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# **Modelling reforms and growth upon the economy: a system dynamics approach.**

## **Abstract**

This paper considers a simulation model, which was obtained using system dynamics methodology. The model arises from analysing causal links among households, firms and government into a closed economy. A base generic model calibrated from European economies serves as reference to examine different policies, which try to attain various objectives. In particular, the model studies the actions and the responses of rational agents to policies that tries to improve unfounded state pension schema and the fertility rate in a way which also pursues an economic growth over extended periods of time.

## **1. INTRODUCTION**

It is well known that the current demographic structure of many developed countries is quite different than it was for centuries. Beside low fertility rate and better national health system, each time less people are in labour market and more people are in retirement. Miles (1999) affirms that in the case of massive immigration absence, or catastrophic new fatal illnesses, by the middle of this century, in several countries, working age people ratio compared to those in retirement age will be only around one half the current level.

It seems obvious that such changes could have a powerful impact upon the behaviour of different economics variables in both the public and private sectors. Because of this, current governments are trying to adopt some strategies to correct the expected impact that these changes could have in economic development and, especially, on the future state pensions scheme. Many of these policies tend to diminish the amounts of social security benefits, or try to increase the fertility rate. It is possible to enumerate some of these current measures: it is permitted that an worker can delay his retirement date by working more years; governments offer fiscal benefits when individuals are incorporated in a private funded pension scheme making regular contributions during their working lives; working mothers receive public transfers to care their children or households get subsidies to help in their children's education cost. In addition, these

policies have also to be harmonised with those policies which pursue an economic growth rate over a sustained period of time. Consequently, it seems that an insight on the answers of the economies to these simultaneous and different actions is necessary.

Since the late 1970s, various authors have investigated the effects of policy changes on the long-term behaviour in economies by considering endogenous growth models. In the majority of these studies, the assumptions are based on microeconomic observations of individual behaviours and on life cycle theory, always assuming a perfect foresight environment. The dynamic hypotheses generate a simulation model, which can be put on a computer and it starts to run. The results of simulations permit to evaluate the impact of different policies in the economy. Lucas (1990) develops a model with agents infinitely lived and emphasises the role of human capital accumulation as the engine of endogenous growth; Jones, et al. (1993) explore the effects of the switch to an optimal tax scheme upon growth rate and welfare level in a representative agent inside a calibrated economy. Hendricks (1999) constructs a model with a finite horizon to nest with an infinite horizon and includes human capital accumulation to study the growth effects of taxes. To analyse the transitory and the long-term effects of policy changes and other exogenous shocks, Bouzahzah et al. (2002) consider a model with overlapping generations of adults where human capital accumulation plays an important role, too.

In the structure of these models interdependencies among variables, accumulations in levels through of flows, delays between actions and responses and non-linear relationships can be observed. In this manner, these models present rich dynamic diversity between current and future events permitting a deep learning process. However, in reference models some individual decisions are not supported from realistic actions, because it seems difficult to believe that a young adult determines his consumption plan over his full-life solving a problem which takes into account his future wealth on finite or infinite horizon. Moreover, most of these models share that the population by an age of 65 start to spend the savings accumulated during their working lives. This assumption is asserted by life cycle theory, which predicts that countries with more elderly population tend to have lower saving rates. In addition, if level of wealth in aged population tends to be null, an altruistic bequest motive cannot

be considered. These assumptions contrast with some evidences displayed in different developed countries. In spite of theory manifests, Miles examines data for six of the major economies, where the average of saving rate for the population over 65 is marginally higher than the average of saving rate for the generation aged from 37 to 47.

In this paper, we present a model to study the self-reinforcing and self-correcting feedback process between governmental policies and actions of rational individuals which act in an economy. Specifically, we construct a base model which captures feedback process from the rules of interaction among households, firms and government. In the model, each actor takes decisions that affect other people's. Households choose a consumption path as a percentage of their net income. They accumulate physical and human capital which could both be transmitted from generation to generation. Firms determine wages and the interest rate. The government finances its expenditures through taxes and balances public budget by trying to reach policy targets. The results simulated are not a prediction but rather a base with which alternative assumptions can be compared. Particularly, we seek to trace the answers of the agents in economy by exploring other possibilities related to changes in population structure. These shifts could be generated by agents themselves or due to exogenous shocks.

This paper is organised as follows. The basic model structure is described in section 2. The results of simulation, that base model structure implies, are discussed in section 3. Different scenarios are detailed and explored in section 4 and conclusions are drawn in section 5.

## **2. THE BASE MODEL**

In its basic structure, the model depicts a closed economy in a way that is consistent with certain general features of European economies. In Winch et al. (2002) we can find various reasons about the pros and cons of generic models. Our position could be justified as long as we pretend a model based on causal structure which is sufficiently accepted in economic literature. The study focuses on a general socio-economic problem concerning various European countries. Therefore, the model does not contain

particularities of specific regions or countries. Using empirical evidence we made its calibration but it does not fit to the data in the same way a time series model does.

The simulation model has a 100 years time horizon that could begin in 1990. The horizon has been selected because it allows us to improve the choice of parameters. In addition, we are able to capture the short and long term effects of different policies. Most part of structure in the model is endogenous. Generation of economic output, wages, interest rate, consumption of households and government, human and physical capital, public debt, public transfers to population are linked by means of causal relationships without taking into account external factors. The model is divided into two interrelated subsystems: private and public sectors. Figure 1 and 2 illustrate fundamental relationships between the agents who act in each subsystem: households and firms and on the other hand, public sector.

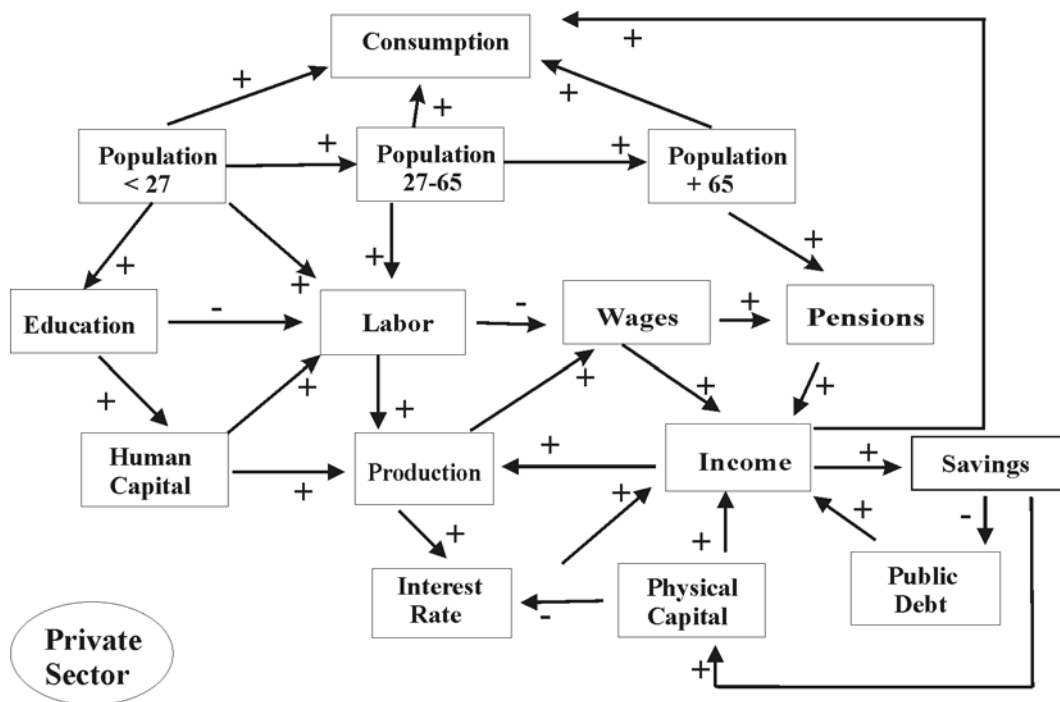


Figure 1

To study the households' actions, we are going to consider overlapping generations of adults. We made this choice in order to desegregate the population by age, which is an

important variable in model development. Individuals will be clustered for six periods of life, from age 17 to age 77, each of them representing ten years. The size of a generation increases over time following the corresponding rate of population growth. This way, for each generation, we could obtain sequences of data in relation to wages, labour supply, consumption, save, wealth or human and physical capital. At the same time six generations are alive and it allows us to be able to get intergenerational links, particularly we can internalise different aspects as links between human capital and labour supply, distribution of wealth or public subsidies by age.

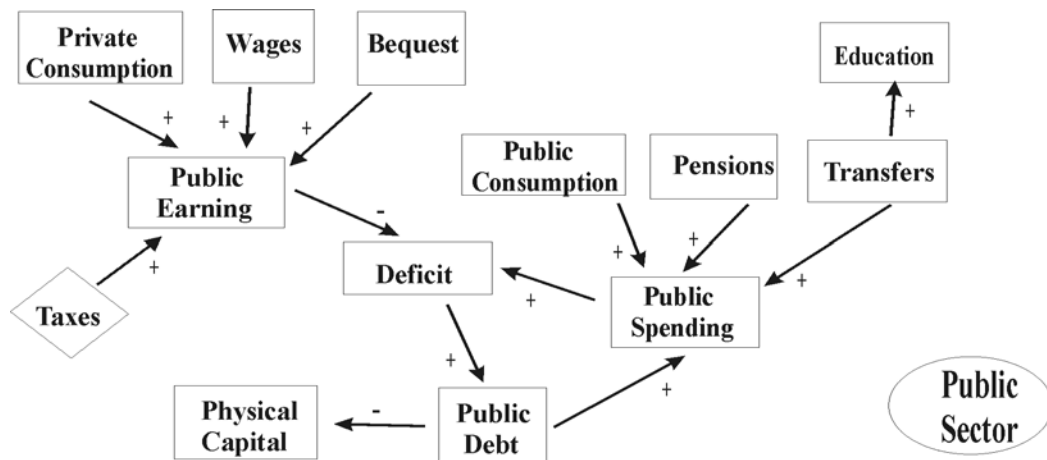


Figure 2

When a young adult enters in the model, i.e., he is 17 years old, he has an endowment of human capital, received from his parents or by schooling, which coincides with the current level into his generation. This individual can allocate his time to current production or to human capital accumulation, i.e., education. In the spirit of Lucas, the accumulation of human capital does not follow the same dynamic than the accumulation of physical capital, since human capital accumulation is a social activity, involving groups of people in a way that has no counterpart in the accumulation of physical capital. When a young individual devotes the fraction  $u(t)$  of his time to current production and the remainder  $1-u(t)$  to education, the growth of human capital,  $h'(t)$ , follows the equation

$$h'(t) = h(t) a (1-u(t)),$$

assuming a linear behaviour. Then, if no effort is devoted to education, human capital stays constant. The former equation illustrates a positive feedback loop and it captures the idea that learning is more productive if an agent interacts with more knowledgeable people.

The time invested in education will improve the own efficiency of labour and the contemporaneous average level of human capital. Specifically, this contemporaneous average level of skill will contribute to raise the productivity of all factors of production. It is denominated by Lucas as external effect related to internal effect directly determined by human capital. In this point, since human capital influences the effective workforce in production and technology, it is important to emphasise that human capital accumulation is partly responsible of economic growth that the model presents.

The individual's decision on whether to prefer education or to spend his time to current production will depend on different factors: current public transfers to education, future expected net wages as well as current net wage into his generation, which represents an opportunity cost. The effect of future expected wages on current decision can be evaluated by observing each generation's current wages.

The model does not contemplate the time a worker devotes to leisure and in second, third and fourth period of live every individual will spend his time in current production. When an individual is in the generation aged from 57 to 67, devotes its time to current production and retirement. Finally, in the sixth period of live, every individual is full-time in retirement. The model does not contemplate funded pension schema and when an individual is retired he receives social benefits from government. The state pension is the same for everyone in retirement. Its amount depends on the average level of current wages and it is not related to past contributions subscribed during working life. This possibility is accurate for most European people.

All workers are identical, but each generation has a different level of skills assuming that some factors, for example learning by doing, job training or even the age, change the ability to learn on the job. For each generation of workers, labour supplied in

efficiency units hinges on their level of skill. The effective workforce in production is the sum of the skill-weighted man-hours devoted to current production.

To obtain the skill-efficiency relationships we combine results from econometric studies with micro evidence on the link between wages by age and the time devoted to education. Miles provides a function to specific a part of labour productivity taking into account the age, which peaks at an age of 42 and falls 60% at an age of 70 from yhe value got at the age of 42. Figure 3 shows this function.

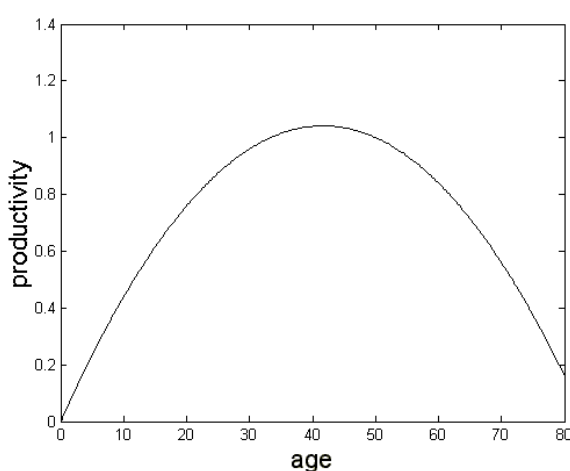


Figure 3

A similar function is used by Bouzahzah to explain partly the effect of age on productivity. Hansen (1993) estimates that efficiency units of labour peak at about 45 years old and fall substantially by age 60. However, wages per hour worked would not fall with age until the individual is close to retirement. This possibility is consistent with the results of Meghir et al., (1996) who find that hourly wages for generations continue to rise until 56.

At each time, existing levels of physical capital and labour supply in efficiency units are used as input in production. Physical capital accumulation is standard and it depreciates at a constant rate. The households are owners of stocks, which are supplied to firms. Competitive firms rent service of labour and physical capital to produce a good, the price of which is normalised to one. Interest rate and hourly wage for each generation are obtained by firms to solve a profits maximization problem. Then, the private factors



are paid according to their marginal productivity and consequently, output will be exhaustively distributed. In addition, the interest rate will be endogenously determined by the domestic capital stock which, in a closed economy version, can be expressed as a function of the levels of wealth for each generation at each point in time.

All the exchanges in the model are goods by goods and therefore, it does not contemplate monetary matters. Households leave their wealth level to its children when the first ones are 77, i.e., when they die. In these cases, it is assumed that their children belong to generation from age 37 to age 47. Introducing an altruist bequest motive we ameliorate the loss of wealth at old ages respect to what life cycle theory suggests.

The government issues bonds and levies taxes on labour earnings, capital income, physical capital inherited and consumption spending to finance its spending. Five types of public expenditures are distinguished: education subsidies, social security benefits, public consumption, interest on public debt and transfers per age. Issuing one period bonds the government finances its deficits. Households consider bonds as perfect substitutes for physical capital and they are paid at the same interest rate.

When the government uses public debt to finance itself, the assets accumulated by households at each date minus debt public will be equal to amount devoted to capital stock used in domestic production. The government budget constraint can be balanced by tax adjustments, changing the amount of public debt, diminishing public consumption or public transfers per age. The aggregated public consumption is determined endogenously and it is considered to be proportional to output. However, this ratio can change in order to balance the public budget. In addition, the evidence seems to show that tax rates change rather slowly and tax decisions made today will persist for some time. This rule imposes stability for the tax structure over time and that inertia policy is incorporated in the model.

Depending on whether an agent belongs to one generation or to another he receives a different wage due to the differences of skill into each generation. Agents who are partly working receive a proportion of corresponding wage. For each generation, net

labour income is the product of labour supply in efficiency units and the post-tax real wage per unit.

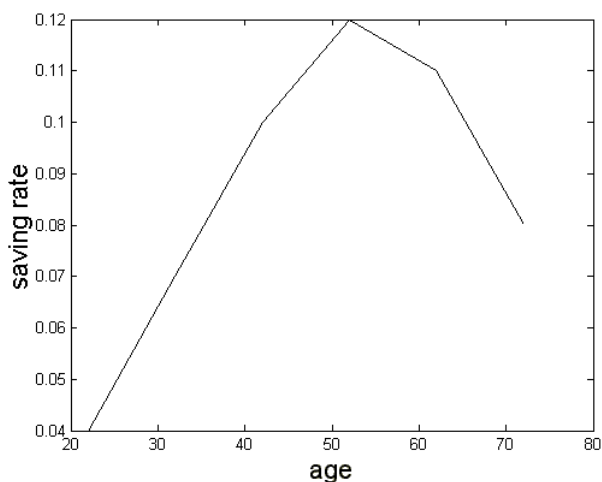


Figure 4

Household's consumption is constrained by his after tax labour income, state pensions and net capital income plus public transfers. We consider that every household uses a fraction of their net income to consumption and the remainder is devoted to save. This assumption does not contrast with that of the existing literature. However, the model explores an endogenous non-linear function to determine the impact of age upon saving rates. This function peaks at about 52 years of age and falls slowly by age 77 (see figure 4). Observing panel data, for example see, European Community Household Panel, we can find great differences between the function adjusted and the patterns of behaviour revealed for these series. In them, it is obvious that the saving rates present strongly fluctuations. Trying to replicate the time series properties, for each generation, saving rate will be approximated by a random walk process with annual shocks. The different saving shocks are independent of each other. Therefore, these uncertainties magnify the saving rates effects on the economy and lead to aggregate fluctuations, which arise in empirical results.

### **THE RUN BASE**

This section describes the choice of parameters and exogenous variables which are need to run the base model as well as to obtain its results. It is often argued that one of the main disadvantages of generic models is the difficult to calibrate some parameters. This fact is especially true when a model uses skill levels on which there is not consensus in

literature. Using certain results reached by Bouzahzah, we will accept values of parameters and exogenous variables when they allow us to obtain a certain level of annual economic growth over a sustained period of time.

The election of the parameters not related to human capital is simpler. The population stays constant during the whole simulation horizon. The initial value of population is split by generations at same proportion. On contrary, initial value of physical capital is selected taking into account the age. Both are selected to obtain an adequate interest rate during the simulation. The physical capital depreciate rate is set to 0.04/years, which is practically a standard datum in industrialised economies. The number of available hours that a worker has for a year is determined by

$$8 \text{ hours/day} \times 5 \text{ day/week} \times 48 \text{ week/year} \times (1-u)$$

where  $u$  is the fraction of time devotes to education or retirement, which is only possible for young generation and for the cohort from age 57 to age 67.

The amount of pension benefit is set to 0.8 of the average level of current wages after taxes. The individuals retire at age 65. The production function is adjusted via Cobb-Douglas with a constant technology parameter, which is set to 8; the share of capital income and Lucas externality, which affect to production function, are set to 0.3 and 0.1, respectively.

In the model there is two aspects related to age: relative efficiency on labour and relative function of savings. The first is estimated using an equation that combines an annual productivity function and a function that transforms educational investment into labour efficiency. Saving rates are adjusted to be normally distributed with a mean equal to the average of saving rates in European countries following data shown in Miles. These random effects are assumed to have a very small standard deviation, just 1%.

Time spent in education captures its dependence respect to two separate factors. A factor collects opportunity cost assumed by a student which is obtained by comparing current wage in generation from age 17 to age 27 with the maximum of current wages in the rest of generations. The other factor is expressed as a function of public transfers

to the youngest generation. When there are not public transfers, the second factor is null, but when transfers increase, time spent in education can reach 1/2 of available time in that generation if we join both factors. This treatment assumes that a student could complete its university studies. The function selected assumes that young people study when they have perspectives of future opportunities and public transfers tend to increase the desires of education. Without public transfer, educational cost will be supported by parents, who belong of 47 to 57 aged group.

At this point, we think that is important emphasise that in recent empirical investigations there is a growing scepticism on the role of human capital to explain economic growth. Data seem to show that countries with strong educational investment do tend to be more productive than others. But it is not true that productivity rises over time with human capital in the way suggested by the theory. In fact, some authors, for example De la Fuente et, al. (2000), seek reasons to explain why the contribution of educational investment to productivity growth may be negative. In general, it is possible to say that the theory does not have a widely consensus about real impact of human capital on economic growth, at least about its quantitative influence, and in addition, it seems difficult to estimate both human capital stock and its accumulation. Actually, authors as Jones et, al. (1993), Stokey et, al. (1995), consider that accumulation of human capital follows the same structure than physical capital. Assuming this panorama and as we have already said, in this paper, human capital accumulation follows the theory develops by Lucas.

In the base model, initial value of human capital level and the parametric specifications of its flow are chosen to obtain certain stability on the economic growth process. Successive first-order delay determine human capital in the rest of generations. Knowing human capital in each generation, number of available hours and the equation of relative efficiency, we can find labour supplied in efficiency units which is required to determine output and, of course, wages.

An important part of model building is related to maintain public finance equilibrium. It implies that the model has to include all different accounting cases that government can find. The government's business plan must be successfully. The public sector has a

constraint on public debt which cannot be superior to 6% of GDP taking account the Maastricht's criterion. Moreover, we must remember that we are studying a close economy and then it is not possible to obtain foreign saving. During the simulation, the plan has to be able to finance the pensions and certain percentage of public spending. It is necessary to take into account that if there was a public debt from previous period, the government must pay that debt and the amounts of interests. Also, we assume that government realizes that education constitutes a way to generate economic growth sustained over time and, hence, it cannot forget transfers for education. The model reflects that government's actions must foresee these facts and, in addition, it has to give responses as soon as possible to undesirable situations.

To accomplish the plan, the government will take certain measures. It turns out that public consumption is adjusted as percentage per capita of output and it can oscillate between a maximum and a minimum value. This approach suggests that temporally a variety of public expenditures can be cut, infrastructure investment instead social infrastructure. Similarly, public transfers for education can be modified as a function of public earnings minus the amounts devoted to pensions and public consumption. To this respect, when public budget presents deficit, government could increase taxes. For simplicity, we assume government can only modify the consumption tax, which at the beginning of simulation is set to 14%. Physical capital inherited and capital incomes are taxed at rates 0.06 and 0.18, respectively which coincide with tax in Spain. The base model only comprises transfers for education. Nevertheless, when public earnings minus public spending is positive, which could arise in expansion periods, transfers to other generations are allowed.

Under these decision rules the base model can be simulated. The results of simulation are shown in next section together with results of different scenarios. However, it seems important to emphasise that at the beginning of simulation we have assumed that an initial level of public debt exists. Behavioural hypotheses in base model and initial conditions permit to eliminate that initial level of debt over the course of the next year and then, public debt stays null over time of simulation. During that period, taxes do not suffer any changes and they are able to finance public spending.

## SCENARIOS

Before the implementation of scenarios, the system dynamics was submitted to extreme conditions and validation of behaviours. Structure validation tries to prove that the agents follow the rules established. It is necessary to note that, the running can fail when the households' savings jointly with public earnings do not permit to balance public expenditures taking into account that taxes cannot have a continuum growth. The economy crashes because in a closed economy is not possible to consider foreign saving. Accepting this fact and sensitivity results, we decide to simulate three scenarios. Each of them introduces new assumptions in base model, which affect to population structure. To perform the simulations we use Powersim Constructor 2.51. In all cases, the base model variables trajectories shown in figures 5, 6 and 7, are marked with number one.

- Changing population structure.

The base model assumes that population stays constant. However, it seems a model desirable feature that it captures realistic situations. In this perspective, we pretend to study three possibilities. They consist a system dynamics with more population than base model. New population is obtained from two different sources: an improvement in health care and an immigration process.

An improvement in health care will stimulate that aged population abandon the system slower than in the base model. To adapt the base model to the new situation, we consider that the level for generation from age 67 to age 77 contains population over 67's, whereas the remainder of parameters are not modified. The evolution of variables are marked with number two in figure 5. Third scenario supposes that system dynamics absorbs exogenously young population. An immigration process could contemplate this circumstance, which is a real and current phenomenon in many developed countries. To incorporate new assumption in the model, the rate of entry to the system is modified and the rest of parameters keep the same values than base model. Evolutions of variables are indicated by number three in figure 5. Finally, the fourth possibility combines both second and third situations. We use number 4 to mark variables trajectories.

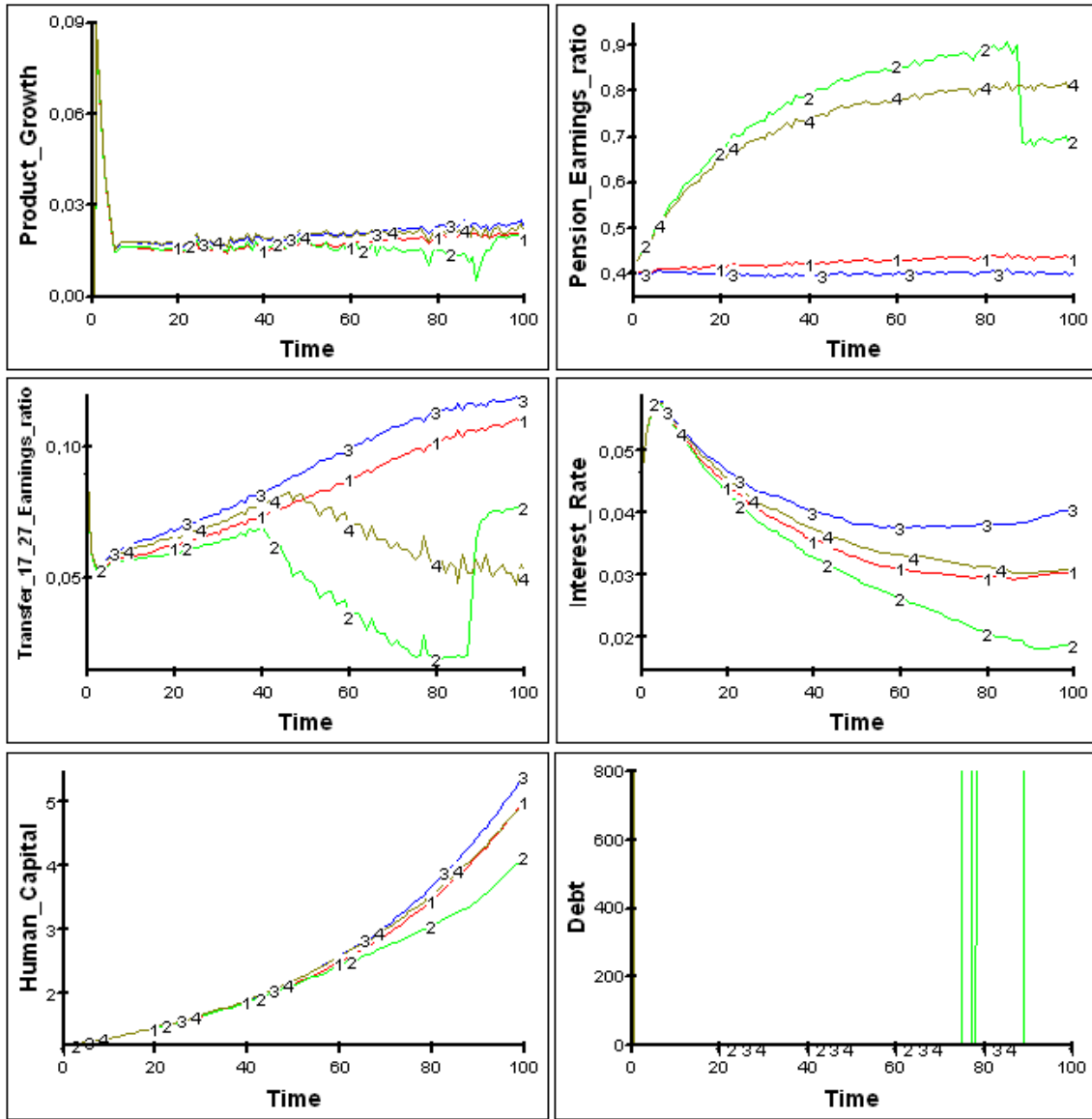


Figure 5

In all cases, the system dynamics is embodied in different perspectives and the patterns of behaviour of the variables are affected. The differences regarding trajectories are more similar in the short-term than in the long-term. The immigration process in isolation provokes a slightly improvement on growth rate and it generates an increase in each generation wages increase. As a consequence, expected returns are higher and young population prefers education. Moreover, since death rate does not change while entry rate remains stable, the amount of pensions stays practically constant and government devotes an important fraction of its earnings to subsidize education. Both effects generate an important growth of human capital. In contrast, the increase in pensions starts soon to absorb an important fraction of public budget when aged

population is majority. It provokes that public debt increases, consumption tax grows and public transfers for education fall drastically. In each generation, wages decrease and as a consequence, the amount devoted to pensions decreases. In the long-term, high taxes jointly with low pensions permit to reach a public budget equilibrated. Figure 5 shows trajectories of some selected variables.

The immigration process compensates ageing in population and the distinction between the results of third scenario and the base model are irrelevant in respect to growth rate, interest rate, taxes and wages. However, it is possible to observe as public earnings are distributed in a different way in both scenarios. The differences exhibited are due to population structure. When the system has more population, public earnings are higher, but the system also supports more aged population and, consequently, social benefits grow. The government has to pay irremediably pensions and, hence, public educational investment decreases in the long-term because both variables have the same source of financing.

- Improving the fertility.

We consider the same situations analysed on previous scenarios but we add a new governmental policy, which tries to improve the fertility rate. The governmental measure is developed on two aspects. On the one hand, working mothers would access to a new subsidy and, on the other hand, mothers or fathers would devote more time to children care. Obviously, these situations contemplate a partly endogenous population growth. Trying a simplification, we assume this measure will only impact on generation from age 27 to age 37. As above cases, the policy will affect to labour market and to public budget, since temporarily less people is devoted to production and the government will have a new transfer, which will provoke an increase in aggregate public expenditures.



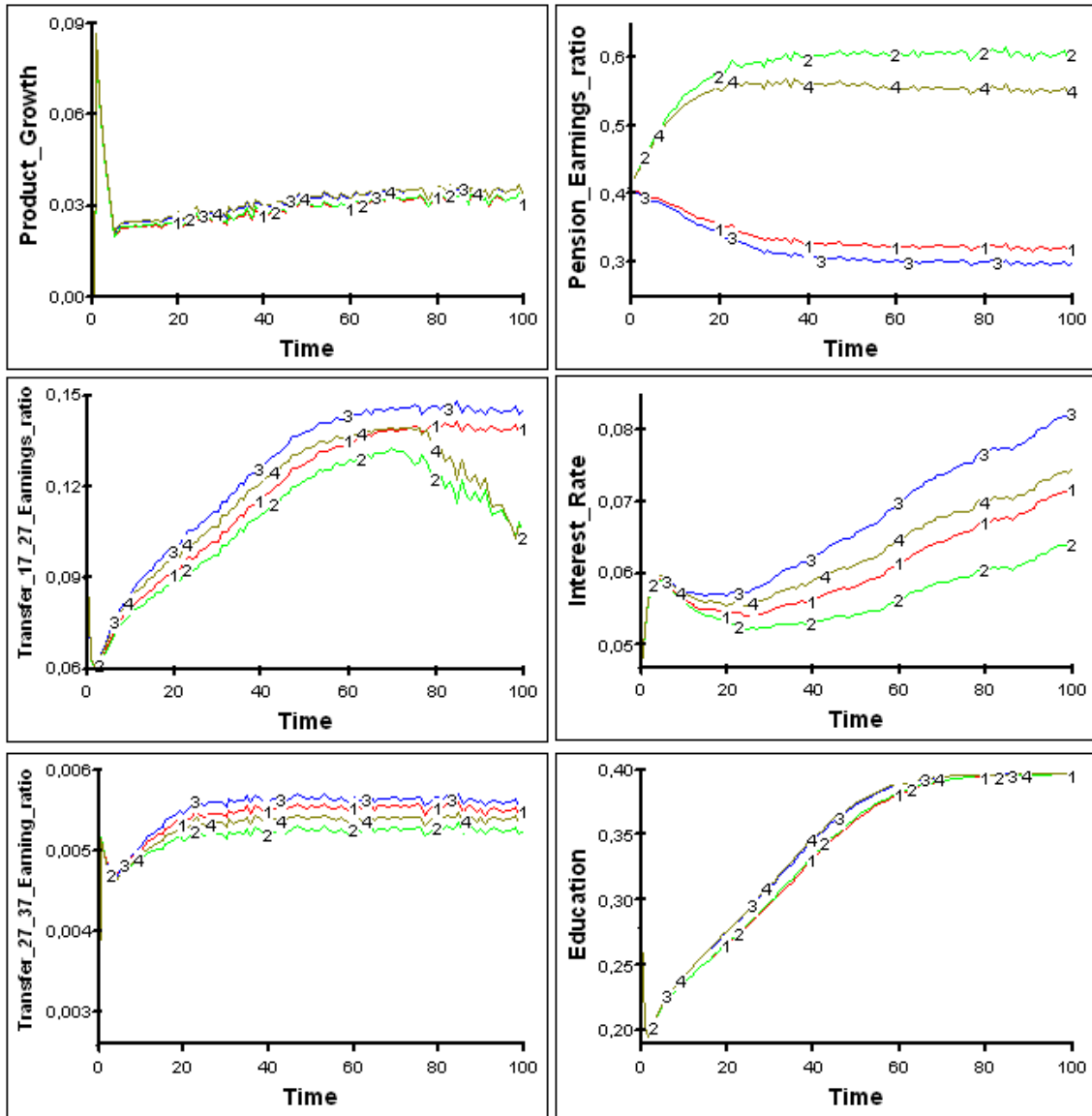


Figure 6

Assuming that the measure is effective on population, it has not a decisive influence on product growth, human capital or public debt, since these variables present similar patterns of behaviour on the different assumptions about population structure. The government does not have problems to finance its budget and taxes stay constants. The simulations show a output gradually increase and how the saving rates depress. This in turn, the interest rate increases. That growth depends on population structure and it is more evident when the system supports more young people. In contrast, this growth is practically stable when exists ageing in population. Public consumption rises and time devoted to education peaks close to half horizon and by then it stays practically stable in the long-term. Educational public transfers tend to stays stables and it varies slightly

among scenarios fundamentally in the short-term. Consequently, the new policy will not have any influence on wages. Figure 6 compares different profiles of variables obtained in these situations with the ones observed in the base model.

If we observe the evolution of public transfers received for the cohort from age 27 to age 37 we can verify that the model respond correctly to new policy since these transfers are greater when less young people is in system. It seems also important to emphasise that the economic growth rate that the different situations contemplate is due to educational investment because the share of physical capital in product decreases stronger in the long-term.

- Postponing retirement.

This position assumes that an individual can decide to stay in labour market until reaching seventy years. It seems reasonable that the decision cannot be adopted for all members into aged generations due to motives of health for them. To model this option, we consider that all individuals of 57 to 67 aged group stay in labour market. Obviously, the measure proposed by government tries to diminish the pays of social security benefits. Once again, this policy is studied jointly with the assumptions of first scenario and they can be similarly distinguished in figure.

The direct effect of this policy is a slow growth of output due to the increase of activity in labour market. The pension-public earning ratio enhances and education presents a faster growth. The interest rate decrease rather slowly and consumption grows into each generation. When population leaves later the system, it is interesting note that level of wealth is practically concentrated into generation from age 67 to age 77, since that generation accumulate 40% of total level of wealth. In addition, the level of wealth for cohorts from age 37 to age 67 reaches 60% of total level and, consequently, the youngest are the poorest. Again, consumption tax does not change during the simulation. Results are presented in figure 7.

#### **4. CONCLUSIONS**

Our purpose was to build a computable and generic model based on causal relationships among agents, which act in an closed economy. We describe the decision rules of each

actor, which lead to patterns of behaviour. Education is an important variable in the model to explain partially the endogenous economic growth that the model presents. Uncertainty was implemented by considering households' saving rates are normally distributed.

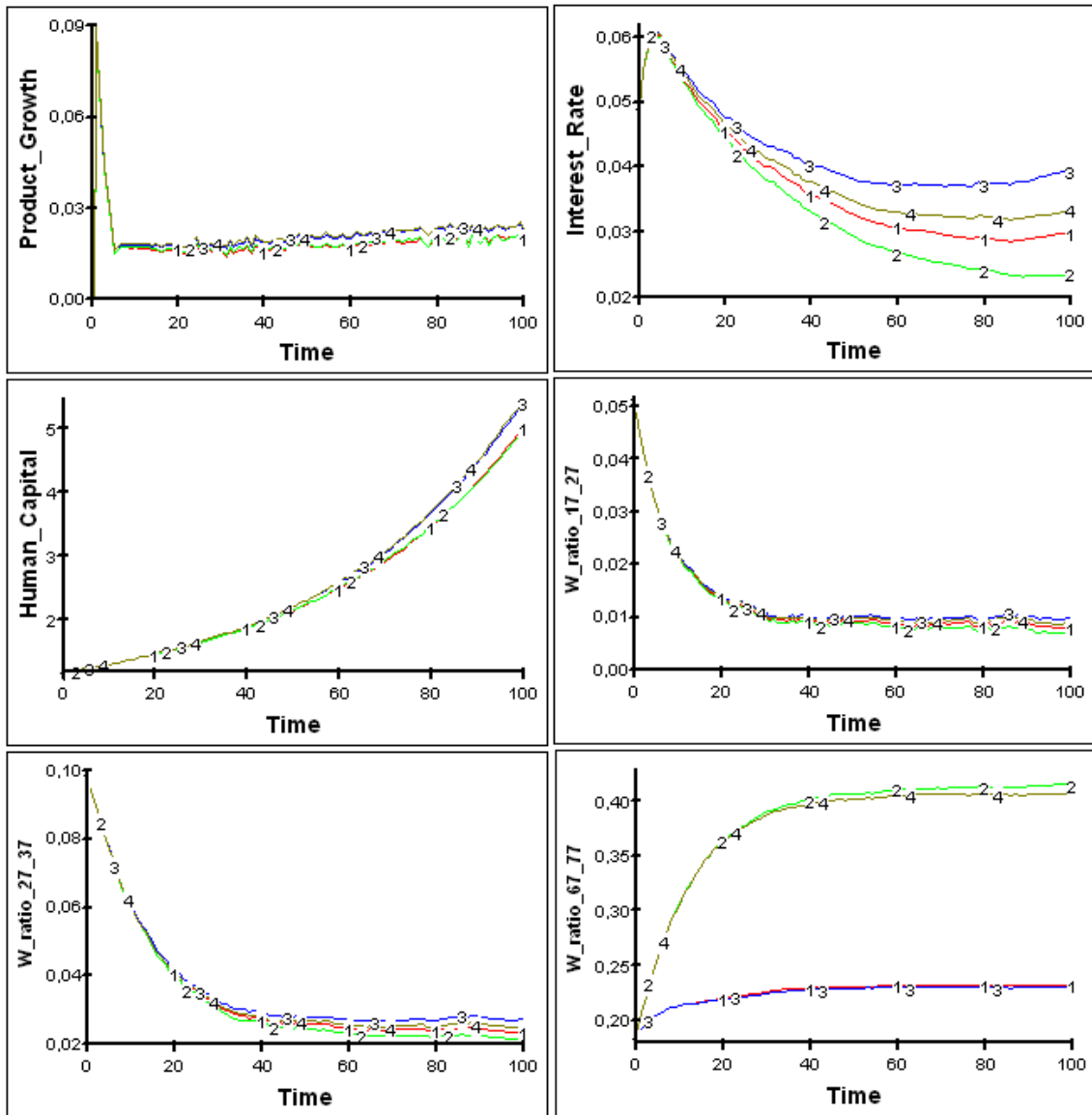


Figure 7

A base simulation model was submitted to extreme conditions to test the robustness of parameters and the agents' action rules. This study is important because there is no consensus on parameters that affect to accumulation of human capital. There is even disagreement on its own accumulation. Further simulations were used to assess the effects of different policies related to changes on population structure. An immigration

process, an improvement health system or both simultaneously, were simulated. But also, the former possibilities were analysed together with governmental actions, which lead to increase fertility rate or to decrease public spending.

The simulations give reasonable results. Many variables present similar qualitative behaviours though there are some quantitative differences on scenarios. That possibility can be observed on wages or public consumption, which both depend on output and, as a consequence show exponential growth. An extend educational policy also induces a strong growth of human capital on all model's specifications, but that growth is smaller when an immigration process is considered. On the contrary, other variables exhibit a different mode of behaviour to the changes analysed. Such as the interest rate, public debt or physical-product ratio.

We find a small economic growth in all model specifications and a rate of interest quite sensitive to changes in population structure and policies. The results simulated suggest that governmental policy must be driven to a constant and progressive enhancement of education and fertility rate. Its effects on growth and taxes are opposed to those generated by ageing in population.

Obviously, the analysis proposed can be improved in different ways. In first place, the model does not totally explain the expected rates of economic growth. In the short-term, we can compare the percentages got by the model with current real data in European economies. The most favourable case analysed by the model gets a growth rate close to 0.02% if we eliminate initial conditions. At this point, to explain better the real process of growth in economies, numerous authors agree that the models must incorporate both an intensive educational policy and assumptions about exogenous growth. In second place, the model presents limitations and simplifications. It does not internalise processes such as immigration, birth rate, and other social and economic structures, which could permit further investigations. We agree with Meadows et al. (1972, p. 21) when they wrote: "The model we have constructed is, like every other model, imperfect, oversimplified and unfinished". Finally, the functions adjusted, initial conditions and parametric values could be improved if the characteristic of generic model is eliminated by trying an approach to some country.

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