the birth rate and (female) labor participation. We will account for this in the model as well. For females it is well-recognized that they frequently face a choice between (increased) participation or getting children. Again, although individuals are quite aware of the fact that working longer hours induces them to get less children, the individual will not bother himself about the fact that, if all individuals will do likewise, the over-all birth rate of the population will be reduced.

In various countries we find an explicit or implicit upper bound on fertility. The only - child - policy in China is an obvious example. In other countries the housing market may put an effective limit on the family size like in Japan or in The Netherlands. Those limits will be incorporated in this model and we shall consider the Chinese case as a special example.

In this paper we assume that there are three parties in an Overlapping Generations economy: the workers, the retired, and the state. The workers care for themselves; the retired have their pension savings and some political clout, but their influence is indirect through government; the state cares for the workers *and* the retired. The state has taken over the task to care for the weak (i.e. the retired) from the working citizens, who are less able and/or unwilling to do this as individuals. The working citizens pay taxes to the state and the state uses part of it to look after the weak, thus freeing the individual citizens from their altruistic tasks: altruism is institutionalized. This is a matter of efficiency. This model implies that the state and the individual workers in general will have different objectives and hence different objective functions to be maximized. We are looking for a Nash - equilibrium between the workers and the state.

The model presented builds on the general equilibrium two-period overlapping generation model (OLG), first presented in the seminal papers by Samuelson (1958, 1975) and Diamond (1965). Endogenous or elastic labour supply is ignored in most of the subsequent literature dealing with social security[2]. Breyer and Stolte (2001), who present a model of majority voting, is an exception, as they endogenize the labour supply decision. Based on this idea, already presented in Breyer (1994a), the authors found that in case the workers can avoid the payment of taxes by reducing their labour supply, the burden of ageing will penalize more heavily the retired than the young. Casamatta et al. (2001) consider early retirement issues in the context of direct voting and conclude that a PAYG pension system inducing early retirement also generates a higher welfare than one that does not affect retirement decisions.

In a very recent contribution Razin et al. (2002) present an argument why

[2]For comprehensive surveys on the political economy of social security we refer to Verbon (1993), Breyer (1994) and Galasso and Profeta (2002).

pay-roll taxes may not increase in the scenario of an ageing population. In their model attention is paid to human capital investments, where individuals have different talents for learning. Labour supply is assumed to be exogenous, whereas in our model we assume labour supply to be endogenous.

These models are based on majority voting, with decisions on the structure of PAYG system being taken once and for all. Cooley and Soares (1999) and Boldrin and Rustichini (2000) departed from this approach by introducing a dynamic, repeated-voting game, where voting takes place every period: at the first stage individuals have the option to set-up a PAYG system and in every subsequent period they may vote on the continuation or abandonment of the original system. In both articles it is shown that a PAYG system arises at equilibrium, and once it is in place it will never be dismantled. This implies that the first generation that votes for the installation of the system completely determines its design for the coming periods. In Boldrin and Rustichini (2000) additional attention is paid to the dynamics of the political equilibrium and its effects on capital accumulation, while Cooley and Soares (1999) work also on measuring the welfare effects of the politico - economic equilibria. In the last contribution labour supply is endogenised like in our paper.

Despite the wide use of 'the median voter', one may argue that as there are social security programs in democratic *and* non-democratic countries, median voter models are less appropriate to explain the existence of such programs in authoritarian systems or in multi-party democracies. We give a contribution by modeling the decision making in the framework of a government that has its own objective function, which comprises the citizen's utility function as one of its arguments. This is the case in representative democracies, but it can describe also the reality in non-democratic countries, where dictators have to avoid public outrage. In this respect the work by Meijdam and Verbon (1996) predates this paper as these authors use a similar approach to study the effects of ageing on the economy.

Some aspects of the ageing problem have been studied in a context of (computable) general equilibrium OLG - models. Examples of this approach are Auerbach and Kotlikoff (1987), Raffelhuschen and Risa (1995) and Miles (1999). These models provide a normative analysis in a context of a large number of simultaneously living population cohorts. The model presented in our paper is focusing on a positive rather than on a normative approach.

A considerable literature looks at intergenerational transfer systems with endogenous fertility considering the effect of demography on the (macro) sustainability of the PAYG system. An early bird in this literature is Van Praag and Poeth (1975). They attempted to model a third type of old-age income provision: transfers from children to parents. In this case old age income is dependent on one's offspring as in Nishimura and Zhang (1992). Intra-family transfers arise due to altruism from children to parents. Kolmar (1997) reverses the direction of altruism assuming that parents care for their children's welfare and derives the optimal PAYG-pension formula related to the number of children raised. Cigno (1993) studied intergenerational transfers where any kind of altruism is assumed to be away. Within a three-periods OLG world, it is shown that transfers from selfish middle-aged individuals (the only ones with own income) to their parents and offspring can be sustained if people see transfers from the middle-aged individual to the young as loans and from the middle-aged to the old as debt repayments.

We do not include transfers from children to parents as a third pension system as it is relatively unimportant in real-world developed economies. It is replaced by the institute of compulsory membership of a national PAYG-system.

In this paper we distinguish between the capital reserve system, which is fed by employees who save on a mandatory basis, and the nation-wide PAYG - system. We observe that most retired citizens are supported from both sources. The mix differs between countries. The novel contributions of our paper are that we look at the mix and the total level of pensions as the outcomes of a political Nash-equilibrium with the individual citizens and the government as players. We allow for endogeneity in population growth, in labour supply and in technological growth. Moreover, we will check whether elastic labour supply and stronger preferences for leisure will stimulate the expansion of unfunded PAYG systems in face of an ageing population.

This paper is organized as follows. First, in section 2, the two-period model that will be used is presented. In section 3 the equilibrium is derived. In section 4 numerical results are analysed. In Section 5 we evaluate our results and draw some conclusions.

2 The Model

2.1 The Citizen

We assume that individuals live for two periods. During the first period of life they work and during the second period they are retired. In this economy the worker has two choice variables: savings S_t and labor supply φ_t. In reality labour supply may be varied in a number of ways, e.g., by shorter hours, early retirements, longer holidays, etc. If we replace the 'individual' by the 'household', labour supply may also vary because one or both of the spouses do not work full-time or has an incomplete working history. Then we talk of household supply. In this paper we will not make such differentiations. We scale the variable φ_t such that $\varphi_t \in [0, 1]$. We also assume that the worker takes the full-time hourly wage rate w_t, the interest rate r_t, the growth rate g_t and the pay-roll tax θ_t as exogenously given.

A worker's consumption equals

$$C_t^t = \{(1 - \theta_t)w_t - S_t)\}h(\varphi_t)A_t \tag{1}$$

The superscript stands for the birth cohort and the subscript for calendar time. We assume that each worker embodies A_t labour efficiency units, when he is working the full working week and during the whole period. If he/she works for a fraction φ_t, his/her labour output will be $h(\varphi_t)A_t$. The share φ_t can either be seen as the number of years spent working until (early) retirement or as the number of working hours per week. The function $h(\varphi_t)$ $(0 \leq h(.) \leq 1)$ expresses the (non-linear) relation between labour effort and labour income, with $h'(.) > 0$. If an individual gets w_t per efficiency unit if he is working full time, it is reduced to $w_t h(\varphi_t)$, when he works part - time. The gross wage will be then equal to $w_t h(\varphi_t) A_t$. The variable θ_t is the fraction of wage w_t, which is paid as contribution to the PAYG system. Savings amount to S_t per labour efficiency unit supplied. In the second period of life the individual will be retired and the consumption will be:

$$C_{t+1}^{t} = \{P_{t+1} + (1 + r_{t+1}) S_t\} h(\varphi_t) A_t \tag{2}$$

where P_{t+1} represents the PAYG - pension and $(1 + r_{t+1}) S_t$ represents the pension from the funded pillar, both per unit of effective labour supplied by the individual in the first period. The interest rate is denoted by r_{t+1}. We assume for the (working) individual a separable lifetime utility function

$$U^t = U_1(C_t^t, 1 - \varphi_t) + \rho U_2(C_{t+1}^t) \tag{3}$$

where ρ is the individual time preference discount rate. The working period utility depends on consumption C_t^t and leisure $(1 - \varphi_t)$, while the retirement period utility depends on consumption C_{t+1}^t only.

In order to allow for further numerical treatment we shall assume that the consumption utility of an individual is specified as a function of the Constant Relative Risk Aversion (CRRA)-type, that is, $U(C) = C^{(1-\gamma)}/(1-\gamma)$. In line with most empirical estimates we assume that the relative risk aversion parameter γ is larger than one $(\gamma > 1)$. This implies that the utility value is negative but increasing in C and tending to zero asymptotically. If we assume that $U_1 = U_c(C).U_{le}(1 - \varphi)$ where the first factor is consumption utility and the second factor is leisure utility, it follows that for U_{le} positive and monotonically increasing in leisure an increase in leisure would lead to a decrease of overall utility U_1. It implies that we have to adapt our specification of the leisure part to account for $\gamma > 1$. We assume the specific form: $U_{le}(1-\varphi_t) = \frac{1}{(1-\varphi_t)^{\varepsilon}}$, where $\varepsilon > 0$. Lifetime utility is

$$U^t = \frac{(C_t^t)^{1-\gamma}}{1-\gamma} \frac{1}{(1-\varphi_t)^{\varepsilon}} + \rho \frac{(C_{t+1}^t)^{1-\gamma}}{1-\gamma} \tag{4}$$

The citizens' utility function becomes then after substitution of (1) and (2) in (4):

$$U^t = \frac{(\{(1-\theta_t)w_t - S_t)\} h(\varphi_t) A_t)^{1-\gamma}}{(1-\gamma)(1-\varphi_t)^{\varepsilon}} + \rho \frac{(\{P_{t+1} + (1+r_{t+1})S_t\} h(\varphi_t) A_t)^{1-\gamma}}{1-\gamma} \tag{5}$$

2.2 Demography

We assume that population L_t grows at the rate n_t per period, $L_{t+1} = (1 + n_t)L_t$. It is assumed, based on the observed trends in the last century and on demographic family- planning- surveys, that the longer working weeks go hand in hand with smaller families. Thus increased working efforts will reduce population growth. The equation of population growth is specified as

$$n = \tilde{n} - e\varphi_t^{\chi} \tag{6}$$

The idea is that there is a maximum birth rate $\tilde{n}$ which is reduced with a heavier work burden. Typically this reduction will be non - linear. We assume $e, \chi \geq 0$. There is a maximum growth rate $\tilde{n}$ and a minimum rate $\tilde{n} - e$; both rates may be negative.

2.3 Technology

For the sake of simplicity we consider a one-commodity closed economy, where the commodity can be either used as a capital or as a consumption good. Consequently, the current aggregate capital stock is the sum of savings of all old individuals:

$$K_{t+1} = S_t h(\varphi_t) A_t L_t \tag{7}$$

We assume a Cobb-Douglas production function, which yields :

$$Y_t = K_t^{\alpha} (A_t h(\varphi_t) L_t)^{1-\alpha} \tag{8}$$

and $y_t = k_t^{\alpha}$, with $k_t = (\frac{K_t}{A_t h(\varphi_t) L_t})$, where y and k stand for the production and the capital per employed output efficiency unit. In the case of competitive markets the interest and wage rates per employed unit of effective labour equal the marginal productivity of capital and labour, respectively. We get as usual:

$$r_t = \frac{dy}{dk} = \alpha k_t^{\alpha-1} \tag{9}$$

$$w_t = y_t - r_t k_t = (1-\alpha) k_t^{\alpha} \tag{10}$$

In this paper we distinguish between labour input φA and effective labour output $h(\varphi)A$. We assume a non-linear relationship $h(\varphi_t)$. In this paper we assume

$$h(\varphi_t) = {\varphi_t}^{\lambda}, \ \ \lambda \geq 1 \tag{11}$$

In the case of $\lambda = 1$ there are no scale effects. We shall assume that the worker is aware of the fact that his hourly wage will be reduced if he supplies less hours.

We assume technological growth g_t in the sense that

$$A_{t+1} = (1 + g_t) A_t \tag{12}$$

Also here we shall assume that g_t is endogenous, that is, $g_t = g(\varphi_t)$. If labor supply is low, it is less profitable and there are fewer opportunities to enhance the quality of labour by learning-by-doing and inventing in labour-augmenting technology than when participation is high. We specify

$$g_t = \tilde{g} * \varphi_t^{\eta}, \ \ \eta \geq 0 \tag{13}$$

The maximum growth rate is denoted by $\widetilde{g}$. When $\eta = 0$ and $\lambda = 1$ we are back into the situation of 'pure' exogenous growth.

We see this as a macro-relation of which the individual worker is unconscious. It does not affect his labour supply.

The total growth rate of the labour force in terms of efficiency units is denoted by υ_t, and we have $(1 + \upsilon_t) = (1 + g_t)(1 + n_t)$.

2.4 The state and the PAYG social security system

Decisions on the size of the PAYG system can be modelled in at least two ways: one is to assume a direct voting process, where the decision will depend on the 'median voter'. However, if the political spectre is not one-dimensional, it is frequently impossible to define a 'median voter'. The median-voter solution is irrelevant in non-democratic or multi-party systems. The other way, which shall be followed here, is to consider the state, represented by its government, as a separate agent in the economy. This is obviously the everyday practice in most countries. The rationale for the existence of a state is that it can do things which citizens want but cannot do themselves or only at much higher costs. This holds especially for the production of collective goods, merit goods, and all kinds of basic collective insurances like for old-age, disability, defense in case of war, and natural disasters. This makes it also possible that individual citizens have not to bother about such tasks. Individuals do not have to care for their anonymous fellow - citizens, because the state will care for them if necessary. The state becomes a defender of the weak. These activities are financed by levying a tax θ_t. In the simplified world, which we consider, the weak are thought to be identical with the retired (generation $t-1$). They have no leverage to ask for contributions from the workers (generation t) and mainly they dispose only of a minority of the votes.

The government takes into account the interests of both the currently living workers and the retired. So government policies are influenced by both living generations. It behaves as if it is maximizing a *composite utility function* (W), a weighted average of the utilities of the different generations. It will be called the government objective function (GOF), which we specify as

$$W = U^t(C_t^t, 1-\varphi_t, C_{t+1}^t) + \delta(n_t)U^{t-1}(C_t^{t-1}) \quad (14)$$

The first term in (14) represents the lifetime utility function of the present workers. The last term stands for the utility of the currently retired. The weight $\delta(n_t)$ reflects the relative weight that is assigned to the retired, the weight of the young generation being set at one. We assume $\delta_t = \frac{\tilde{\delta}}{1+n_t}$. For the baseline scenario the value $\tilde{\delta} = 1$ will be considered. If the population does not accept the government's behavior, that is its GOF, there will be discontent. If that discontent is large enough, the government or at least its GOF will be changed, either by democratic means or by revolution. We will assume in this paper that the GOF reflects the expectations of the citizens as to what the government should stand for.

We notice that the government has only one instrument in this model, the tax rate θ_t, by which it can influence the present and future consumption of the workers C_t^t, C_{t+1}^t and the consumption of the presently retired C_t^{t-1}. We assume that the workers when making their decisions on saving and labour supply do this under the hypothesis that the current tax rate will be left unchanged in the future.

We notice that it looks as if the government has a finite horizon of only one period ahead. However, we may extend this to a more - period or even in-finite horizon. We may consider the following extended government objective function

$$W = U^t(C_t^t, 1-\varphi_t, C_{t+1}^t) + \delta(n_t)U^{t-1}(C_t^{t-1}) + \zeta U^{t+1}(C_{t+1}^{t+1}, 1-\varphi_{t+1}, C_{t+2}^{t+1}) \tag{15}$$

where we assume in this example that the government is sensitive to the interests of the first-next unborn generation as well. We notice that in a dynamic equilibrium consumption will increase by the growth rate $g(n)$ and hence utility by $g(n)^{1-\gamma}$. It follows that the above expression can be rewritten in terms of the original GOF with other weights. The generalization is rather straightforward for a longer time horizon. Although we will not take this more-period extension explicitly into account, it follows that the model is also useful when the government takes the interests of future generations into account.

The government collects contributions from the workers and pays all the revenue as pensions to the elderly, so an equality between expenditures and tax revenues holds. Thus the PAYG pension is determined by the budget constraint:

$$P_t * A_{t-1} * L_{t-1} * h(\varphi_{t-1}) = \theta_t * w_t * A_t * L_t * h(\varphi_t)$$

and we find

$$P_t = \theta_t w_t (1+\upsilon_t) \frac{h(\varphi_t)}{h(\varphi_{t-1})} \tag{16}$$

The rules of behaviour are now obvious. The workers maximize their utility by deciding about their labour supply φ_t and their savings S_t. The state maximizes the GOF with respect to θ_t. Moreover, a Nash behaviour is assumed: both the individual and the government take the decisions of the other part as given.

If there exists a stationary equilibrium, there have to be values S, φ, θ which are constant over time such that the first-order-conditions for both parties are satisfied. Moreover, we have to account for the relations (6), (11) and (13).

2.5 The first - order conditions

Maximization of citizen's utility in equation (5) with respect to φ gives

$$\frac{\partial U^t}{\partial \varphi_t} = (C_t^t)^{-\gamma} \frac{1}{(1-\varphi_t)^{\varepsilon}} \frac{C_t^t}{h}.h' + \varepsilon (C_t^t)^{1-\gamma}. \frac{1}{(1-\gamma)(1-\varphi_t)^{\varepsilon+1}} + \rho\{(C_{t+1}^t)^{-\gamma} \frac{C_{t+1}^t}{h}.h'\} = 0 \tag{17}$$

As $h = \varphi^{\lambda}$, we notice that $\frac{h'}{h} = \frac{\lambda}{\varphi}$ and we get

$$\{\frac{C_t^t}{C_{t+1}^t}\}^{1-\gamma} = \frac{-\rho\lambda(1-\varphi_t)^{\varepsilon+1}}{(1-\varphi_t)\lambda + \frac{\varepsilon\varphi_t}{1-\gamma}} \tag{18}$$

We get for the first-order-condition with respect to savings:

$$\frac{\partial U^t}{\partial S_t} = (C_t^t)^{-\gamma} * (-A_t h(\varphi_t)) * \frac{1}{(1-\varphi_t)^{\varepsilon}} + \rho (C_{t+1}^t)^{-\gamma}(1 + r_{t+1}) A_t h(\varphi_t) = 0 \tag{19}$$

and after further simplification:

$$\frac{C_t^t}{C_{t+1}^t} = (\rho(1 + r_{t+1})(1-\varphi_t)^{\varepsilon})^{-\frac{1}{\gamma}} \tag{20}$$

The government takes the decisions of the individuals as given. The first-order-condition for government optimizing behaviour is given by:

$$\begin{aligned}\frac{\partial W}{\partial \theta_t} &= (C_t^t)^{-\gamma}(-w_t A_t h(\varphi_t)) * \frac{1}{(1-\varphi_t)^{\varepsilon}} + \\ &+\rho(C_{t+1}^t)^{-\gamma}(w_{t+1}(1+\upsilon_{t+1})A_t h(\varphi_{t+1})) + \\ &+\delta(C_t^{t-1})^{-\gamma}(w_t(1+\upsilon_t)A_{t-1}h(\varphi_t)) = 0\end{aligned} \tag{21}$$

After simplification we get:

$$\begin{aligned}&-(C_t^t)^{-\gamma}(w_t h(\varphi_t))\frac{1}{(1-\varphi)^{\varepsilon}} + \rho(C_{t+1}^t)^{-\gamma}(w_{t+1}(1+\upsilon_{t+1})h(\varphi_{t+1})) + \\ &+\delta(C_t^{t-1})^{-\gamma}(1+\upsilon_t)\frac{1}{(1+g_t)}w_t h(\varphi_t) = 0\end{aligned} \tag{22}$$

or

$$\begin{aligned}&-(C_t^t)^{-\gamma}(w_t h(\varphi_t))\frac{1}{(1-\varphi)^{\varepsilon}} + \rho(C_{t+1}^t)^{-\gamma}(w_{t+1}(1+\upsilon_{t+1})h(\varphi_{t+1})) + \\ &+\delta(C_t^{t-1})^{-\gamma}(1+n_t)w_t h(\varphi_t) = 0\end{aligned} \tag{23}$$

We notice that factor prices w_t and r_t are also influenced by θ_t.

3 The Equilibrium

In the equilibrium, as usual, we assume that the variables φ_t, S_t and θ_t, and consequently w_t and r_t are constant over time. The only sources of growth are the population growth n_t and the technological progress g_t. Variables without time index represent equilibrium values.

The solution to the three first-order-conditions of our model, two for the individual and one for government behaviour, will give the solution for the variables of our model. We will go back to the first-order-conditions of the individual problem. For leisure, from equation (18) we get:

$$\{\frac{C_t^t}{C_{t+1}^t}\}^{1-\gamma} = \frac{-\rho\lambda(1-\varphi)^{\varepsilon+1}}{(1-\varphi)\lambda + \frac{\varepsilon\varphi}{1-\gamma}}$$

or

$$\{\frac{C_t^t}{C_{t+1}^t}\}^{1-\gamma} = \frac{-\rho(1-\varphi)^{\varepsilon+1}}{1-\varphi(1+\frac{\varepsilon}{\lambda(\gamma-1)})} \tag{24}$$

For savings, from equation (20) we find

$$(\frac{C_t^t}{C_{t+1}^t})^{-\gamma} = \rho(1+r)(1-\varphi)^{\varepsilon} \tag{25}$$

The first-order condition for government behaviour (23) becomes after some algebra:

$$-(C_t^t)^{-\gamma}\frac{1}{(1-\varphi)^{\varepsilon}} + \rho(C_{t+1}^t)^{-\gamma}(1+\upsilon) + \delta(C_t^{t-1})^{-\gamma}(1+n) = 0 \tag{26}$$

Simplifying and dividing by $(C_{t+1}^t)^{-\gamma}$, while taking into account that in equilibrium $C_{t+1}^t = (1+g)C_t^{t-1}$ we get

$$-(\frac{C_t^t}{C_{t+1}^t})^{-\gamma}\frac{1}{(1-\varphi)^{\varepsilon}} + \rho(1+\upsilon) + \delta(1+g)^{\gamma}(1+n) = 0 \tag{27}$$

3.1 Leisure

Combining the first order conditions for leisure (24) and the government (27) we get the equation in φ

$$-(\frac{\rho(1-\varphi)^{\varepsilon+1}}{\varphi(1+\frac{\varepsilon}{\lambda(\gamma-1)})-1})^{\frac{-\gamma}{1-\gamma}}\frac{1}{(1-\varphi)^{\varepsilon}} + \rho(1+\upsilon) + \delta(1+g)^{\gamma}(1+n) = 0 \tag{28}$$

After some simplification we get the first-order condition for leisure:

$$-\left(\frac{\rho}{\varphi(1+\frac{\varepsilon}{\lambda(\gamma-1)})-1}\right)^{\frac{\gamma}{\gamma-1}}(1-\varphi)^{\frac{\gamma+\varepsilon}{\gamma-1}}+\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n)=0 \quad (29)$$

The solution to this reduced form equation gives the value for the optimal labor supply φ in equilibrium. We notice that this is an equation in one unknown φ as δ, n and g and consequently υ are functions of φ as well. Having determined the endogenous φ we may roll back the system and solve for the other unknowns. Unfortunately there is no closed -form -solution for this equation, so it turns out that we have to use numerical methods. The outcomes of numerical solutions will be presented below in Section 4.

3.2 Contribution rate

The equilibrium contribution rate θ is now found from equation (27). We get:

$$\left(\frac{C_{t+1}^{t}}{C_{t}^{t}}\right)^{-\gamma}=\frac{1}{(1-\varphi)^{\varepsilon}}*\frac{1}{(\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n))} \quad (30)$$

$$\left(\frac{(1+r)S+P}{(1-\theta)w-S}\right)^{-\gamma}=\frac{1}{(1-\varphi)^{\varepsilon}}*\frac{1}{(\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n))} \quad (31)$$

After some straightforward algebra we obtain an explicit solution for θ:

$$\theta = \frac{(1-\frac{S}{w})H-(1+r)\frac{S}{w}}{1+\upsilon+H} \quad (32)$$

$$\text{with } H = ((\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n))(1-\varphi)^{\varepsilon})^{\frac{1}{\gamma}}$$

3.3 Interest rate and Savings

Combining the first-order-conditions for the government with the individual's savings problem, equations (27) and (25) we get:

$$(\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n))(1-\varphi)^{\varepsilon}=\rho(1+r)(1-\varphi)^{\varepsilon}$$

$$\rho(1+\upsilon)+\delta(1+g)^{\gamma}(1+n)=\rho(1+r)$$

yielding

$$r=\upsilon+\frac{\delta}{\rho}(1+g)^{\gamma}(1+n) \tag{33}$$

The interest rate is a function of the growth rate of this economy υ plus a term that depends on the political weight of the old δ. In case the government does not take into account the utility of the old, i.e. $\delta=0$, we find the traditional golden rule solution of capital accumulation. If δ increases, it is hard to say what will be the effect on r, because n, g and υ depend (via φ) on δ as well. However, the numerical explorations will provide some insight in the sensitivity of the solution with respect to parameter values.

We are now able to derive the optimal savings per labour effective unit in equilibrium. Using a Cobb-Douglas production function we have $r=\alpha k^{\alpha-1}$ in a competitive equilibrium. It follows that, in equilibrium, the capital stock becomes, $k=(\frac{r}{\alpha})^{\frac{1}{\alpha-1}}$. Savings are then

$$S=(1+\upsilon)(\frac{\upsilon+\frac{\delta}{\rho}(1+g)^{\gamma}(1+n)}{\alpha})^{\frac{1}{\alpha-1}} \tag{34}$$

4 Numerical Explorations

The model outlined above hangs on the solution of the non-linear equation (29). If we want to analyse the dependency between the various parameters and the outcome variables, we have to take recourse to numerical simulations, where we vary the parameter values. We will now present numerical results of our model.

The basic parameters of the model are:

a. population parameters $\tilde{n}, e$ and χ, where $\tilde{n}$ stands for maximum population growth per period , $(\tilde{n} - e)$ stands for minimum growth and χ stands for the birth rate elasticity with respect to the length of the working week;

b. the technological parameters $\alpha, \widetilde{g}, \eta$ and λ, where α stands for the production elasticity of capital in the Cobb-Douglas production function, $\widetilde{g}$ for maximum productivity growth, η for the growth elasticity with respect to the working week and λ for the labour output elasticity with respect to the working week;

c. the individual parameters γ, ε and ρ, where the first two describe the effect of consumption and leisure on the utility and where ρ stands for the subjective time discount rate;

d. the political parameter $\tilde{\delta}$, which reflects the weight assigned to the retired part of the population.

We should be aware that we deal with a period length of a generation of say about 35 years. It follows that a maximum population growth rate $\tilde{n}$ of 0.3 per period of 35 years is equivalent to about 0.7% per year. Similarly the parameters e, $\tilde{g}$, and ρ have to be annualized. We will start from a baseline scenario. We will assume as our baseline scenario an exogenous maximum population growth rate $\tilde{n}$ of 0.7% per year, an exogenous maximal technological growth rate $\tilde{g}$ of 2.5% per year, and a subjective time discount rate of about 1% per year. The values for the growth rate reflect the observed ones in several real economies, the time preference is in line with Miles (1999) and further references presented therein. All the other parameters of the model are independent of the period length. For the relative risk aversion γ a value of 2 is taken. The capital elasticity in the Cobb-Douglas production function (α) is set at 25%. For the political weight of the old δ we take $\frac{\tilde{\delta}}{1+n}$ (starting with $\tilde{\delta} = 1$ in the baseline scenario). The relative preference of leisure vs. consumption, expressed by ε is fixed at 0.7. For η and λ, we assume 0.8 and 1.4. For the impact of the labour effort on demographic growth, we take $e = 0.2$ and $\chi = 0.8$. This baseline scenario is chosen partly because empirical estimates are known, e.g. for α. For the other part they have been chosen by calibration, as we looked for realistic outcomes.

Later we will look at the sensitivity of the outcomes of our model to changes in some of these parameters, the first of them, the population growth rate, to see how different demographic scenarios will influence the design of the two pensions systems.

To summarize, our baseline scenario becomes:

$\widetilde{n}$	e	χ	ε	ρ	γ	$\widetilde{g}$	λ	η	α	δ
0.3	0.2	0.8	0.7	0.7	2.0	1.4	1.4	0.8	0.25	$\frac{1}{1+n}$

We are interested in the resulting values for the endogenous variables. Those variables are:

n	the population growth rate per period
npa	the effective population growth rate per annum (p.a.)
g	the effective technological growth rate (per period)
gpa	the effective technological growth rate (p.a.)
φ	the labour supply (p.p.)
θ	the contribution rate to the PAYG system
y	Income per efficiency unit: $k^{\alpha}h(\varphi)$
υpa	the growth rate of the economy (p.a.)
rpa	the interest rate (p.a.)
k/y	capital output ratio (p.a.)
S/w	Savings over gross wage ratio
FR	Funding ratio: $\frac{(1+r)S}{(1+r)S+(1+\upsilon)\theta w}$
$BenR$	Benefit ratio: $\frac{C_t^{t-1}}{C_t^t}$
$AvgW$	Total welfare: $U_t^t + \frac{1}{1+n}U_t^{t-1}$

Most of the variables do not need further explanation. The capital - output ratio is the ratio of a timeless variable and one which is calculated per period, so it has to be annualized by multiplying it by 35. The funding ratio, which is the fraction of old-age income that stems from the funded pension system, measures the mix between the PAYG - and the capital - reserve- system. Total welfare stands for the average utility of the workers and the retired, weighted by their population shares.

Table 1: Outcomes for the baseline scenario.

npa	0.4%
gpa	2.1%
φ	0.704
θ	13.2%
y	0.198
vpa	2.5%
rpa	6.3%
k/y	1.181
$\frac{S}{w}$	10.6%
FR	74.1%
$BenR$	77%
$AvgU$	-14.961

The resulting outcomes are a population growth of 0.4 % and a productivity growth of 2.1% per year. The labour participation ratio φ becomes 0.70. This means that people will work slightly above two thirds of their maximum working time. The social security tax is 13% of the labour income. The total output grows at the rate 2.5 %. The capital output ratio is 1.181 and savings will collect a bit more than 10% of the gross wage. The resulting funding ratio is about 74%. This means that about three quarters of the retirement income is coming from own savings while the remainder stems from the pay-as-you-go system. The benefit ratio is here 77%, that is, the retiree's income is about 3/4 of the worker's income.

The really interesting question is now to test the dependence of the outcomes on the choice of the parameters by simulating the solutions to this model under a range of parameter estimates. Actually, sensitivity analysis should form an important part of any numerical simulation analysis. The ranges of values considered (arithmetic sequences of 10 elements) are presented in Table 2. The outcomes in Table 3 are almost always monotonic functions of the input parameters. Although those relationships do not exhibit constant elasticity, the average arc-elasticities over the relevant ranges are indicative of those relationships. The values of the elasticities of the impacts of changes in the endogenous variables as functions of changes in the exogenous parameters of the model are presented in Table 3.

Table 2: The ranges of the parameter values

	Lower bound	Upper bound	Increment
$\widetilde{n}$	-0.6	0.4	0.1
	(-0.015)	(0.01)	
e	0	1.0	0.1
χ	0	1.0	0.1
ε	0.1	1.1	0.1
ρ	0.35	0.85	0.05
	(0.009)	(0.018)	
γ	1.5	4.0	0.25
$\widetilde{g}$	0	2.0	0.2
	(0)	(0.032)	
λ	1.0	2.0	0.1
η	0	2.0	0.2
α	0.15	0.35	0.02
δ	0	2.0	0.2

In parentheses the corresponding annualised values are presented.

Table 3A: Impact elasticities of the demographic and individual preferences parameters

	$\tilde{n}$	e	χ	ε	ρ	γ
n	0.995	-3.029	0.202	0.200	-0.026	-0.302
g	-0.001	0.001	0.000	-0.204	0.028	0.297
φ	-0.002	0.002	0.000	-0.255	0.035	0.371
θ	-0.451	0.629	-0.051	-0.460	-0.145	0.242
y	-0.030	0.042	-0.003	-0.292	0.320	-0.230
υpa	4.510	-1.544	0.029	-0.092	0.013	0.133
rpa	0.037	-0.051	0.003	-0.084	-0.332	0.792
k/y	-0.083	0.115	-0.008	0.196	0.812	-2.241
S/w	0.427	-0.383	0.017	0.118	0.823	-2.128
FR	0.195	-0.237	0.013	0.128	0.061	-0.120
$BenR$	0.038	-0.053	0.004	-0.146	0.093	-0.185
$AvgW$	0.545	-0.397	0.013	-0.587	0.252	-3.575

Table 3B: Impact elasticities of the technological and political parameters

	$\tilde{g}$	λ	η	α	$\tilde{\delta}$
n	0.012	-0.210	-0.005	0.000	0.011
g	0.988	0.219	-0.339	0.000	-0.012
φ	-0.016	0.273	0.006	0.000	-0.014
θ	0.351	-0.459	-0.091	-3.777	2.134
y	-0.280	-0.167	0.114	-1.151	-0.266
υpa	0.570	0.098	-0.209	0.000	-0.005
rpa	0.352	0.090	-0.140	0.000	0.320
k/y	-0.772	-0.210	0.315	1.000	-0.735
S/w	-0.385	-0.127	0.155	1.323	-0.739
FR	-0.088	0.109	0.033	1.046	-0.341
$BenR$	-0.045	-0.256	0.018	0.000	0.338
AvW	0.130	-0.373	-0.056	-1.197	-0.238

It is obviously impossible to comment on all 120 elasticities. So let us concentrate on the most important values. The first three parameters $\widetilde{n}$, e, and χ have their expected effects on the population growth rate n. The effect of χ is actually very small. The impact of $\widetilde{n}$ and e on the level and composition of the pensions are very considerable: higher population growth implies a lower PAYG tax rate, a higher growth rate (vpa) and higher average welfare.

The next three parameters are the individual ones. The leisure preference parameter ε has strong negative effects on the labour supply and on the contribution rate to the PAYG system, and also on technological progress, income and average welfare. Furthermore, the pension system will become more funded when the leisure elasticity increases. When the risk aversion parameter γ increases, we find that the labour supply and the PAYG-contribution rate increase, while the population growth rate, the savings rate and the capital intensity strongly decrease. Savings and capital intensity are strongly affected by the time preference ρ, which, as expected are seen to increase with ρ, while average welfare increases as well. The level of the PAYG-contribution rate is seen to decrease with stronger preferences for future rather than current consumption.

Now let us look at the technological parameters. The capital intensity and the savings rate fall considerably with increasing maximum technological progress $\tilde{g}$. It appears that most of the growth will trickle down in an enlarged PAYG - system. Inversely, if the possibilities for growth, as reflected by the upper bound $\tilde{g}$, are diminishing, this will lead to a greater dependency on own savings and a reduction of social security, thus to less welfare on the average. This may be the situation at the end of a technical innovation wave (or the end of a Kondratiew cycle), where the upper limit of growth seems to reduce. The higher λ, the more wage is reduced for less intensive participation in the labour market. It follows that labour supply rises as workers are stimulated to work full-time. The contribution rate strongly decreases, the population growth rate n shrinks and the savings rate decreases if λ increases. It seems that in western economies, where unskilled piece work is diminishing and hence λ is increasing, we see this phenomenon coming up, although countered by an increase in leisure preferences in some Western countries. A change in η, the sensitivity of technological growth with respect to longer hours, has positive effects on capital intensity and savings but has negligible effects on the labour supply and the contribution rate. An increase in the capital intensity α will lead to a strong tendency toward a more funded pension system, with an accompanying reduction of θ and the PAYG-system and an increase in the savings rate. Despite the change in the system mix the total benefit ratio remains constant, when α varies.

Finally, let us look at the effect of $\tilde{\delta}$. If the retired generation becomes more influential, that is the government becomes more a countervailing power to the workers, it results in a huge increase of the PAYG-system with a simultaneous but lesser reduction of the capital-reserve system. Labour supply φ will marginally decrease. The income level will decrease as well, while the interest rate will increase. The savings ratio and the capital-output ratio fall considerably. Not unexpectedly the benefit ratio will increase and the average welfare will decrease.

Let us conclude the analysis of the results of our model by investigating the consequences of the Chinese "only-child" policy [3]. A strict enforcement of that policy will imply that the size of each generation is half the size of their parents' generation. Thus the maximum exogenous population growth rate $\tilde{n}$ is -50%. To allow for comparisons all the other parameters will be kept equal to the ones in the earlier baseline scenario.

Table 4: The Chinese "only-child" policy

npa	gpa	φ	θ	vpa	y	rpa	k/y	S/w	FR	$BenR$	$AvgU$
-4%	2.1%	0.707	50.5%	-0.9%	0.216	5.6%	1.512	4.1%	43.6%	68.8%	-43.123

[3] We exclude other effects as the gender imbalance and the non-citizen status of second and lower- ranking children.

It can be observed that, although this policy will have no sizeable effect on the labour supply, the size of the PAYG pillar will be very significantly increased. In a stationary environment the contributions to the PAYG system will collect more than half of the labour income and simultaneously savings will amount to 4% of the gross wage. Thus, the compound effect of this policy when applied to its full extent is a very significant increase in the relative importance of the unfunded pillar and a slight decrease of the relative position of the elderly, due to a reduction in the benefit-ratio. Average welfare will shrink sharply.

5 Conclusion

In this paper we developed an OLG - model where labour supply is endogenously determined in the model. The same holds for the population growth rate and the mix of the old - age pension system between PAYG and funded pillar. It is evident that this model is still a very stylized version of reality. It is a two - period model with a homogeneous population. Nevertheless, this exercise in comparative statics tells us something about the current situation and the tendencies which may be expected in reality in the near future, as these results hold for a broad range of parameters values. A decrease of the maximum population growth rate $\tilde{n}$ will result in an increase in the contribution rates to the PAYG system, a smaller accent on the capital reserve system, a lowering of the benefit ratio, and a strong fall in average welfare. Combining this phenomenon with an increase in the leisure elasticity ε will have ambiguous results in some variables, but it will also lead to a strong decrease of average welfare and the benefit ratio.

In our view these tendencies are found in the Western world. In the post-industrialist economy we find indeed that leisure and the use of leisure have got much more importance. We think especially of the shortening of the working week, sometimes supported by law as in France where a maximum working week of 35 hours has been imposed by law. We see also that the birth rate in all western countries is falling dramatically as a result of the changing evaluation of parenthood but also as improvement in medical technology made it possible to delay the birth of the first child. The stylized model presented in this paper is an attempt to understand the relationships between the various variables and to predict the mix between social security and funded pensions when birth rates fall to unprecedented low levels.

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