A Multi-Agent System for the Pay-As-You-GO (PAYGO) Social Security Scheme

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Abstract. Multi-Agent Systems (MAS) are suitable for dealing with applications where the environment is both dynamic and very complex, with several type of competitors to get involved. Thus, in this paper, we import MAS conceptualization into the well-known (quasi) Pay-As-You-GO social security scheme; practically useful for many Western Economies. First, we start our analysis with the individual agent and subsequently we move towards a system containing many (cognitive) social agents that considers relations, coordinations and interactions.

Keywords: Multi-Agent Systems; Pay-As-You-Go Social Security Scheme; Social Insurance; Contingency Funds.

1 Introduction - The Pay-As-You-Go Social Security Scheme

1.1 The Traditional Version of the Scheme

In this section, some introductive and fundamental elements for social insurance are presented and briefly discussed. This effort is significant, since it provides an overview of the environment in where the agents have to deal with.

The **P**ay-**A**s-**Y**ou-**GO** (**PAYGO**) social security scheme, in its traditional form, requires no accumulation of funds as the other actuarial funding methods do. In practice, there exists a small fund, but only for liquidity purposes. In a certain time period (normally one calendar year), the insured group of lives is divided in two subgroups, the workers (or active members) and the beneficiaries (or pensioners or retirees). According to this approach, the output of today's work-force is partially transferred to today's retirees. Thus, the equation which represents this transition is the following

$$bP = cwL \tag{1}$$

where b is the level of average pension and P the number of eligible beneficiaries (or pensioners). Consumption on pensions, bP, is financed by an appropriate proportional contribution c (percentage rate 100s) on total covered wages (salaries).

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Typically, there is an individual wage ceiling above which, no contribution is collected, and normally a maximum pension is associated with. If L is the number of workers who participate in the scheme (not necessarily all the working-age population, see for more details 2^{nd} section) and w is the average covered wage (salary), then cwL is the total respective revenue collected. This simple model shifts immediately any balance perturbation onto beneficiaries or/and contributors.

1.2 The Basic Principles

The concepts of intergenerational solidarity and equity, and the long-term sustainability are the three most important requirements for a successfully operating PAYGO.

The willingness of both young and old generations to participate in a common pool, sharing actual experience, including any losses emerging is defined as **intergenerational solidarity**; see [17], for further discussion.

Moreover, the fact that all the generations are equal to each other is defined as **intergenerational equity**. A metric that is implied this equity, according to [15], is the rate of return. *The interest rate that equalizes the stream of contributions to the interest rate applicable had the contributions actually be invested*, see [9]. This rate of return can be calculated either for individuals or for cohorts of lives.

Furthermore, as the following two paragraphs clearly present, the operating system should also be concerned for the **long-term sustainability** of public pension arrangements under conditions of population ageing.

Member states should undertake ambitious reforms of pension systems in order to contain pressures on public finances, to place pension systems on a sound financial footing and ensure a fair intergenerational balance, see [3].

A strategy pursuing the aim of equal treatment for all generations can cope with . . . demographic changes only through an intergenerational redistribution i.e. a rebalancing in favour of the younger and as yet unborn cohorts, see [13].

1.3 The Rising Cost

Applying the international demographic trends of ageing populations, it is clear that the public pension systems of all the countries operating under the PAYGO scheme will face the rising cost over the next few years. For instance, eq. (1), see [11] and [12], demonstrates that, to maintain balance under a constant amount of a pension benefit, c will have to increase if the decline in fertility rates leads to a decrease in L at the same time as a decrease in mortality rates leads to an increase in P.

1.4 Why Defend the PAYGO Social Security Scheme?

Now, even if there is a considerable rising cost which, will cause a lot of problems in the next decades, the governments still have to defend the PAYGO scheme and the reasons for this choice are very distinct and clear. Many countries have a PAYGO state pension, so a potential change towards a fully funding method

will generate a double cost for a certain cohort of lives and an analogous deficit in the national budget till the whole system returns to a new equilibrium under the new financing method.

Additionally, if not all, of these countries have ageing population and therefore need to amend the parameters of the system (such as retirement age, quantum in relation to earnings, number of years of contributory history before qualifying for full benefit, etc) in order to maintain a financially sustainable system. On the other hand, PAYGO scheme can not be useless because there are certain advantages as: the simplicity of its structure, the whole population may be easily covered without any complications, there are no problems with the indexation of benefits or with the efficient investment management as there is no reserve funds etc. (for further discussion, see [1] and [6]).

Consequently, it should be stressed that only considering the reasons above, they provide us with strong evidences why the PAYGO scheme should be further studied and enriched. Definitely, this study is a step into this direction, see next subsections. However, more research work should be done.

1.5 Revisiting the Idea of the Contingency Fund

In [7], it has been firstly introduced a (quasi) PAYGO scheme which incorporates a contigency fund in the system. With the existence of this fund, an interesting combination of the advantages of the PAYGO scheme with those of the fully fund schemes is provided. Moreover, we should mention that this non-zero reserve fund is acting as a buffer, fluctuating deliberately (in the short run) and absorbing partially or completely the unexpectedness in mortality, fertility rates or other random events, see for more details the following section. Afterwards, the contingency fund returns to zero when the fluctuations disappear, leaving the system at a new equilibrium point.

A new extension of the proposed a (quasi) PAYGO scheme by [7] that also adopts the concept of the contingency fund has been considered by Pantelous and Zimbidis, see [11] and [12]. In those papers, several other parameters have been introduced optimizing the derived benefits for the society. For instance, we might mention the different kind of beneficiaries, of contributors etc.

Now, in the end of the 1^{st} Section, we have a clear view for the importance of the PAYGO scheme into the national and global pension systems. In the next section, the PAYGO scheme is further benefited by the use of the Multi-Agent Systems' methodology. A complex system of different agents are introduced for the calculation of different significant parameters.

2 A New Approach Based on Multi Agent Systems

2.1 Multi Agent System

The quasi PAYGO social security scheme proposed by [7], and expanded by [11] and [12], can be further benefited using the **M**ulti-**A**gent **S**ystems' (**MAS**)

conceptualization. Analytically, in the existing literature, see for instance [14], [18] and [16], it is more than clear that MAS can supply us with all the appropriate tools to study deeper and even (sometimes) wider what the aspects of inputs are that plausibly explain interactive (social) behaviour. Hence, considering more realistic applications, in our case the PAYGO scheme (as well as every other MAS) can be concerned with the *behaviour of a collection of distributed autonomous (heterogeneous) agents aiming at optimizing funds and making stabilized and viable the national pay-as-you-go social security plan.*

In this part of the section, following the thoughts of [8], we propose the real characteristics of a generic PAYGO scheme. Note that these characteristics are also compatible in several MAS.

- Thus, each agent has incomplete information or capabilities for solving the problem. Additionally, each agent has a limited viewpoint.
- There is no global system control.
- Data is decentralized.
- Computation is asynchronous.

Inferred from the above centralized-importance characteristics, we can assume that the main component founded in every Multi-Agent Systems is the autonomous *agent* and its associated *behaviour* in an *environment*. Consequently, the main contribution of the paper is to explain PAYGO scheme's environment starting with the individual agent and subsequently going towards a system of (cognitive) social agents that considers relations, coordination and interaction between agents. As has already been mentioned, the purpose of the paper is to provide, -according to the authors' knowledge- for the first time, a detailed study of the PAYGO scheme through the notion of MAS, which is very significant paradigm for several other **S**ocial **S**ecurity **A**dminstration (**SSA**) projects.

2.2 The Overall Structure of the PAYGO Scheme

In this section, we have two main goals:

1. First, we want to describe briefly the basic characteristics of each agent appeared in the PAYGO scheme proposed by [11] and [12], and
2. simultaneously we consider relations, coordination and interactions among them.

Moreover, this new approach, which is based on the conceptualization of the MAS, is also able to project (or/and to forecast) effectively social security's finances (i.e. trust fund balances) decades into the future. In this direction, two significant things are required, see [2]:

1. a scheme that shows how *key* economic and demographic agents interact with *policy rules* to determine financial flows, and
2. assumptions about the *annual values* for those agents.

In our analysis, we should also have in our mind that the structure of the proposed quasi PAYGO scheme determines how changes in assumptions affect the systems finances and thus how uncertainty about those assumptions results in uncertainty about the financial status of the SSA policies.

Analytically, a PAYGO scheme should rely on *outputs* of about nine primarily important agents, see **figure 1**. These agents are presented briefly below. We consider the **agent** *for the information about the*

- **fertility rate**
- **mortality rate**
- **immigration rate**
- **unemployment rate**
- **incidence** and **termination** of the claims for **D**isability **I**nsurance (**DI**)
- **real wage growth**
- **inflation** - it affects intermediate demographic and economic variables that determine the accumulation of money in the Social Security trust funds
- **interest rate** - the ninth primary input affects the trust funds directly

The nine agents involved in the PAYGO scheme are living in a highly inaccessible environment surrounded with social (unpredictable or partially

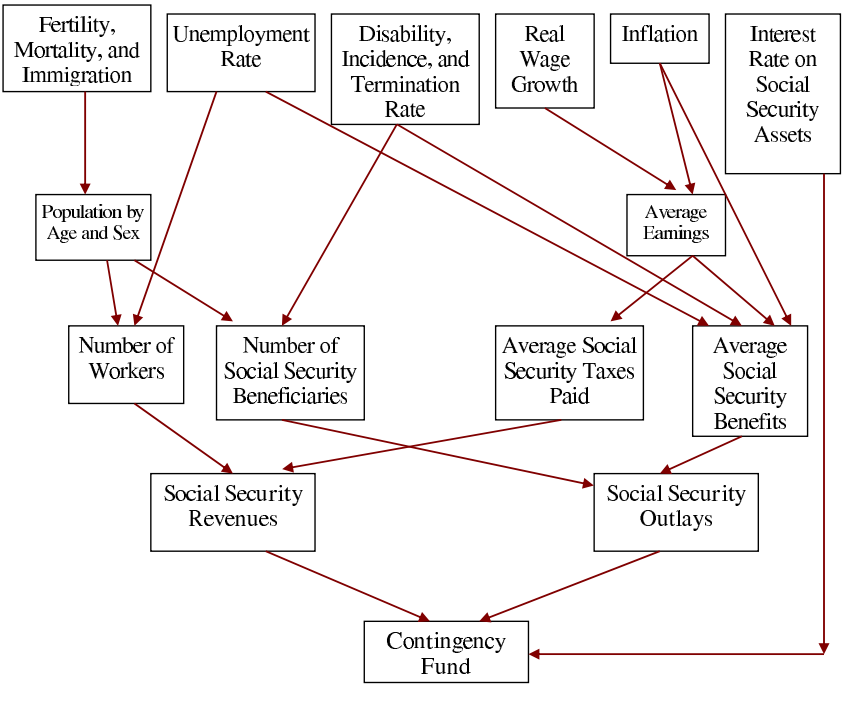

Fig. 1. In this figure the nine primary agents that affect the balance of the PAYGO social security scheme are presented. Moreover, their interactions with a line are provided. See [2].

predictable) parameters. Thus, a special language is required to communicate with each other, and not only a simple set of strict rules. This is a consequence, because they continuously have to adapt to new situations in a changing environment. However, in this paper -as we can see from the very next lines- we are not interested in developing any kind of language, since the characterization of the agents' environment and the connection among them are being discussed.

Generally speaking, although the PAYGO scheme is an actuarial model with parameters such as mortality or fertility to be significantly introduced, the interest rate policy is also important, since the higher the interest rate, the faster the trust funds grow (assuming, of course, a positive balance). Moreover, SSA revenues and outlays equal numbers of people (workers or beneficiaries) multiplied by Euro (or dollar)-amounts (average Social Security taxes paid or average benefits). Numbers of people, in turn, are based on population totals, and Euro (or dollar)- amounts are based on earnings.

Those relationships are briefly explained below, see also **figure 1**.

• **Connecting population by age, sex, and marital status:** In practice, every PAYGO scheme begins with a huge multi-column matrix that includes counts of people by *age*, *sex*, and *marital status*. Once the agent has selected future annual values for the mortality and fertility rates and the level of immigration, the model applies the mortality rate to the current population to compute the number of deaths by age and sex. Afterwards, it applies the fertility rate to the female population in order to determine the number of births, for instance, by the age of the mother. This dynamically changing information, along with the assumed net number of immigrants, is added to last years population to obtain the new population figure (with a new age and sex distribution). After that, the agent might distribute the new population among four marital-status groups: single, married,divorced, and widowed - according to age and sex.

• **Calculating the number of workers:** Into the PAYGO scheme, *three* factors are considered to the total working-age population (mainly people ages from 15 to 75) to obtain a view of the total number of workers covered by the SSA, see also [2]:

1. The total working-age population multiplied by the labor force participation rate is finally equal to the *labor force*.
2. The labor force multiplied by the employment rate give the *workers*.
3. The workers multiplied by the covered-worker rate provide the *covered workers labor force participation rate*.

Over the last half century, the labor force participation rate, i.e. the fraction of the working-age population that is employed or looking for employment, has changed significantly. For instance, it is easy to consider that the proportion of women in the labor force has increased steadily and substantially, though the participation rate for women age 65 or older has stayed the same. Although those facts inform complexity, many questions still remain. For example, *how much further will the labor force participation rate for women increase?*, And *long-term trend*

toward earlier retirement for men continue, or will the rate observed over the past 15 years endure?

• **Measuring the employment rate:** Actually, the employment rate is equal to 1 minus the unemployment rate. In our approach, as well as in several other actuarial models, the unemployment rate is being considered and measured, since it is much more easier to collect data for "unemployed workers".

In practice, the **I**nternational **L**abour **O**rganization (**ILO**) has been regulated that the "unemployed workers" are those who are currently not working, but are willing and are able to work for pay, currently available to work, and have actively searched for work. However, it is clear that not all unemployment is *open* and *counted* by the several government agencies, so the official statistics on unemployment may not be accurate at all. Moreover, into a such complex environment, the agent should have some extra mechanisms that filter out information focusing mainly into the most comprehensive results and enabling the calculation of the unemployment rate by different group categories such as race and gender.

• **Finding the covered - worker rate:** The covered-worker rate is the percentage of employees who work in employment (fully or partially) covered by the SSA. Although that rate will increase slightly as older government workers who are less likely to be covered retire, it is expected to remain relatively stable over the next 75 years, see [2]. Moreover, as it can be easily understood, the covered-worker rate is based on the outputs of the agent which is responsible for the determination of the unemployment rate and, definitely, for several SSA's data.

• **Calculating the number of beneficiaries (or pensioners):** The PAY GO scheme has dozens of categories of beneficiaries, see [10] including retired workers, disabled workers, widows and widowers, and children. Some of the larger categories are broken down by age and sex, but the major division is between retired workers, their dependents, and the survivors of deceased workers and disabled workers and their dependents.

In this case, the agent which is responsible for the outputs relative to the number of beneficiaries, should consider data for each age and sex group. As a result, projecting growth in the number of those beneficiaries is fairly easy for a given age - and sex - specific population. Although changes in labor force participation, earnings patterns, and retirement rates affect the number of beneficiaries, the percentage of the elderly in the population has a much greater impact on Social Securitys finances.

• **Projecting per capita revenue and benefit levels:** Levels of Social Security revenues and benefits per person depend primarily on the growth of wages. That growth in turn can be separated into two sources: the *real wage growth* (which is effectively determined by productivity growth) and the *inflation.*

• **Determining the average revenue levels:** By definition, see [2], the amount of Social Security payroll contributions (or taxes) paid per capita can be determined by multiplying the average effective, contributive (or taxable) payroll by

the statutory contribution (or tax) rate. Under current law, the contribution (or tax) rate is constant; thus, the only uncertainty about the average revenue levels comes from the income (or taxable) payroll. Actually, we can use equally the notion "contribution" and "tax", because it is appeared to have the same meaning in PAYGO schemes. Not that there exists a difference between the "tax rate" in Financial and Actuarial Sciences.

In this case, the agent should evaluate firstly the average taxable earnings of the past years, then it might increase that number by considering nominal wage growth as it is clear, in this part of the process, the agent should take into consideration the agents which are providing us with the sum of the inflation and the real wage growth (the first two exogenously projected economic agents).

Growth in the average payroll contribution paid by a worker tracks the average wage growth very closely, but not exactly. Workers pay Social Security contributions only on amounts below the statutory maximum set for taxable earnings. PAYGO scheme does not permit users to vary that assumption. Still, any uncertainty about the effect of distributional changes on the growth of the taxable payroll is probably small compared with uncertainty about the overall wage growth.

• **Determining the average benefits:** An average benefit level must be projected for each of the Social Securitys many beneficiary categories. To analyze the effect of changing the complex benefit formula, PAYGO scheme employs a micro-simulation that projects average benefits for newly retired and newly disabled workers. (Micro-simulation involves producing exact calculations of benefits for a simulated sample of the population and aggregating the results from the sample. That type of simulation is necessary because the effects of the policy changes on different workers vary widely depending on factors such as those workers wage levels and years of employment.)

PAYGO scheme should take into account thousands of newly entitled beneficiaries from *Continuous Work History Data*, which includes each workers entire wage history. Using those wage histories, the model calculates a benefit for each worker and then computes averages for newly retired and newly disabled workers. The input variables in PAYGO scheme that affect benefit levels are *wage growth*, *unemployment*, *inflation*, and, to a lesser extent, *disability rates*.

In the end of this subsection, it should be pointed out that the definition of a *complete* agent, i.e. with all the necessary *components*, is always under strong debates and very deep thought. Many components will be discovered, removed or replaced during the designing process of the agent, consulting the knowledge of an agent model designer. In the literature of MAS, we have found a nice bottom-up example with many significant architecture characteristic, see figure 2 in [4] and [5].

Into this figure, we can clearly observe what is the complexity that occurs when we have to build a model considering just few components. Therefore, in order to obtain good outputs from our model, we have to make great efforts in certain parts of the architecture, for instance how the perception has grown towards a specialised topic - fertility, mortality etc. Fortunately, these

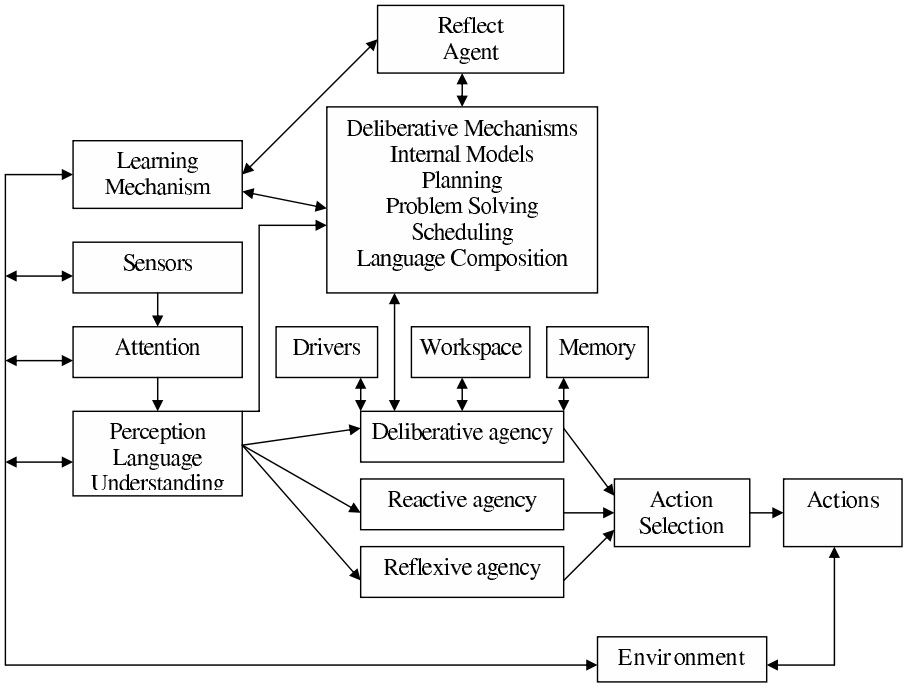

Fig. 2. An agent with components, see [4]

varying points of view have delivered many agent's types that can be put together/constructed from a collection of components; even the way they are implemented varies.

3 Conclusions - Further Research

The system described in this paper presents a new approach to the PAYGO social security scheme proposed by [7], [11] and [12] and has the potential to improve the quality of *decision-making policies* by ensuring more accurate data. Moreover, since several agents have been introduced, this analysis implies that the benefits for the society will be increased.

Different communities of users in the public or/and private actuarial-insurance and financial sector can be identified and used to improve the exploitation of Social Security Administration projects. In this direction, a lot of work should be done. Analytically, we have to provide with more details about each of the agents involved in the PAYGO scheme. Many components of the agent can be discovered, removed or replaced during the designing process. Moreover, when a society has a desire to improve over time the pension system with the help of its experience, then the involved agents require intelligence or a cognitive system's architecture and a memory of representations and experiences from the past in

order to be able to learn from previous actions. For the above ideas, further research should be done.

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