ELSEVIER

Journal of Economic Dynamics & Control
25 (2001) 951–966

JOURNAL OF Economic Dynamics & Control

www.elsevier.nl/locate/econbase

Parametric pension reform with higher retirement ages: A computational investigation of alternatives for a pay-as-you-go-based pension system ☆

Serdar Sayan*, Arzdar Kiraci

Department of Economics, Bilkent University, 06533 Ankara, Turkey

Accepted 12 June 2000

Abstract

This paper discusses parametric reform options to control losses generated by a publicly managed pay-as-you-go (PAYG) pension system under alternative deficit reduction (reform) strategies involving changes in contribution and replacement rates and statutory retirement ages. Two different problems corresponding to different pension reform strategies are considered using computational techniques. The techniques are illustrated through exercises employing data for the financially troubled pension system in Turkey.

JEL classification: C61; C63; H55; J26; J11

Keywords: Pension reform; Computational methods; Solution algorithms

☆The authors would like to thank seminar participants at Bilkent University Economics Department and colleagues attending the Fifth International Conference of the Society for Computational Economics in Boston for useful comments and discussions. Comments by two anonymous referees were extremely helpful and are greatly appreciated but the responsibility of any errors and omissions that might have remained belongs to the authors.

* Corresponding author. Tel.: + 90-312-290-2071; fax: + 90-312-266-5140.
E-mail address: sayan@bilkent.edu.tr (S. Sayan).

PII: S0165-1889(00)00062-2

1. Introduction

Publicly managed pension systems providing old-age or pension insurance coverage, face financial difficulties in many countries across the world. Most of these systems are run as pay-as-you-go (PAYG) schemes requiring pension payments to current retirees to be financed out of contributions collected from currently active workers and their employers. The primary reason these systems face financial difficulties is the increasing ratio of retirees to workers (the dependency ratio), most typically caused by the natural aging of population. Following from increasing life expectancies and declining fertility rates over time, population aging is essentially a demographic phenomenon and cannot be controlled by pension authorities or policy makers. Unless the resulting increases in dependency ratios can somehow be checked, pension balances will continue to deteriorate, eventually causing sizable deficits.[1] Avoiding such deficits requires controlling dependency ratios through changes in statutory entitlement ages (or minimum retirement ages) and/or adjustments in the values of contribution and replacement rates.[2]

A parametric pension policy reform, as it is sometimes called (Chand and Jaeger, 1996), involves changing the existing values of pension program parameters within politically and demographically acceptable limits so as to prevent the size of pension deficit from exceeding tolerable levels determined by governments. Such a reform may involve once-and-for-all as well as gradual changes in the values of contribution and replacement rates. However, the statutory retirement age is typically increased gradually through a predetermined time path. Regardless of the way they are introduced, new parameter values are expected to be compatible with the targeted level of deficit and to allow for demographically realistic contribution and retirement periods. Because the new parameters would be picked by policy makers, the political feasibility of reform would also require avoiding configurations which might radically undermine the living standards of working and retiree populations.[3] So, for policy makers to make

[1] High dependency ratios have already begun to challenge the financial sustainability of publicly run pension schemes in many countries (particularly, members of the OECD) forcing policy makers to take measures to curb the growth in pension deficits (Kohl and O'Brien, 1998).

[2] Contribution rates are payroll tax rates by which contributions (or old-age insurance premiums) are collected, and replacement rates are those that tie pension payments to wages/salaries earned prior to retirement.

[3] The availability of configurations might further be restricted by additional constraints and different priorities assigned to various outcomes of reform. Within this context, the timing of reform relative to election cycles and the implied distribution of the burden between the working young and retired elderly may be important considerations for policy makers in deciding whether or not a proposed configuration should be legislated. This issue has been considered in an earlier version of this paper presented at the Fifth International Conference of the Society for Computational

informed choices, alternative configurations meeting these restrictions must be identified.

The purpose of this paper is to identify a set of parametric reform options to rehabilitate the publicly run, PAYG pension system in Turkey under alternative strategies involving once-and-for-all, and gradual changes in pension parameters. The Turkish example is particularly interesting because the state pension system in Turkey already faces a severe financial crisis despite a relatively young population/workforce (Kenc and Sayan, 2000). Unlike other countries where similar pension systems face financial difficulties largely due to population aging, the crisis of the Turkish system stems from the retirement ages that are exceptionally low by international standards.[4] The evident need to increase minimum contribution periods/retirement ages distinguishes pension reform efforts in Turkey from the experience of other countries, where policy makers had relatively little room to adjust retirement ages along with other two parameters (Sayan and Kiraci, 2000). The numerical results reported in the paper make it possible to compare the magnitude of required increases in the retirement ages under each reform strategy considered.

The paper is organized in such a way that the explanation of each strategy is followed by a description of the relevant algorithm used to generate numerical results based on Turkish data. Section 2 describes the numerical optimization exercises carried out to identify parametric reform options for Turkish pension system under two different reform strategies, discusses the implementation of algorithms employed and reports results. Section 3 concludes the paper by summarizing policy implications and lessons that can be drawn from the computational analysis.

2. Computational analysis of reform options

As pension reform becomes a higher priority in the policy agendas of many countries, a growing number of studies use numerical techniques to investigate

Footnote 3 continued

Economics in Boston (June 24–26, 1999), which used an optimization framework with the objective function defined in such a way to allow policy makers to assign different weights to alternative policy goals and is available upon request from the authors. Yet another consideration in picking the parameter configuration to be introduced may be given to the intergenerational aspects of the distribution of reform's burden on presently living and future generations (see, for example Boll et al., 1994).

[4] Presently, it is possible for women/men to retire as early as 38/43 years of age in Turkey but by the major pension reform proposal which is currently awaiting the final approval of the President to become a law, the minimum retirement age for women/men would be 58/60. Under intensive pressure from trade unions and other groups, the government modified the proposal to extend the transition period for gradual increases in the minimum retirement age to 10 years.

parametric reform options for PAYG pension systems. The discussion in this section links up well with this literature, which is briefly surveyed by Chand and Jaeger (1996). Especially relevant studies include Halter and Hemming (1987), Van den Noord and Herd (1994), and Boll et al. (1994), ILO (1996) and Sayan and Kiraci (2000). The results here are also likely to provide useful inputs and experiment scenarios for dynamic overlapping generations general equilibrium analyses of social security reform, adding to an already sizable literature (see Joines et al., 1999 for a survey). Particularly good examples of overlapping generations general equilibrium analyses of parametric pension reform similar to that discussed here can be found in Sayan and Kenc (1999) and Miles (1999). Huang et al. (1997) consider the general equilibrium impact of transition from a PAYG to a fully funded system.

The rest of this section discusses the computational framework developed for this paper. The discussion begins by considering a once-and-for-all change in minimum retirement age and other pension parameters, proceeding thereafter to the issues arising with the constrained optimization problem.

2.1. Pension reform through a once-and-for-all change in system parameters

Even though a sudden and flat increase in minimum retirement age would likely be politically infeasible, consideration of such policies serves as a good starting point for our search for new pension parameters that balance the expenditures and revenues of a PAYG pension system.

Letting D represent the difference between total pension payments to the retirees and total contribution receipts over the specified period of time running from, say, t_0 to τ, we can write

$$D = \sum_{t=t_0}^{\tau} \frac{1}{(1+\delta)^{t'}} \left(RR \sum_{a=A}^{le} \sum_{ra=A}^{a} \overline{rw}_{ra,a,t-(a-ra)-1} r_{ra,a,t} - CR \sum_{a=a_0}^{mwa} rw_{a,t} w_{a,t} \right), \tag{1}$$

where CR is the average rate for employee and employer contributions combined ($0 < CR < 1$), RR the average replacement rate tying pension benefits to wages earned prior to retirement ($0 < RR < 1$), A the minimum retirement age ($A < \bar{A} \leqslant mwa$, where mwa is maximum working age), δ the discount rate, $w_{a,t}$ the number of workers at the age of a at time t, $rw_{a,t}$ the average real wage earned by active workers at the age of a at time t — adjusted for the earnings cap or wage ceiling that determines the maximum amount out of which contributions are collected, $r_{ra,a,t}$ the number of pensioners who retired at the age of ra, but are aged a at time t, $\overline{rw}_{ra,a,t-(a-ra)-1}$ the average work time earnings of pensioners who retired at the age of ra, but are aged a at time t, ($\overline{rw}_{ra,a,t-(a-ra)-1} \equiv \sum_{j=1}^{n} rw_{ra,a,t-(a-ra)-j}/n$ where n is the number of years in averaging period — taken to be equal to 10 here), a the age index running from the beginning of working-life, a_0, to le, life expectancy in years ($le > mwa$), ra the actual retirement age index running from A to mwa, t the time index running from initial period, t_0, to τ, the end of model horizon, and $t' = t - t_0$, with all variables and indices other than A, CR and RR taking their values beyond the control of pension authorities.

Given this notation, total pension payments to be made at any year t are calculated by multiplying the number of retirees, distinguished by their current ages and the ages of retirement, with the applicable pension for the corresponding age group. Applicable pensions at time t are calculated through an indexation scheme requiring each retiree to be paid a certain proportion, RR, of the 10-year average of real wages earned prior to retirement. Since a retiree who retired at age ra and is now aged a must have been collecting pensions for the past a–ra years, the average, wage ceiling-adjusted real wage income (s)he earned during the last 10 years of her/his career as a worker can be denoted by $\overline{rw}_{ra,a,t-(a-ra)-1}$, implying that (s)he is entitled to collect $RR\%$ of this amount in pension payments. Each active worker aged a at time t, on the other hand, is paid $rw_{a,t}$ and contributions are collected at the rate of $CR\%$ of this income adjusted for the wage ceiling (i.e., the maximum level of wages or salaries by which contributions and pension payments are calculated). D in (1) therefore shows the difference between the sums of future (expected) pension payments and total contribution receipts in real present value terms over the time horizon considered. The time horizon for the computational exercises is chosen to be the period between 1995 and 2060. 1995 marks the period when Turkish pension deficits began to reach alarming magnitudes. The time horizon ends in 2060, since Turkish population is projected to remain stable beyond this year, implying that a parametric pension reform introduced to avoid deficits over this horizon would not need to be reversed afterwards.

Eq. (1) is taken as the objective function in a constrained optimization problem requiring the minimization of D with respect to A, CR and RR, subject to the exogenously given, projected values of real wages, retiree and active worker populations and other relevant constraints. Given that publicly managed pension systems do not typically seek surpluses (with $D < 0$), however, a more realistic and relevant problem to consider would be to identify A, CR and RR values which would be compatible with a certain nonnegative value for D over the period under consideration. Since expenditures exceed receipts when $D > 0$, choice of a positive target value for D implies that the pension system is allowed to run a deficit. Because many governments view pension systems as a channel to make income transfers to working and/or retiree populations, they would often be willing, in fact, to allow public pension systems to run 'reasonable' deficits — with the definition of reasonable varying across governments and macroeconomic conditions.

When considering this more realistic version of the pension reform problem for Turkey, the target level of pension deficit over the 1995–2060 period was set equal to zero since the losses generated by the public pension schemes (and by the social security system at large) in this country have already reached alarming proportions (Topal, 1999; Sayan and Kiraci, 2000). Given this target, the problem for the relevant time horizon would be[5]

$$\underset{A,CR,RR}{\text{Minimize}}\ |D| = \left| \sum_{t=1995}^{2060} \frac{1}{(1+\delta)^{t'}} \left(RR \sum_{a=A}^{le} \sum_{ra=A}^{a} \overline{rw}_{ra,a,t-(a-ra)-1} r_{ra,a,t} - CR \sum_{a=a_0}^{mwa} rw_{a,t} w_{a,t} \right) \right|$$

$$\text{subject to} \sum_{ra=A}^{a} r_{ra,a,t} + w_{a,t} = p'_{a,t} \quad \text{for } \forall a \leq A, \forall t,$$

$$0 < CR < 1, \quad 0 < RR < 1, \quad A \leq mwa, \tag{2}$$

where $p'_{a,t}$ represents the year t population of age group a minus the number of unemployed adults who are at the age of a in time t. Hence, the equality constraint in (2) states that anyone who is older than the minimum retirement age A and not unemployed at time t must either be a worker or a retiree who has been collecting pensions for the past a–ra years. Since the minimum retirement age marks the lower limit for summation in the first constraint, any increase in A introduced as part of a pension reform would increase the size of working population at the expense of the retiree population. So, each counterfactual increase in A considered requires regenerating projections on the working population by age groups and retiree population by (current as well as the actual retirement) ages in such a way to satisfy the equality constraint, and recalculating applicable incomes for retirees and workers.[6] This is, in fact, what raises the complexity of identifying the [A, CR, RR] triplets minimizing $|D|$, and prevents the use of standard nonlinear programming solvers that come with commercially available software packages such as GAMS. To overcome the computational difficulty posed by this, a grid-search algorithm with a large data handling capacity was written in Gauss and used as described below.

Projected real wages and active worker/retiree populations by ages (aggregated over genders) were exogenously fed into the algorithm first. To make full use of the demographic projections available from ILO (1996) by age groups, the real wage series was projected into the year 2060 by taking into account the likely growth in economywide labor productivities as well as productivity differentials due to seniority so as to allow for real wage differences across different age groups. The original ILO (1996) projections on working and retiree

[5] With the absolute value operator, the global minimum for the objective function in (2) will be zero ruling out the possibility of pension system running a surplus over 1995–2060.

[6] It must be noted that because of the multiplicative $\overline{rw}_{ra,a,t-(a-ra)-1}$ term in the objective function, this constraint cannot directly be incorporated into the objective function.

populations by age assumed that current pension regulations would be maintained over the 1995–2060 period, and hence, the current level of minimum retirement age would remain at its currently low level. Thus, each 1-year increase counterfactually introduced to the minimum retirement age during the search for optimal configurations of A, CR and RR required that population projections be manipulated in such a way to transfer retirees younger than the value of A under consideration to working population.[7] So, after every incremental increase in A, the algorithm calculated the left-hand side of equality constraint in (2) and calculated the appropriate real income terms to find the associated value of intertemporal pension balance, $|D|$. $|D|$ was then recalculated by incrementing RR over (0, 1) interval by 0.05 each time and computing the corresponding value of CR. The combinations which yielded $|D| = 0$ are plotted in Fig. 1. So, each point on the three-dimensional graph in the figure corresponds to a combination of CR, RR and A balancing the contribution revenues and pension payments in real present value terms as required by the deficit reduction target of the government.

The cross-section plot in the upper-right window in Fig. 1 shows the possible retirement ages associated with alternative replacement rates for a given contribution rate of 0.2, which corresponds to the average of rates currently applied by the three publicly run institutions providing pension coverage in Turkey. Also marked in the figure in this window are current replacement rates of 0.65 and 0.95 used by the largest two of these institutions. The figure shows that if the contribution rate is to be maintained at its current average of 20%, current replacement rates used by three pension institutions would require minimum retirement ages varying between 58 and 65 for the system to have a zero balance over the 1995–2060 period.[8]

2.2. *Pension reform through gradual increases in the retirement age*

The foregoing discussion indicates that if pension parameters are changed once-and-for-all, the minimum retirement age must be at least 58. But if this rise in A is made effective for everyone immediately, thousands of workers who made their retirement plans under the pre-reform configuration of parameters would have to stay at work for several more years than they originally intended

[7] Since we took into account the possibilities of death, unemployment and early retirement due to disabilities over the entire model horizon, the actual process we followed to regenerate projections after every increase in A was more complicated than is described here. Such details are skipped as they do not directly contribute to the discussion in the rest of this paper.

[8] Obviously, the exact timing of reform would affect the magnitude of changes that need to be introduced to statutory retirement ages and contribution/replacement rates. Since delays in legislating parametric reform would increase the initial level of deficit to be dealt with, such delays would drive statutory retirement ages and contribution rates higher and/or replacement rates lower.

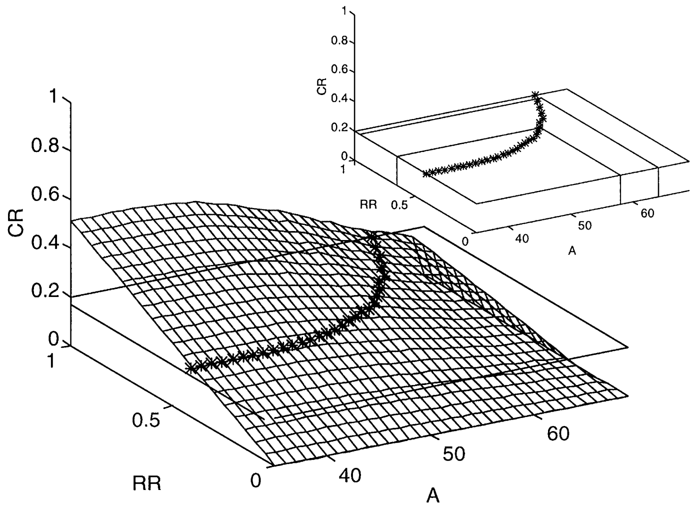

Fig. 1. The set of pension parameters that could eliminate the intertemporal pension deficit over 1995–2060.

to. Because convincing workers to postpone retirement without notifying them well in advance would be very difficult (if not impossible), such an increase in the retirement age is not politically feasible. If only the retirement age of junior workers is increased, on the other hand, it would be impossible to balance the pension deficit until 2060. To avoid this, the problem can be formulated to allow the retirement age to be increased gradually over time, thereby leaving enough time for current workers to plan ahead.

In this alternative formulation, the objective is to minimize the difference between contribution revenues and pension payments over a path that the minimum retirement age will follow between 1995 and 2060, subject to a given value for CR and a given range for RR. Since the working and retiree populations at any given period t are functions of the retirement age as discussed in Section 2.1,[9] the problem can now be expressed as

$$\underset{\alpha}{\text{Minimize}}\, D = \left| \sum_{t=1995}^{2060} \frac{1}{(1+\delta)^{t'}} \left(CR \sum_{a=15}^{75+} rw_{a,t} w(A_t)_{a,t} - RR \sum_{a_t}^{75+} \sum_{ra_{t=A_t}}^{a_t} \overline{rw}_{ra,a,t-(a-ra)-1} r(A_t)_{ra,a,t} \right) \right|$$

[9] Since the relationship between working or retiree populations and the minimum retirement age is too complicated to be represented through a well-known functional form, the series were generated through an iterative process as in Section 2.1.

$$\text{subject to } A_{t+1} = A_t + \bar{A}(\alpha)e^{-\alpha(t-1995)},$$
$$\alpha > 0,$$
$$0.65 \le RR \le 0.95,$$
$$CR = 0.2,$$
$$A_t \le 65. \tag{3}$$

In this problem, a dynamic path was chosen for the retirement age by finding the value of α, a parameter capturing the rate of change of the retirement age over time. A variant of the search algorithm was used to find the values of α minimizing the objective function for different RR values lying in the given interval. For each value of α considered, the corresponding minimum retirement age was calculated from the difference equation in the first constraint. (To solve the difference equation in the constraint for $\bar{A}$, we let $A_{1995} = 43$ and $\lim_{t\to\infty} A_t = 65$ where 43 is the minimum retirement age that is currently in effect for male workers and 65 is a reasonably high upper limit for retirement age increases in Turkey — that is, we took $mwa = 65$. Starting with a guessed solution of the form $A_t = \beta_0 + \beta_1 e^{-\alpha(t-1995)}$, further manipulations would yield $\bar{A} = -22[e^{-\alpha} - 1]$ enabling us to write the constraint as $A_{t+1} = A_t - 22[e^{-\alpha} - 1]e^{-\alpha(t-1995.)}$.) Then, the resulting age was used to generate the yearly workforce, $w(A_t)$, and retiree population, $r(A_t)$, series which, in turn, were plugged into (3) to have the corresponding value of $\tilde{D}$ calculated. The same steps were repeated by considering a smaller (bigger) value for α whenever $\tilde{D}$ turned out to be greater (smaller) than zero. The iterations were continued until the value of α specified to the sixth digit after the point could not be changed any longer. (This optimization exercise was repeated for replacement rates varying between 0.65 and 0.95.)

Since minimum retirement ages could only take integer values, it was impossible to get $\tilde{D}$ strictly equal to zero. But the search routine was highly successful as the optimal value of α satisfied the following inequality:

$$\frac{\left|\sum_{t=1995}^{2060} 1/(1+\delta)^{t'}\left[0.2\sum_{a=15}^{75+} rw_{a,t}\,w(A_t^*)_{a,t} - RR\sum_{a_t}^{75+}\sum_{ra_t=A_t^*}^{a_t}\overline{rw}_{ra,a,t-(a-ra)-1}\,r(A_t^*)_{ra,a,t}\right]\right|}{\sum_{t=1995}^{2060} 1/(1+\delta)^{t'}\left[0.2\sum_{a=15}^{75+} rw_{a,t}\,w(A_t^*)_{a,t} + RR\sum_{a_t}^{75+}\sum_{ra_t=A_t^*}^{a_t}\overline{rw}_{ra,a,t-(a-ra)-1}\,r(A_t^*)_{ra,a,t}\right]} < .00025, \tag{4}$$

where the numerator on the left-hand side is $\tilde{D}^*$, the optimal value of $\tilde{D}$, and the denominator is the sum of the components of the difference in $\tilde{D}^*$. So, this gives a performance indicator independent of currency units in which $\tilde{D}^*$ is measured. The behavior of the ratio in (4) with respect to changes in α is plotted in Fig. 2

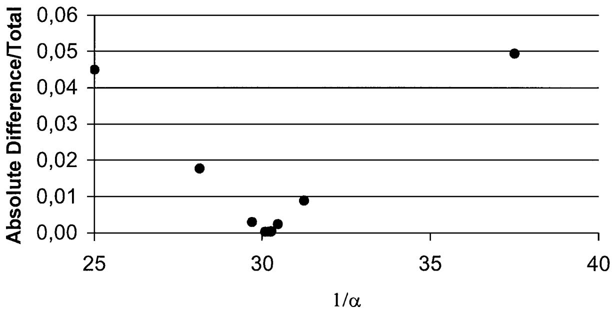

Fig. 2. Behavior of pension deficit with respect to changes in α.

where α^*, the optimal value of α, is observed to be equal to 1/30 approximately (0.033062 to be more precise).

The three-dimensional plot in Fig. 3 shows the dynamic paths of the minimum retirement age resulting under α^* across different replacement rates considered.[10]

The results behind Fig. 3 indicate that for the intertemporal pension deficit over the 1995–2060 period to be eliminated, people to enter the workforce in the aftermath of reform would be facing a minimum retirement age of 58 or more, whereas currently active workers who are planning to retire as early as 43 years of age will have to postpone retirement by a number of years depending upon their current age.[11] Table 1 reports the number of years remaining until

[10] We also investigated the path minimum retirement age would have followed, had the replacement rate also been allowed to adjust over time. Since allowing *RR* to change over time without specifying its path rendered the dimensions of the problem unmanageable with the previously employed search methods, a hybrid dynamic programming technique introduced in Fackler and Miranda (1999) was used to solve this problem by defining a time-dependent version of the Bellman equation (Intriligator, 1971; Miranda, 1999). While providing important lessons for computational analysis, this exercise did not produce any results which could enrich the policy discussion in any significant way. So, no further discussion on this exercise is given here but the results and a description of the implementation of this technique can be obtained from the authors.

[11] To compare the results in Fig. 3 to those in Fig. 1, one can consider the cases of replacement and contribution rates set at 0.65 and 0.20, respectively. Fig. 1 and the results in Table 1 indicate that under the once-and-for-all change scenario, minimum retirement age would be increased to 58 for everyone so as to render $|D| = 0$ at these rates. The gradual adjustment scenario allows some generations to retire (and hence, to begin drawing benefits and to stop contributing) earlier than this age but achieving $|D| \approx 0$ would still be possible since later generations would be required to stay in the workforce beyond the age of 58. As the foremost contour in Fig. 3 indicates, the retirement age would be at least 58 for everyone who is in the workforce after 2028.

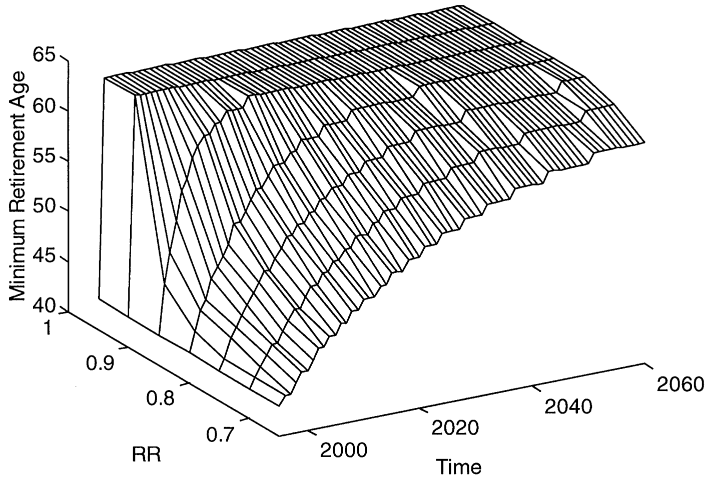

Fig. 3. Behavior of minimum retirement age over time for different replacement rates.

retirement for workers at different ages in 1995 under both reform scenarios considered. Table 2 presents the same results for workers in different age groups in 2040 (i.e., people who were yet to be born in 1995). (To assure comparability of results across scenarios, all results reported in the tables were obtained by assuming a replacement rate of 0.65 and a contribution rate of 0.20.)

Under the scenario in Section 2.1, when $CR = 0.20$ and $RR = 0.65$, the minimum retirement age would have to be increased to 58 for everyone regardless of whether they are currently in or yet to enter the work force. But since forcing workers who are at the age of 42 (41, 40, etc.) at time t and planning to retire at $t+1$ ($t+2, t+3$, etc.) to postpone retirement plans for 16 (or more) years would not be fair (if not infeasible), the present scenario gradually increasing the retirement age over time would be more sensible. This is, in fact, the reform strategy that has recently been put into use in several OECD countries (Kohl and O'Brien, 1998; SSA, 1997), even though gradual increases in retirement age are determined in a less-sophisticated fashion.[12]

[12] The retirement age for people covered by the OASI program in the U.S. to be eligible for full benefits, for example, will be increased by 2 months per year until 2022 (SSA, 1997).

[13] While alternative assumptions about the nature of demographic transition and workforce participation behavior are also likely to affect results, the absence of alternative population and workforce projections prevented us from carrying out sensitivity tests for changes in projected population and workforce series here. This, however, is one of the directions our research is planned to take in near future.

Table 1
Minimum retirement age for currently active workers before and after pension reform

Before reform		After reform			
		Without gradual adjustment in A		With gradual adjustment in A	
Worker's current age	Years until retirement	Minimum age of retirement	Years until retirement	Minimum age of retirement	Years until retirement
42	1	58	16	45	3
41	2	58	17	47	6
40	3	58	18	48	8
39	4	58	19	49	10
38	5	58	20	50	12
37	6	58	21	51	14
36	7	58	22	51	15
35	8	58	23	52	17
34	9	58	24	53	19
33	10	58	25	53	20
32	11	58	26	54	22
31	12	58	27	54	23
30	13	58	28	55	25
29	14	58	29	56	27
28	15	58	30	56	28
27	16	58	31	56	29
26	17	58	32	57	31
25	18	58	33	57	32

2.3. *Sensitivity of results*

Since the results reported so far are expected to change under alternative discount and productivity growth rate assumptions, the sensitivity of results with respect to these parameters is considered in this section.[13]

The results are robust to changes in the projected real wage series resulting from small deviations from assumed productivity growth rates since real wage changes affect the revenues and expenditures of the pension system in the same direction. Similarly, the sensitivity of results to changes in the assumed value of discount rate, δ, remains sufficiently low not to raise serious concerns about the usefulness of the previous discussion.

Keeping the definition of pension balances in (1) in mind and starting from $[A, CR, RR]$ triplets satisfying $|D| = 0$, a *ceteris paribus* reduction in the discount rate will increase the value of $|D|$ above zero. To return this value back to zero, one or more of these pension parameters (statutory retirement age, A; contribution rate, CR, and replacement rate, RR) must adjust. The direction of change in each parameter required by a reduction in the discount rate, δ, can

Table 2
Minimum retirement age for active workers in the year 2040 before and after pension reform

Before reform		After reform			
		Without gradual adjustment in A		With gradual adjustment in A	
Worker's age in 2040	Years until retirement	Minimum age of retirement	Years until retirement	Minimum age of retirement	Years until retirement
42	1	58	16	60	18
41	2	58	17	60	19
40	3	58	18	60	20
39	4	58	19	61	22
38	5	58	20	61	23
37	6	58	21	61	24
36	7	58	22	61	25
35	8	58	23	61	26
34	9	58	24	61	27
33	10	58	25	61	28
32	11	58	26	61	29
31	12	58	27	62	31
30	13	58	28	62	32
29	14	58	29	62	33
28	15	58	30	62	34
27	16	58	31	62	35
26	17	58	32	62	36
25	18	58	33	62	37

intuitively be analyzed, by keeping the other two parameters constant. For optimal values of CR and RR satisfying $|D| = 0$, for example, statutory retirement age must be increased to counter the effect of a reduction in the discount rate on the desired pension balance. (By increasing the number of contributing workers and reducing the number of retirees drawing benefits, this will restore the desired balance at $|D| = 0$.) This implies that for given values of contribution and replacement rates, the optimal value of statutory retirement age is negatively related to changes in the discount rate. This intuitive reasoning is supported by sensitivity results reported in Table 3 which presents the optimal value of the statutory retirement age for alternative values of replacement rates and a contribution rate of 0.20, under each of the scenarios considered.

3. Conclusions

This paper discussed the identification of parametric reform options to control losses generated by a publicly managed, PAYG pension system under

Table 3
Minimum retirement ages for alternative replacement rates under different discount rate assumptions when $CR = 0.20$

	Alternative replacement rates[a] (the once-and-for-all change scenario)							Alternative replacement rates[a] (the gradual adjustment scenario)						
δ	0.65	0.70	0.75	0.80	0.85	0.90	0.95	0.65	0.70	0.75	0.80	0.85	0.90	0.95
0.01	61	63	64	65	65	65	63	64	65	65	65	65	65	65
0.03	60	61	63	64	65	65	65	63	64	65	65	65	65	65
0.05[b]	58	60	61	63	64	65	65	62	64	65	65	65	65	65
0.07	56	58	59	61	62	64	65	61	63	64	65	65	65	65
0.09	53	57	58	60	61	63	64	60	63	64	65	65	65	65

[a]The results with minimum retirement age equals 65 indicate that the constraint requiring the minimum retirement age not to exceed maximum working age (*mwa*) is binding — see (2) and (3).
[b]The assumed discount rate behind the results reported in Sections 2.1 and 2.2.

alternative deficit reduction (reform) strategies including one time jumps, as well as gradual changes in contribution/replacement rates and statutory retirement ages. For this purpose, two different problems each corresponding to a different pension reform strategy were analyzed using different computational techniques applied to the Turkish pension system. The first problem involved identification of alternative pension parameters compatible with a given target for revenue-expenditure balances of a pension system. The solution of the problem, obtained through a numerical search algorithm was shown to be non-unique unless additional constraints are imposed to reflect the priorities of policy makers. It was argued that replacing the existing pension parameters at once rather than gradually over time could be particularly problematic if the new configuration calls for higher retirement ages for everyone including workers who plan to retire soon. Given the difficulties in convincing such workers to postpone their retirement plans, an alternative reform strategy involving gradual increases in retirement age was considered by solving a constrained optimization problem in which the pension deficit is minimized subject to a dynamic retirement age path and a one time change in replacement rates.

The results indicated that retaining current values of replacement and contribution rates while trying to eliminate Turkish pension deficit over 1995–2060 period would require a substantial one-time increase in the minimum retirement age. If a gradual increase in the minimum retirement age is chosen instead, on the other hand, some generations will be allowed to retire at a lower age than the minimum age implied by the one-time jump scenario, but later generations will be required to stay in the workforce beyond this age.

References

Boll, S., Raffelhüschen, B., Walliser, J., 1994. Social security and intergenerational redistribution: a generational accounting perspective. Public Choice 81, 79–100.

Chand, S.K., Jaeger, A., 1996. Aging populations and public pension schemes. Occasional Paper 147, International Monetary Fund, Washington, DC.

Fackler, P.L., Miranda, M.J., 1999. Hybrid methods for continuous state dynamic programming. Paper Presented at the Society for Computational Economics, Fifth International Conference, Boston, June 24–26.

Halter, W.A., Hemming, R., 1987. The impact of demographic change on social security financing. IMF Staff Papers 34, 471–502.

Huang, H., Imrohoroglu, S., Sargent, T., 1997. Two computations to fund social security. Macroeconomic Dynamics 1, 7–44.

ILO, 1996. Social Security and Health Insurance Reform Project. Final report to Turkish government, ILO, Geneva.

Intriligator, M.D., 1971. Mathematical Optimization and Economic Theory. Prentice-Hall, Englewood Cliffs, NJ.

Joines, D.H., Imrohoroglu, A., Imrohoroglu, S., 1999. Computing models of social security. In: Marimon, R., Scott, A. (Eds.), Computational Methods for the Study of Dynamic Economies. Oxford University Press, London.

Kenc, T., Sayan, S., 2000. Demographic shock transmission from large to small countries: an overlapping generations CGE analysis. Journal of Policy Modeling, forthcoming.

Kohl, R., O'Brien, P., 1998. The macroeconomics of ageing, pensions and savings: a survey. Economics Department Working Paper 200, OECD, Paris.

Miles, D., 1999. Modelling the impact of demographic change upon the economy. Economic Journal 109, 1–36.

Miranda, M.J., 1999. AE 802 Computational economic dynamics lecture notes. Ohio State University (available on-line at http://agbusmgt.ag.ohio-state.edu/ae802/lectures.htm).

Sayan, S., Kenc, T., 1999. Long-term consequences of rehabilitating a financially troubled pension system: an overlapping generations, general equilibrium analysis for Turkey. Economic Research Forum Working Paper No. 9914, ERF, Cairo.

Sayan, S., Kiraci, A., 2000. Identification of parametric policy options for rehabilitating a pay-as-you-go based pension system: an optimisation analysis for Turkey. Applied Economics Letters 8(3), forthcoming.

SSA, 1997. Social insurance programs. Office of Research, Evaluation and Statistics Publication No. 13-11758, Social Security Administration, Washington, DC.

Topal, N., 1999. Is the Turkish social security system in need of reform? ESDS Employment Studies Working Paper No. 22, University of Hertfordshire, Hertfordshire.

Van den Noord, P., Herd, R., 1994. Estimating pension liabilities: a methodological framework. OECD Economic Studies 23, 131–166.