THE MIX BETWEEN PAY-AS-YOU-GO AND FUNDED PENSIONS AND WHAT DEMOGRAPHY HAS TO DO WITH IT

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Abstract

A model is presented that explains the mix between funded and unfunded pension systems. It turns out that total pension and the relative shares of the two systems may be explained and are determined by the population growth rate, technological growth, the time-preference discount rate, that relative risk aversion, the production function, and the political representation of the old. A fall in the population growth rate, even to negative values, will imply a reduction of the interest rate and an increase in the capital-output ratio. Whether the pension system will shift to more or less funding depends on the political weight of the elderly. If the elderly succeed in getting more weight in the political process if their population share increases, which is likely when the population shrinks, the accent on the PAYG- system will increase. A fall in the population growth rate will result in a reduction of average welfare. This reduction is more severe, the larger the political power of the elderly.

JEL Code: H55, D91, D64, J14, J26.

Keywords: old-age pensions, pay-as-you-go, intergenerational transfers, retirement benefits.

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1. INTRODUCTION

Is the modern welfare state sustainable when the population growth rate is much lower than it is today? In most European countries, until the nineties we saw a tendency towards an increasing role of the state. In recent years, however, the tide has turned and most countries with an ageing population try to reduce the role of the government. Some pessimists plead for and/or predict a total dismantling of the welfare state. If we believe that real economies have the property to tend to a general equilibrium, the main result of this paper is that a permanent reduction of the population growth rate, even if it becomes negative, will not lead to a total dismantling of the welfare state. That scenario is unlikely even if the population growth rate turns to negative values, and the population is actually shrinking. However, we may expect and will have to accept a decrease in the average welfare level.

In this paper we shall consider retirement pensions within the framework of the redistribution function of the government. Examples of redistribution are state pension schedules for the elderly and family allowances for families with children, social assistance, and provisions in kind (like health care, education, the provision of safety by the police and the army, etc.). These provisions are typically at non-market prices and frequently even at zero prices. The input for the system comes from tax revenues and social contributions. In this paper we consider a stylized demography with a generation of workers and a generation of retired. We shall restrict ourselves to the transfer between the generation of workers and that of the retired, which we see as characteristic for the modern welfare state.

In a modern welfare state retirement pensions can be partly financed by a pay-as-you-go system, where the workers pay part of their wages to provide an old-age benefit to the already retired. A second part is funded and provided by earlier savings by the workers. In general this is obligatory saving in the setting of company or other pension funds. This is the funded part of the pension. At the moment there is considerable variation in how old- age pensions are financed. In the U.K. and the Netherlands the role of funded systems is very significant, providing 40% of total pension income in the former[1]. In other countries, as France, Italy and Germany almost all of the pensions are fed by a pay - as - you - go (PAYG) system[2]. One of the main questions is what mix between the two systems we may expect.

[1] The Economist (2002).

[2] See Kohl and O'Brien (1998) for comparison on pensions arrangements in several

In economics and political science there are elaborate theories explaining the existence and the tasks of a government and of a state. In this context we focus on one feature in particular: the state as the agent for institutionalised altruism. Most human beings are not perfect egoists. They tend to care for the weak and even for future generations. However, in a mass society it is very difficult for individuals to implement that care. As an individual, it is difficult to find the people who need (your) help, and if you have found any, to be sure that these are the most needy. Even if so, in our modern societies individuals are unable to give the necessary support as efficiently as specialised institutions may do. The existence of social security arrangements frees us from the moral obligation to be altruistic as individuals as well. Apart from this role, the state also represents our own egoistic interests in those fields where the state can be a more efficient provider than the market. Given this specific role of the modern government, we assume that the government is an actor in the decision process, with its own objective function. The citizens define the government objective function (GOF) through the democratic process but the GOF is not necessarily identical with the individual utility function of citizens. Citizens have their own *individual* welfare functions (IWF), according to which their individual behaviour is shaped. This reflects the realistic situation where the government or state is seen as a separate entity with its own goals, norms and instruments.

It would be tempting to look deeper in the question how the GOF is formed. In that case the GOF itself becomes endogenous. Then we would need a theory on the state itself. We abstain from doing that, as this would be in our view unrealistic in a two-generations world. In a true two-generations world a democratic process would have a majority of the young, while the elderly would have no voice. This might yield a situation as in the ancient Republic of Sparta where the elderly were left behind to die in the mountains. If the population growth rate is negative, we would get the opposite result. In reality we have a much more diverse population with different interests. The political specter is more-dimensional, where the young are bargaining for more education, sport facilities, etc. and the old ask for more pension, health care, etc. Hence, there are in this more-dimensional world many different ways to determine a median voter. The result is a compromise between interest groups. The outcome depends also on the historical framework, the

OECD countries.

ethical and religious basis of the community and so on. Given all these considerations we shall assume an exogenous GOF that assigns weight to the strong and to the weak part of the population.

We model the political decision process in the spirit of a Nash equilibrium, where both workers and government optimize their own utility functions with respect to the instrument variable(s) they can dispose of, taking all the other variables as given.

In this paper we look at a highly stylized overlapping generations model (Diamond, 1965), where we have only two population subgroups: the workers and the retired. Hence, the redistribution system is one of intergenerational transfers. The workers pay taxes at the rate θ out of their labour income into the system, and the retired get a pension. The pension rate is a function of the current contributions and the population growth rate. We assume that the system is of the PAYG type[3].

The main question we look after is whether our model may provide a unique tax rate θ, which defines a specific stationary redistribution among the generations. The second question is how this θ depends on the population growth rate n. At the moment the ratio between the numbers of retired and workers, the *dependency ratio,* is increasing dramatically, causing public unrest about the future sustainability of existing social security arrangements. The question is then whether the mix between PAYG and funded systems on a mandatory basis (defined by the tax rate and individual savings, respectively) is irrelevant, as the present variety of mixes in European economies suggests, or that there is a long-term equilibrium mix. And if so, how does it depend on the population growth rate and the technology? Hence this paper has a positive character. We do not look at what ought to be but only on what we may expect in the long run. Although our model is highly stylized, which it has in common with most of the literature, we do think that the outcome may give useful insights for practical policy.

In contrast to most of the literature, where $n > 0$ is assumed as a matter of routine, present reality demonstrates that negative population growth is

[3]Strictly speaking, old-age pensions are only one component of the intergenerational tranfers system. As there are flows between the two groups, and as part of these flows is in kind (e.g. old-age care, or education for the workers), it is fairly difficult to measure whether the net benefit goes to the workers or to the retired. That is, the "ex-ante" sign of θ may be positive or negative. The value of θ is not an indication for the total volume of the flows between the two generations but it represents only the *difference* between the two flows, and that will be the only value considered in this paper.

a real possibility. We are especially interested in what we may expect if the growth rate of the population is negative. That is, the population is actually shrinking. The relevance of this question is evident, as in most Western countries populations are expected to shrink in the near future (see Boeri, Bőrsch-Supan and Tabellini, 2001). In the literature the case of a negative n is mostly explicitly or silently ignored. A well-known result in the literature is the 'golden rule'[4] $r = n$. The endogenous interest rate equals the population growth rate. However, for shrinking populations this gives difficulties as r would become negative. In the framework of a neo-classical production structure, say a Cobb-Douglas production function, it would imply a zero or even a negative price of capital with dire and unrealistic consequences for employment. Our model admits for (moderate) negative population growth, without the interst rate becomig negative.

In our model we assume that individual workers decide for themselves and that the state is in charge of the interests of all of us, that is workers and retired. The workers determine their savings (S) for their old age where they take taxes (θ) as given. We assume a government with its own objective function, which reflects the workers' interests *and* the interests of the retired. The state maximizes this function with respect to θ where it takes individual savings as given.

The shaping of the GOF depends on the way in which the government is formed. In a Western-style democracy, the GOF will be the result of parliamentary consensus or at least it will reflect the opinions of a majority. Under a dictatorship, the GOF is likely to reflect the opinions of the dictator and his clique only. Moreover, the government may (and in most democracies will) assign a weight to the interests of future still unborn generations. Hence, the government has a special role as the 'defender of the weak' (the presently retired and the unborn). Hence, the GOF consists of two subtargets, the interests of the present workers and the interests of the 'weak', who have not enough economic or voting power.

If both parties, the individual workers and the government, maximize their objective functions, we get a stationary equilibrium with a non-zero θ. If the well-being of the "weak" is not taken into account, we find the traditional golden rule path (Samuelson, 1958). In all other cases we find a dynamically efficient economy, with $r > n$. The solution of the system, especially for θ,

[4] For reason of exposition we assume here that there is no productivity growth.

appears to depend on population and technological growth rates as usual, and on the value of the capital elasticity in the production function, the risk aversion, the individual time discount rate, and the weighting system in the government's objective function.

It is difficult to evaluate the result as an *optimal* mix, because it is the result of a compromise between the citizens and the government. Hence, we would characterize this paper as positive rather than as normative research. We call the outcome a *sustainable* equilibrium as it is the joint result of the optimizing behavior of workers and the government.

The structure of the paper is as follows. First we have a look at the literature in section 2. In section 3 we develop our model. In section 4 we solve that model. In section 5 we discuss some numerical results. We end with a discussion and some conclusions.

2. SETTING IN THE LITERATURE

Before embarking on our model and findings, let us have a look at the position of this paper in the literature, without claiming completeness.

The seminal paper in the overlapping generations (OLG) literature is that by Samuelson (1958)[5]. He finds that in a more-generation model the equilibrium interest rate would be the ('biological') population growth rate; it would equal the social optimum interest rate, which Samuelson sees as an astonishing result. However, in that world there are no durable goods which can be handed over to the next generation, which implies that no trade takes place between individuals of different ages. Samuelson demonstrated that the introduction of a 'social compact' could make the social optimum a stable and achievable equilibrium. Looking at a similar problem, Aaron (1966) showed that pay-as-you-go social security improves the utility of each individual, if the growth rate of the economy is larger than the (exogenously given) interest rate.

The basic paper in the OLG-literature is Diamond (1965). It introduces production, and the general equilibrium interest rate is not necessarily efficient anymore. There is no collective social security system; instead there is a government issuing debt and collecting taxes. Through debt management, the government is able to eliminate dynamic inefficiency in an OLG-economy.

[5] Allais (1947) predates some of Samuelson's results.

Samuelson (1975) introduces a social security trust fund. He finds that a social security fund may, under certain assumptions, replace private voluntary savings.

Feldstein (1985) doubts the realism of Samuelson. We quote Feldstein (p. 304):

> "More generally, as Samuelson has noted, a social security trust fund could acquire enough capital to bring the economy to golden-rule efficiency. In general, this would require that the social security obligations are more than fully funded and may require the trust fund to own the nation's capital stock. As a practical matter, however, the social security program in the United States and in many other countries operates on a pay-as-you-go basis without a capital fund".

Feldstein also considers the possibility of a mix between a funded and a PAYG-system. He looks for an optimal security system, where he admits for the possibility of myopia (that is, that individuals "underestimate their future social security benefits"). However, Feldstein makes the restrictive assumption that "to avoid the problem of an endogenous and varying rate of return, I assume that the marginal product of capital remains constant". This is tantamount to assuming an exogenous wage, interest rate and capital/labor ratio. However, one of the most interesting and relevant questions concerning the existence of a PAYG-system is which effect it will have on wages and the interest rate.

Another stream of the normative literature looks at the transition from a PAYG-system to a funded system, checking whether such a transition can be made without violating Pareto optimality. The main problem that the present workers will have is to save for a much larger funded pension then the previous generation; they will object to paying simultaneously to a PAYG fund, without enjoying during their retirement the same benefits. Some parties have to accept a deterioration of their position. This transition problem is not the main focus of this paper.

Homburg (1990) shows in his seminal contribution "that a PAYG-system may be converted into a capital reserve system without inflicting damage upon anyone". However, like Feldstein he takes factor prices as exogenous, which is acceptable for a small open economy but not for a closed economy.

Breyer and Straub (1993) extend this result to the case of an closed economy with endogenous factor prices, but their result holds only in the case that lump-sum transfers are used or pension benefits are actuarially fair. On the other hand, Brunner (1996) claims that a transition towards a funded system cannot be a Pareto improvement. Sinn (2000) presents comparisons between PAYG and unfunded systems and advocates why a transition towards a funded system might generate Pareto gains or why not.

Another segment of the literature that tries to describe and explain the existence of intergenerational flows, and unfunded old-age pensions in particular, takes recourse to political decision theory. We will focus just on the main contributions. For more details we refer to the comprehensive surveys on politics of old-age pensions by Verbon (1993), Breyer (1994) and Galasso and Profeta (2002).

Most of the literature on decision making that describes and explains the existence of intergenerational flows is based on direct majority voting or Median Voter theory, since Browning's (1975) seminal contribution, in which people differ only in age, and the decisive voter is the median age individual. In more recent literature a two-dimensional political spectre has been assumed, usually age and income, due to different skills or abilities. Among more recent references, Tabellini (2000) or Conesa and Krueger (1999), consider within-cohort income redistribution as a reason for the set-up or maintenance of PAYG systems, the former with (weak) mutual altruism, the latter with income uncertainty. The common result is that a coalition of old people and the poorest part of the young generation are voting for a social security scheme running on a PAYG basis, the size of such a system being determined by the median voter, usually a (relatively) poor young voter. Casamatta, Cremer and Pestieau (2000b) find in an alternative setup a different result: when pension benefits are partially linked to contributions, the winning coalition will include the medium-wage workers rather than their low-wage colleagues. Within this class of models, Breyer & Stolte (2001) distinguish themselves from others by assuming that the retired and workers close to retirement are already the majority of the population and can determine the tax rate without any coalition with part of the young workers.

Most of these models are based on static voting, with decisions on the structure of PAYG system being taken once and for all. More recently, Cooley and Soares (1999) and Boldrin and Rustichini (2000) introduced a dynamic 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 a PAYG system is shown to arise at equilibrium, and surprisingly, once it is in place it will never be dismantled. This implies that the first generation that votes for the installation of the system determines its design and a multiplicity of social security equilibria can be sustained. 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 political-economic equilibria.

For our paper the Median Voter theory is not the best choice to model decision making, as the population is split up into two brackets only: the workers and the retired. Normally, the workers will have the majority and the median voter will trivially be a young individual. Workers would always have it their way. This does not mean that the Median Voter paradigm is not a relevant choice in more complex situations of public economics.

We model a world where a government with its own objective function decides on PAYG pensions. We assume that this GOF is modelled as a weighted sum of the utilities of the different groups or generations. Moreover, the government may assign a weight to the well-being of yet unborn generations. Hence, in this arrangement the government acts as the defender of the workers *and* of the 'weak' (the retired and the future generations), who have no explicit decision power themselves. The weight of the retired in the GOF is denoted by a parameter δ. The success of each group depends on this political weight distribution. The workers decide on the level of the funded 'mandatory' pension.

This paper assumes that the stationary equilibrium is a Nash equilibrium between two players: the workers and the government, where the workers defend their own *particular* interests and the government represents the *general* interest, taking care of both workers and the retired. In this respect our paper has the same point of departure as the earlier paper by Meijdam and Verbon (1996), who were probably the first to suggest a Nash-approach in this specific subject. The main theoretical difference between the two papers is that we assume that the government fixes the social security system under the assumption that it will stay constant over future periods, while Meijdam and Verbon assume that the government fixes social security for the current period only. This difference in behavioral assumptions leads evidently to different conclusions. Moreover, our model specifies a CRRA- utility function, while the utility function is left unspecified by Meijdam and Verbon. This restriction enables us to assess the outcomes numerically and to focus especially on the equilibrium mix. Grossman and Helpman (1998) use a related approach to government decision making, when studying the effects of gifts or campaign contributions to (short-lived) government officials upon the politics of intergenerational transfers, albeit within a simpler economic environment. In their model the young do not consume, so the intertemporal optimization problem is neglected, whereas that problem is at the core of our research.

This paper is intended as a contribution to the literature by combining four features: modelling the decision making on unfunded pensions in the framework of a government acting as an independent agent rather than following the median voter approach; allowing for the possibility of a negative population growth rate; explanation of the variation in the mixes between funded and unfunded pension systems; by the numerical assessment of the effects of differences in population growth rates on the funded and unfunded components of retirement income.

3. THE MODEL

Although, strictly speaking, this paper only deals with intergenerational transfers in general and not with old-age pensions only, in the abstract traditional setting which we also employ in this paper, there is no way to make a distinction between the wider and the narrower concept. The only difference between social subgroups that we distinguish in the framework of this paper, is with respect to the status of 'being retired' or 'working'.
We assume that the life of individuals is split up into two periods. During the first period they are working and during the second period they are retired. Let us assume a natural population growth rate of n_t per period.

The population L_t grows according to the equation $L_{t+1} = (1 + n_t) * L_t$.

Each individual embodies a number of A_t labour efficiency units, which number grows per period by a factor $(1 + g_t)$ due to labour-augmenting technological growth. Hence, the number of efficiency units per worker develops according to $A_{t+1} = (1 + g_t) * A_t$.

The sum of the efficiency units over the population as a whole gives the labour force in terms of efficiency units. The total growth rate of the labour force in terms of efficiency units is denoted by ν_t, defined by $(1+\nu_t) = (1+g_t)*(1+n_t)$.

3.1. The Citizen

A worker's consumption equals

$$C_{t,1} = \{(1-\theta_t)w_t - S_t)\}A_t \tag{1}$$

where the transfer ratio θ_t is that fraction of his/her wage rate, which is transferred to or received on balance from the state. As said before, this fraction can be positive or negative. The wage rate is w_t and S_t stands for the amount of savings, both per labour efficiency unit. In our notation, the subscript t stands for the date of birth, and i $(i = 1, 2)$ stands for the status of 'working' or 'retired', so that $C_{t,1}$ is the current per capita consumption of a young individual. Similarly, the consumption of the currently retired is

$$C_{t,2} = \{\theta_t(1+\nu_t)w_t + (1+r_t)S_{t-1}\}A_{t-1} \tag{2}$$

Where the first term inside the curly brackets represents the PAYG pension and the second term represents the funded old-age pension. The interest rate is denoted by r_t. We assume for the (working) individual a separable utility function, where both period-utility functions are concave but not necessarily identical, reflecting possibly different need structures, depending on the age of the individual. More precisely, we have a two-period utility function:

$$U_1(C_{t,1}(S_t, \theta_t)) + \rho * U_2(C_{t+1,2}(S_t, \theta_{t+1})) \tag{3}$$

where ρ is the *individual* time preference discount factor.

We assume for the worker that he has only one variable which he can influence, viz. his savings S. We also assume that the individual worker takes his wage rate, the interest rate, the growth rate and the transfer ratio as given. We notice that, due to the concavity, there is only one optimal S for a given θ.

The retired have no instrument variable to be optimized and, hence, their utility may be written as $U_2(C_{t,2}(S_{t-1}))$. In this simple model there is no independent role for the retired. Their interests have to be represented by the government.

Let us now become more specific by adopting the well-known Constant Relative Risk Aversion (CRRA) utility specification (Arrow, 1971 and Pratt, 1964) for both period-utility functions. We have

$$U(C) = \frac{C^{1-\gamma}}{1-\gamma} \tag{4}$$

where $\gamma > 0$ is the coefficient of relative risk aversion. In the limiting case of $\gamma = 1$, this function tends to the logarithmic utility function.

3.2. The Production Side

We assume that there is only one commodity, which can be used either as capital or as a consumption good. We assume that workers save an amount S_t per labour efficiency unit over their working life. Summing the investments of all retirees, we get the aggregate capital stock

$$K_t = A_{t-1} L_{t-1} S_{t-1} \tag{5}$$

If S is constant over time, the capital k per worker grows by $(1+g)$, and total capital K grows by $(1+\nu)$.

We assume a constant returns to scale technology. For the sake of convenience we choose a Cobb-Douglas production function with capital elasticity α. When assuming efficient production, the interest and wage rate will equal $r_t = \alpha k_t^{\alpha-1}$ and $w_t = (1-\alpha)k_t^{\alpha}$.

The capital per labour efficiency unit, denoted by k_t in period t, equals

$$k_t = S_{t-1}/(1+\nu) \tag{6}$$

3.3. The Government

The second player in this game is the government, which taxes and subsidises the workers and the retired. The tax revenue is spent on government production, like education and infrastructure, and on an income redistribution between the workers and the retired. In most developed economies, the main redistribution systems will include old-age retirement pensions and children benefits. As we assume that the government does not save, we have an equality between expenditures and tax revenues. It follows that, if the retired profit on balance, the workers will pay, and vice versa. One might think that the redistribution will always be in favour of the retired, but in this wider framework this is by no means obvious. As we are just looking at net transfers, expressed as a share of gross wages per labour efficiency unit, from now on we will call θ the PAYG tax rate.

Government represents the interests of both the currently living workers and the retired. It does this by maximizing a *composite utility function* (W). The government takes all variables as being given, except for the transfer ratio θ, which is its policy instrument. We assume:

$$W = \{U_1(C_{t,1}(\theta)) + \rho U_2(C_{t+1,2}(\theta))\} + \delta(n)U_2(C_{t,2}(\theta)) \tag{7}$$

The terms in curly brackets in (7) represent the utility function of the present workers. As the present workers are interested in their *lifetime welfare,* their relevant utility function contains a part which refers to their future life in retirement. The third term stands for the utility of the currently retired.

The weight δ reflects the relative weight that the government assigns to the retired. How it is determined is a question of politics, which we assume to be exogenous to our model. However, one may think that δ depends for instance, on the generation's probability of supporting or influencing the government or the numerical strength of each generation. So, in short, the weight distribution may depend on the ratio between the number of retired and workers, which is $1/(1+n)$, and on the representation of the interests of the retired in the political system. Notice that the government at time t is not interested in $C_{t-1,1}$ as bygones are bygones. This gives an asymmetric character to the government objective function. Actually, if the last term would be $\delta\{U_1(C_{t-1,1}(\theta)) + \rho U_2(C_{t,2}(\theta))\}$, i.e., the lifetime utility of the currently old, under general equilibrium we would return to the usual golden rule and there would be no reason for an independent role of the government.

Although governments are, as a rule, most interested in their own election period, they are not so short-sighted that they would not take the interests of future generations into no account at all. We suggest the following extended government objective function:

$$W = [U_1(C_{t,1}(\theta)) + \rho U_2(C_{t+1,2}(\theta))] + \varphi_1[U_1(C_{t+1,1}(\theta)) + \rho U_2(C_{t+2,2}(\theta))] + \delta U_2(C_{t,2}(\theta)) \quad (8)$$

where we assume in this example that the government is sensitive to the interests of the first-next unborn generation. The generalization is rather easy for a longer time horizon.

For a CRRA function we have in a stationary environment:

$$U(C_{t+1}) = U(C_t).(1+g)^{1-\gamma} \quad (9)$$

where we assume that in the steady state individual consumption grows at the rate $(1+g)$ per period. If w_t and S_t, defined per labour efficiency unit, are constant over time, individual consumption has to grow at the growth rate of labour productivity as well. The consumption growth is only caused by the fact that, during each period, the individual embodies more labour efficiency units. A similar observation can be made for the 'retirement part'. Hence, it follows that we may rewrite the above extended social welfare function as

$$(1 + \varphi_1(1+g)^{1-\gamma})[U_1(C_{t,1}(\theta)) + \rho U_2(C_{t+1,2}(\theta))] + \delta U_2(C_{t,2}(\theta)) \quad (10)$$

Similarly, if we would have an objective function of the type

$$\sum_{i=0}^{\infty} \varphi_i[U_1(C_{t+i,1}(\theta)) + \rho U_2(C_{t+1+i,2}(\theta))] + \delta U_2(C_{t,2}(\theta)) \quad (11)$$

where more than one unborn generation is included, we may rewrite it in a stationary environment as

$$\sum_{i=0}^{\infty}(\varphi_i(1+g)^{(1-\gamma)i})[U_1(C_{t,1}(\theta)) + \rho U_2(C_{t+1,2}(\theta))] + \delta U_2(C_{t,2}(\theta)) \quad (12)$$

We notice that the weights may follow the usual exponential pattern, but this is not necessary. If it does, we have $\varphi_i = \varphi^i$. Then we call φ the *political* time preference discount rate. Notice that there is no reason why it should be equal to the individual time preference discount rate ρ. The only thing which is obviously needed, is that the sum of the weights is finite[6].

It is obvious that the GOF may include an infinity of future generations. We may normalize this welfare function by setting the first coefficient equal to one and we write the extended government's objective function or GOF, in a stationary environment, as

$$[U_1(C_{t,1}(\theta)) + \rho U_2(C_{t+1,2}(\theta))] + \tilde{\delta}.U_2(C_{t,2}(\theta)) \tag{13}$$

where $\tilde{\delta} = \delta / \sum(\varphi_i(1+g)^{(1-\gamma)i})$.

The first term represents the lifetime utility of the present (and future) working generations, while the second term stands for the utility of the currently retired. The weight $\tilde{\delta}$ reflects the weight that the government assigns to the retired, which is compared to the weight of the present (and future) generations, whose accumulated weight is normalized at one.

4. THE EQUILIBRIUM

In the equilibrium, as usual, we assume that S, r, w and θ are constant over time. If we assume that both the individual citizens and the government attempt to optimize their objective functions, we get two first-order conditions.

The first-order condition for the worker is

$$\frac{\partial U_t}{\partial S} = U'_{t,1}(-A_t) + \rho U'_{t+1,2}(1+r)A_t = 0 \tag{14}$$

where the prime denotes the first derivative and where all the variables without time index remain constant. Division by A_t gives

$$\rho U'_{t+1,2}(1+r) = U'_{t,1} \tag{15}$$

The first-order condition for the government reads

[6] We shall assume that $\sum(\varphi_i(1+g)^{(1-\gamma)i}) < \infty$. This is the analogue of the transversality condition in the variational calculus approach.

$$\frac{\partial W_t}{\partial \theta} = U'_{t,1}(-wA_t) + \rho U'_{t+1,2}(1+\nu)wA_t + \delta.U'_{t,2}((1+\nu)wA_{t-1}) = 0 \quad (16)$$

After simplification we get

$$-U'_{t,1} + \rho U'_{t+1,2}(1+\nu) + \delta.U'_{t,2}(1+n) = 0 \quad (17)$$

Now we may consider the two first-order conditions as two equations in the unknowns S and θ. Combining the two conditions (15) and (17), we find

$$U'_{t+1,2}(\rho(1+r) - \rho(1+\nu)) = \delta U'_{t,2}(1+n) \quad (18)$$

Using the CRRA utility specification, we find

$$(C_{t+1,2}/C_{t,2})^{-\gamma} = \frac{\delta(1+n)}{\rho(r-\nu)} \quad (19)$$

Taking into account that per capita consumption can only grow in a stationary equilibrium by $(1+g)$, we get

$$(1+g)^{-\gamma} = \frac{\delta(1+n)}{\rho(r-\nu)} \quad (20)$$

which yields an explicit solution

$$r = v + \frac{\delta(1+n)(1+g)^{\gamma}}{\rho} \quad (21)$$

It follows that the interest rate r is defined by the effective growth rate g, the population growth rate n, the individual time discount rate ρ, and the political weight δ given to the currently retired cohort. If we replace δ by its generalization $\widetilde{\delta}$, it is obvious that the interest of future generations will count as well. The equilibrium interest rate value does not depend on the capital elasticity α. The standard classical golden rule path, where $r = \nu$, is only realized when $\delta = 0$, as expected. As $(1+n) > 0$ by definition, in all other cases we find $r > \nu$. In words, we have always a dynamically efficient economy. More surprisingly, we find for this specification that there is no direct relation between the interest rate r and the transfer ratio θ.

Knowing r, we find the associated k, w, S (all per efficiency unit) by using the CD-technology. We have $r = \alpha * k^{\alpha-1}$ when firms maximize their profits. It follows that

$$k = \sqrt[(\alpha-1)]{\frac{v + \frac{\delta(1+n)(1+g)^{\gamma}}{\rho}}{\alpha}} \tag{22}$$

The other first-order condition for profit maximization yields:

$$w = (1-\alpha).(\frac{v + \frac{\delta(1+n)(1+g)^{\gamma}}{\rho}}{\alpha})^{\frac{\alpha}{\alpha-1}} \tag{23}$$

It is rather evident that these formulae would change if we were to assume another constant-returns-to-scale production function like a CES function. Finally we have

$$\frac{S_{t-1}}{1+v} = k_t$$

The resulting gross savings ratio is

$$\frac{S}{w} = \frac{(1+v)k}{(1-\alpha)k^{\alpha}} = \frac{(1+v)}{1-\alpha}k^{1-\alpha} \tag{24}$$

Substitution for k yields

$$\frac{S}{w} = \frac{\alpha}{1-\alpha} * \frac{1+v}{v + \frac{\delta(1+n)(1+g)^{\gamma}}{\rho}} \tag{25}$$

The transfer ratio θ is now derived from the first-order condition (15)of the individual maximization problem. We get

$$\frac{[((1-\theta)w-S)A]^{-\gamma}}{[((1+v)\theta w+(1+r)S)A]^{-\gamma}}=\rho(1+r) \tag{26}$$

After some simplifications we find

$$\theta=\frac{1}{1+(1+v)\rho^{-1/\gamma}(1+r)^{-\frac{1}{\gamma}}}[1-\frac{S}{w}*(1+\rho^{-1/\gamma}(1+r)^{\frac{\gamma-1}{\gamma}})] \tag{27}$$

This apparently yields a linear relation between θ and S, where θ falls with an increase in S. It is only apparent as r and w are endogenous and vary with S as well.

The solution may be extended for the general GOF as

$$r=v+\frac{\tilde{\delta}(1+n)(1+g)^{\gamma}}{\rho} \tag{28}$$

We see that, the more weight is given to future generations, the relative weight of the currently retired will dwindle to zero. Hence, the more we converge to a dynastic model the more we approach the golden rule path. The convergence towards the golden rule is an intuitively plausible result and conforms to the literature of dynastic models following Ramsey models.

We notice that the sequence $\{\varphi_i\}$ will usually, but not always, follow a traditional geometric pattern. The analysis holds for a general pattern. Let us reconsider $\widetilde{\delta}=\delta/\sum(\varphi_i(1+g)^{(1-\gamma)i})$. We shall assume that $\varphi_i=\varphi^i(1+n)^i$, which implies that future generations are weighted according to their size. In that case, the denominator is a geometric series with ratio $\varphi(1+n)(1+g)^{1-\gamma}$. In order to have the sum bounded, this ratio has to be smaller than one.

The infinite series adds up to the reciprocal of the ratio, hence

$$\widetilde{\delta}=\delta\varphi(1+n)(1+g)^{1-\gamma}$$

5. EVALUATION AND DISCUSSION

It is now time to look at the outcomes of this model when filled in with specific parameter values. There are six basic parameters in the model. The first one, evidently, is population growth n. The time dimension of this model differs from that of everyday life. An annual population growth rate of 0.75% is equivalent to a growth rate of $1.0075^{35} - 1 = 30\%$, if we assume that a period (or generation) stands for 35 years. Similarly, a negative growth rate of 1% is equivalent to a negative rate of $(0.99^{35}) - 1 = -30\%$. This implies that we have to choose our values carefully and that period values have to be translated in annual equivalents in order to get meaning. The same considerations hold for the technological growth rate g. The two coefficients which have no time dimension are the capital elasticity α and the relative risk aversion coefficient γ.

We take as our basic parameter configurations:

$$\begin{aligned} n &= -0.3, 0.0, 0.3 \\ \delta &= 0.4, \frac{0.5}{1+n}, \frac{1}{1+n}, \frac{1.25}{1+n} \\ g &= 0.35 \\ \gamma &= 2 \\ \rho &= 0.35 \\ \alpha &= 0.2 \end{aligned}$$

where we allow n and δ to vary. Hence we get 3*4=12 simulations in total. For the parameter δ we take four specifications, viz. a constant 0.4 and three specifications which depend on the (relative) demographic strength of the old ($\frac{1}{1+n}$); we consider scenarios where the retirees' interests can be over- or under-represented, taking the demographic share as a benchmark. We point out that reliable estimates of ρ and δ are not known to us. The same holds for γ, although it is conventional wisdom to set it at about 2. However, Blake (1996) estimated values of between 4 and 8 (see also Drèze, 2000).

The outcomes for this parameter configuration, where we apply three population growth rates, are given in tables 1 to 4. It is obvious that a number of outcomes are interesting. Here we present only the most interesting ones.

First, we are interested in the equilibrium interest rate, which we annualise by taking the 35-root. The second outcome is the capital-output ratio (k/y), where we take into account that capital has no time dimension while output has. We have to multiply the k/y ratio by 35 to make the period k/y ratio comparable to the annual k/y ratio. The savings ratio S/w and the tax rate θ do not pose dimension problems. The same holds for the funding ratio fr, which we define as the fraction of the retirement income which stems from own savings (funded income). It is defined as

$$fr = \frac{(1+r)S}{(1+v)\theta w + (1+r)S} \tag{29}$$

Then we look at the benefit ratio, which we defined as:

$$b = C_{t,2}/C_{t,1}$$

The last two outcomes deal with average consumption and with the income inequality between the two subpopulations groupsof young and old, as defined by Atkinson. Note that this inequality is in fact the 'between-group' inequality in the case where there are only two groups.

For this configuration we find the following outcomes (see tables).

TABLE 1
SOME OUTCOMES OF THE MODEL FOR VARYING POPULATION GROWTH RATES ($\delta = 0.4$)

Annual population growth n	-1%	0%	0.75%
Annual interest rate r	2.6 %	3.6 %	4.3%
Capital/Output ratio k/y	4.64	2.88	2.08
Savings ratio S/w	17%	14 %	12%
tax ratio θ	17.0%	19.1%	19.0 %
funding ratio fr	71%	64%	63%
C_1	0.317	0.287	0.272
C_2	0.220	0.233	0.248
benefit ratio	69.4%	81.2%	91.5%
average welfare $\overline{W}$	-3.975	-3.888	-3.831
income inequality	.032	.011	.002

Table 2

Some outcomes of the model for varying growth rates when the old are underrepresented $\delta = \frac{0.5}{1+n}$

Annual population growth n	-1%	0%	0.75%
Annual interest rate r	3.8%	4%	4.2%
Capital/Output ratio k/y	2.64	2.37	2.15
Savings ratio S/w	10%	11%	13%
tax ratio θ	30.2%	23.4%	18.3%
funding ratio fr	53%	59%	64%
C_1	0.251	0.266	0.275
C_2	0.211	0.232	0.248
benefit ratio	83.8%	87.1%	90.4%
average welfare $\overline{W}$	-4.433	-4.035	-3.807
income inequality	.008	.005	.003

Table 3

Some outcomes of the model for varying growth rates with fair demographic share $\delta = \frac{1}{1+n}$

Annual population growth n	-1%	0%	0.75%
Annual interest rate r	5.4%	5.5%	5.7%
Capital/Output ratio k/y	1.33	1.26	1.19
Savings ratio S/w	5%	6%	7%
tax ratio θ	43.2%	35.8%	29.9%
funding ratio fr	41%	45%	49%
C_1	0.183	0.203	0.217
C_2	0.201	0.227	0.249
benefit ratio	109%	112%	114.8%
average welfare $\overline{W}$	-5.184	-4.666	-4.355
income inequality	.002	0.003	0.005

Table 4

Some outcomes of the model for varying growth rates when the old are overrepresented $\delta = \frac{1.25}{1+n}$

Annual population growth n	-1%	0%	0.75%
Annual interest rate r	5.9%	6.1%	6.2%
Capital/Output ratio k/y	1.07	1.02	0.98
Savings ratio S/w	4%	5%	6%
tax ratio θ	47%	39.6%	33.6%
funding ratio fr	38%	42%	46%
C_1	0.164	0.184	0.198
C_2	0.197	0.225	0.248
benefit ratio	120%	122%	125%
average welfare $\overline{W}$	-5.498	-4.942	-4.602
income inequality	.008	0.011	0.012

It is obvious that, with other parameter choices, we would generate different outcomes. Therefore, it does not make sense to do many simulations, the more so as the reader himself can easily compute values for other configurations. Nevertheless, we have found a considerable variation in the outcomes as a reaction to different input values.

The model we described in this paper is obviously still far removed from everyday reality. First, the restriction to a two-period instead of an annual multi-cohort model is unrealistic. In this way we have no room for the possibility that different birth cohorts, e.g., the thirty-years old and the sixty-years old, may have different interests, reflected by different utility functions. The second major shortcoming is the assumption that all people are homogenous. Other points of critique are easily conceived.

Nevertheless, we see this model as a good starting point to get more insight into the pension problem and the problem of intergenerational transfers. The model is not aimed to be normative. It aims at a *description* of reality. It is intended to be a positive theory. As such, even in this very abstract form it is not unpromising. Moreover, unlike most models in this field, it includes the case of (moderately) negative population growth rates. Negative population growth is or will become the relevant situation in most developed economies for decades to come.

The most interesting point is that the model leads to a unique meaningful *sustainable* equilibrium, even if n would be negative. There appears to be a strict relationship between the values of the input parameters, especially the population growth rate, and the resulting output, and the funding ratio. This is most important when we try to get insight into the effects of changes in the population growth n.

By comparing some of the outcomes with comparable observable variables in real life, like the interest rate, the savings rate, etc., we find an indirect way to 'estimate' the values of the underlying unobservable parameters δ, γ and ρ. Obviously, this 'estimation' is crude and lacks the 'finesse' of what econometricians call estimation techniques. However, looking at a rather complicated non-linear model, where we try to generate six or more output parameters by choosing values for three unknown input parameters, it is rather remarkable that we find intuitively plausible input parameter configurations, which succeed in doing that. Moreover, if we were to repeat this technique on various real economies, for instance with different demographies, etc., thus generating real 'observations', it would be possible to adapt basic but unknown input parameters of the model to reality, in such a way that the adaptation (in terms of calculated residuals) becomes optimal. However, this is still a long way ahead and beyond the scope of this paper.

It seems premature to draw specific political consequences from this model, as the level of abstraction is too high. But nevertheless, it raises some questions that are worthwhile thinking about. The first point is that the room for political choices with respect to intergenerational transfers in general, and the pension system in particular, is extremely limited. This holds especially for the benefit ratio and the funding ratio, which cannot be set freely by politicians from outside, as is frequently suggested by political decision makers. This implies that the demographic turmoil of the moment, viz. an autonomous fall in the population growth rate, even to the point of becoming firmly negative, must have far-reaching consequences for the interest rate and the structure of the old - age pension system. As we see from the tables 1 to 4, a decrease in the growth rate will induce a fall in the interest rate and, consequently, a more capital-intensive way of production. This is of course in line with the fact that labour supply is reduced. It also follows that if the weight of the old in the GOF is kept constant (table 1), the intergenerational transfer rate θ decreases and the funded pension system (or relying on one's own savings) gets relatively more weight. However, in the case that weight is proportional to the retirees' numerical strength (tables 2 to 4), which is much more probable, we observe that a fall in the population growth rate will increase the power of the old-aged and consequently cause an *increase* in the tax rate to be set by the government. The PAYG pension system becomes relatively more important, despite its lower return. So as population ageing increases the strength of old, we can expect stronger constituencies in favour of a PAYG expansion. Average welfare decreases. As the weight of the old increases in shrinking populations the benefit ratio increases, where the consumption of the elderly may become even larger than the consumption of the workers.

In the light of this model, the severe problems of the ageing societies in Western and Eastern Europe, but also in Japan and China, have to be reevaluated. The structures where old-age pensions are fixed by law on the basis of a pay-as-you-go system are vulnerable in the long run. In real life those structures are endogenous and depend notably on the growth rate n. If n changes, those structures have to be changed as well, except if the change of the growth rate would be coupled with a change of political preferences as reflected by δ. However, in all realistic situations a mix between the two systems is the final solution. It follows that it is dangerous to fix social security in the form of intergenerational transfers by law, without realizing that the structure will change, and has to do so at the cost of reaching a Pareto-non-optimal situation which is not sustained by the behaviour of the parties involved, whenever one of the basic parameters change. Ideally, such a law should include a *variable* tariff $\theta(n)$. The same holds for the sensitive benefit ratio. It cannot be fixed by law at, say, 70%, unless that figure happens to be the result of the system.

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