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Dynamic immigration control improving inverse old-age dependency ratio in a pay-as-you-go pension system

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ABSTRACT

The sustainability of pay-as-you-go pension systems is a major concern in most European countries. Considering the inverse old-age dependency ratio (the proportion of the class of actives to pensioners) as a sustainability index, based on a classical demographic model, a new optimal control model is proposed where the sustainability index grows along a prescribed trajectory, minimizing the annual immigration flow over a given time horizon. In addition to the admission of young immigrants, immigrant females, by having higher birth rates than the residents, can substantially improve the sustainability index. For the efficiency of the immigration policy, the admission of immigrants is also differentiated by age. Within the limits of our model, the social cost of sustainability in terms of immigration can be estimated on beforehand. Therefore, the simulation analysis of our model may give a sound foundation to the corresponding decision of policy makers.

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1. Introduction

Pay-as-you-go (PAYG) pension systems, in which the pensions are paid from the actual contribution of the active population, face a serious problem for two main reasons of demographic character: both low birth rates and growing survival rates affect the sustainability of the system negatively. Since the inverse old-age dependency ratio, i.e. is the proportion of the active subpopulation to pensioners is a good indicator of demographic sustainability, it will be called shortly sustainability index. For an analysis of sustainability, also considering the well-known problem of longevity risk, see e.g. Alho [1] and Pitacco [2].

Different European countries try to solve the problem in different ways; recent "country studies" are among others: Fehr and Habermann [3] for Germany, Blake and Mayhew [4] for the UK and Sanchez and Alfonso [5] for Spain. Furthermore, for China, Yang [6] examines the effects of the replacement rates and population growth rate on pension benefits and finds the optimal replacement rate. Since the work by Boyle and Freedman [7], a variety of demographic models have been applied for medium and long term predictions concerning the pension systems; for a recent overview and a methodological criticism of them see in Herce [8] and Booth [9].

While the comprehensive study of Rother et al. [10] is dedicated to the fiscal sustainability of PAYG pension systems, we will concentrate on the demographic background of sustainability. It is known (see Angrisani et al. [11] and Alho and Spencer [12]) that, based on a two-sex Leslie type model and Perron–Frobenius theory of non-negative matrices, a population underlying the pension system converges to an equilibrium for the age distribution, provided the birth rates and survival rates remain constant and there is no migration. Although in the literature, a large number of studies dealing with the effect of immigration can be found (for recent summaries we refer to Nannestad [13] and Wenko [14]), to our knowledge, our paper Angrisani et al. [15] is the only study on how an optimal immigration strategy should be determined in order to move the population towards an equilibrium age distribution. In fact, based on Angrisani et al. [15], a convergent algorithm was given which, on the one hand, controlled the population towards a demographic equilibrium (a state of proportional change), and on the other hand, minimized the yearly admission of immigrants. As a result, in the model calculations the dramatic decrease of the inverse old-age dependency ratio has been also eased, however this improvement is actually not sufficient for a real sustainability. See Fig. 1.

The present paper, instead, in the framework of a controlled immigration model, focuses on the continuous improvement (monotonic growth) of the sustainability index, without requiring the system to approach a demographic equilibrium. Based on a classical demographic model, a new optimal control model is proposed where the

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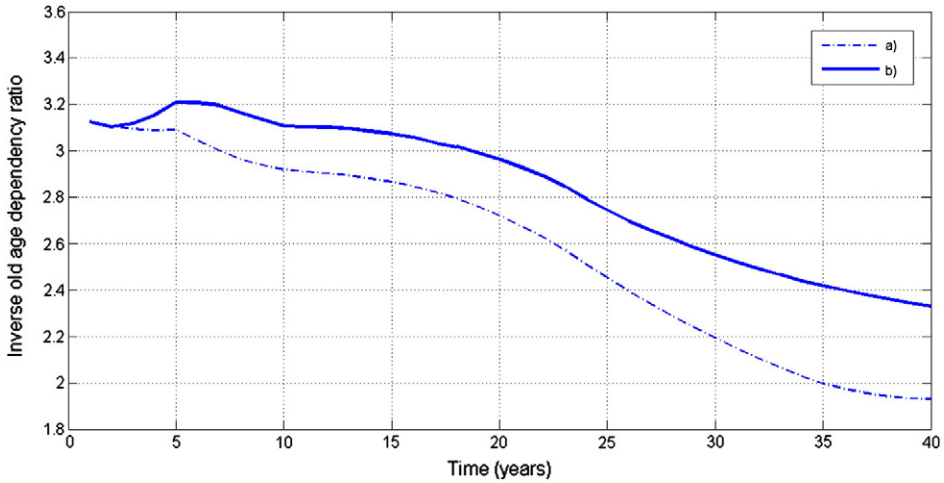

Fig. 1. (Angrisani et al. [15]) Curve a shows the development of the sustainability index corresponding to the de facto 500,000 yearly immigration as constant; curve b corresponds to the immigration control algorithm.

sustainability index grows along a prescribed trajectory, minimizing the annual immigration flow over a given time horizon. In addition to the admission of young immigrants, immigrant females, by having higher birth rates than the residents, on medium term can substantially improve the sustainability index. For the efficiency of the immigration policy, the admission of immigrants is also differentiated by age. Within the limits of our model, the "social cost" of sustainability in terms of a possibly high level of immigration can be calculated on beforehand. Therefore, the analysis of our optimization model may give a sound foundation to the corresponding decision of policy makers.

The paper is organized as follows: in Section 2 we recall the basic demographic model. Section 3 deals with the setup of a new dynamic optimal control model for the demographic dynamics with immigration. The solution of this optimal control problem is programmed in MatLab environment. Section 4 is dedicated to the application of the model to real Italian demographic data (provided by the Italian National Institute of Statistics, ISTAT), with different scenarios for the required trajectory of the sustainability index. The basic model will be also modified to include the fact that in the second generation of immigrant the birth rates approximate those of residents. In fact, in Model A, for a first approximation we neglect the fact that females of the second generation of immigrants have lower birth rates than those of the first generation. In Model B, instead, this adaptation tendency in terms of the rates is also taken into account. A Discussion section closes the main body of the paper.

2. The basic demographic model

In this section, from Angrisani et al. [15] we recall the adaptation of a classical linear dynamic model which can be considered as the demographic background for the study of the PAYG pension system.

We start from the classical Leslie model [16,17], which considers a population without sex structure, where $N \in \mathbb{N}$ is an upper bound of the age of an individual. The population is divided into N age groups in the following way: $x_i(t)$ is the number of individuals of age belonging to the interval $[i, i+1[$, for $i = 0, 1, \ldots, N-1$, at time t. The unit of age and time is the same. If the average *per capita birth rate* in the extiti-th age group is $\alpha_i \geq 0$ and the *survival rate* from age group i to age group $i+1$ is $0 < \omega_i < 1$, then in terms of state vector (population vector)

$$x(t) = [x_0(t), x_1(t), \ldots, x_{N-1}(t)]^T$$

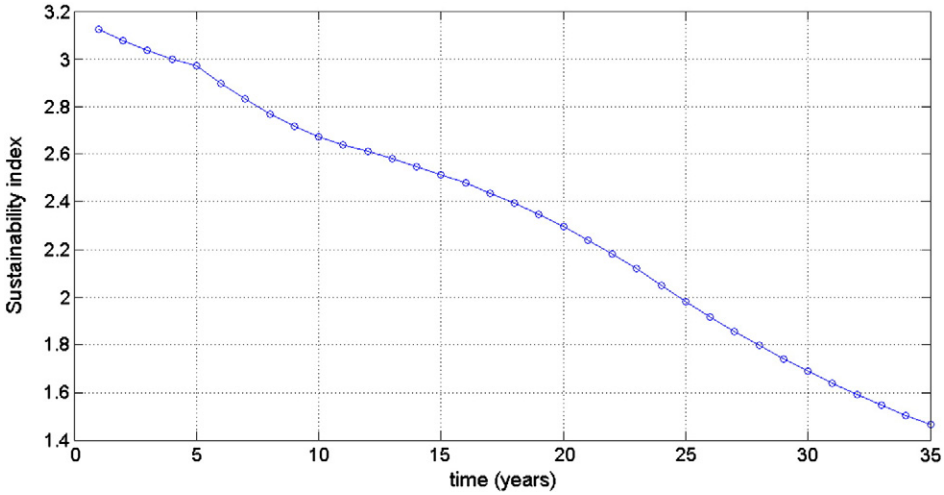

Fig. 2. Decrease of the sustainability index in 35 years, without immigration.

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