GROWTH AND POPULATION AGING: THE SPANISH CASE

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ABSTRACT

In this paper we present a projection of the future evolution of the population and of the dependency ratio in Spain. Several definitions of dependency ratios are derived, all with more economic content than the simple definition of this concept. Finally, the implications of these demographic changes for optimal consumption and saving behavior are analyzed by using, as analytical framework, a growth model with exogenous technical change.

KEYWORDS: Dependency Ratio, Neoclassical Growth Model, Savings Rate
JEL classification number: J11, J14, D91.

RESUMEN

Este artículo presenta proyecciones de la población y la tasa de dependencia de la economía española basadas en escenarios alternativos. Los cálculos hacen uso de varias definiciones de la tasa de dependencia con mayor contenido económico que la definición más simple de este concepto. El artículo también presenta las implicaciones de cada una de las definiciones alternativas en función del escenario adoptado.

PALABRAS CLAVE: Tasa de Dependencia, Modelo de Crecimiento Neoclásico, Tasa de Ahorros.
CLASIFICACIÓN JEL: J11, J14, D91.

1. INTRODUCTION

Recent significant demographic changes, as well as a poor performance of the economy in job creation give reason to doubt the long run sustainability of the Spanish public pension system. A severe slow down in population growth, a low absolute level of the participation rate and high permanent unemployment levels may result in significantly altering the percentage of total population that is dependent on the net transfers generated through taxes levied on the working population. Economists have looked many times into the economic effects of population growth and changes in the dependency rate. The differencial effect of funded and unfunded Social Security schemes has been the main issue involved in their analysis, using as economic tools the overlaping generations model[1]. The approach taken in this paper is somehow different. We compute and forecast dependency indices that measure the balance between needs and resources in an attempt to anticipate future burdens posed on the working population. In this model we do not consider the fiscal system chosen to finance current and future pensions. We find it interesting -as an exercise- to derive the long run optimal reaction in consumption and saving behaviour to changes in said dependency ratios. These demographic shocks transmit disturbances into the economy through their effect on optimal consumption and savings plans. We calibrate the growth model to the Spanish economy so as to analyze the steady state rate of cosumption and savings as well as the dynamic transition from one steady state to the next. In this model we can also check if the optimal savings path requires an increase or a decrease of the capital ratio.

The paper is organized as follows: section 2 explains our demographic projections in relation with previous studies; section 3 defines and computes alternative dependency ratios; section 4 develops an analytical framework with which to perform the simulation analysis; and finally, section 5 presents some concluding remarks.

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[1]For a recent example of this research Auerbach and Kotlikoff (1987).

2. DEMOGRAPHIC PROJECTIONS

For any model attempting to explain the long-term behaviour of an economy, it is extremely relevant to know the evolution of population as well as that of the associated dependency ratios. The lack of available demographic studies at the level of disaggregation required for this article when this project started forced us into making our own projections.

2.1. PREVIOUS STUDIES

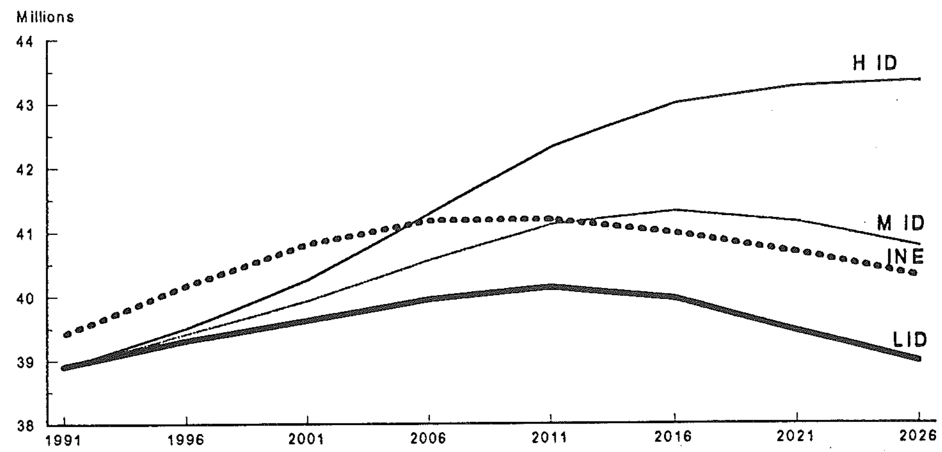
In this section we review three available studies from two different Spanish institutions and from a European international institute.

The INE (National Bureau of Statistics) calculated in 1987 projections of population until the year 2026, although the projection by age only extends until the year 2010. It assumed constant mortality rates fixed at the 1980 levels and two different scenarios on fertility rates: (i) a decreasing trend reaching 1.73 in 1983, which was kept constant for the rest of the projected period, and (ii) the 1980 value of 2.12. Net migration was considered zero for all periods and scenarios. As shown in figure 1, by 1991 INE's projection was off by 600.000 persons. Not only did mortality rates continue to decrease, but fertility rates dropped to 1.30 by 1991.

The projection made by the Instituto de Demografía (ID) became available in March 1994 and extended for a period ending in the year 2026. These estimates were based on three scenarios on mortality, calculated using the Princeton benchmark model, and three scenarios on fertility. Mortality rates were assumed to be slightly lower and fertility rates are assumed significantly higher with respect to the observed 1991 level. Figure 1 which displays the ID and the INE projections is deserving of some comment. Only the low ID projection (LID)

shows a lower level of population predicted for the year 2026 than the INE projection. The low and intermediate ID scenarios, together with the INE projection show a peak at different years between 2011 and 2016. Only the high ID scenario shows no negative population growth over the next twenty five years.

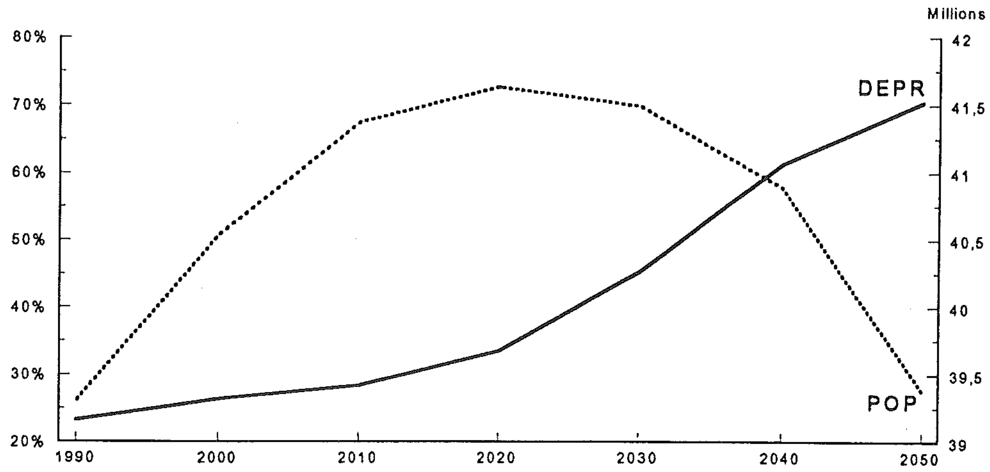
Figure 1.
TOTAL POPULATION
INE (87) E ID (94)



Source: INE (1987), ID (1994)
INE: INE projection (1987)
HID, MID, LID: High, Medium, Low Scenarios, Instituto de Demografía projections (1994)

Last year the International Institute for Applied Systems Analysis (IIASA) published alternative demographic scenarios for 20 large countries. Three alternative hypotheses on fertility, three on mortality and three on migration were used, and 8 scenarios out of the possible 29 selected. Their so called average reference scenario for Spain, with the implied dependency ratio, measured as the ratio between persons aged over 65 and persons aged 20-65, is shown in figure 2. As in some of the scenarios of the other projections, we find that the trend increases until the year 2020, and decreases afterwards, returning to the starting level by the year 2050. The implied dependency rate is alarming, reaching a final level of 70 percent of the population between the ages 20-65.

Figure 2.
POPULATION AND DEPENDENCY RATE: IIASA(1994)



POP: Population projection in millions.
DEPR: Population over 65/ Population between the ages 20-65 (in percentaje).
Source: IIASA (1994).

2.2. OUR PROJECTIONS

The aim of extending the length of the demographic projection, together with the lack of data on population by age groups for computing dependency ratios, prompted us to elaborate our own projections on population. In doing so, our assumptions intend to fulfill two objectives: first, to permit the comparison of our basic hypotheses with the corresponding values observed in the past; and, second, to establish limits on projected tendencies based on the most recent experience.

The initial structure of population is taken from the 1991 Population Census. Age groups are classified in five year intervals. With respect to mortality rates, we maintained the levels corresponding to 1985. The projected reduction in mortality rates used by ID seems excessively optimistic. In addition, the low rate of increase of life expectation in recent years

leads us to think that there might be a limit to the reduction in mortality rates, and that we may be close to reaching it.

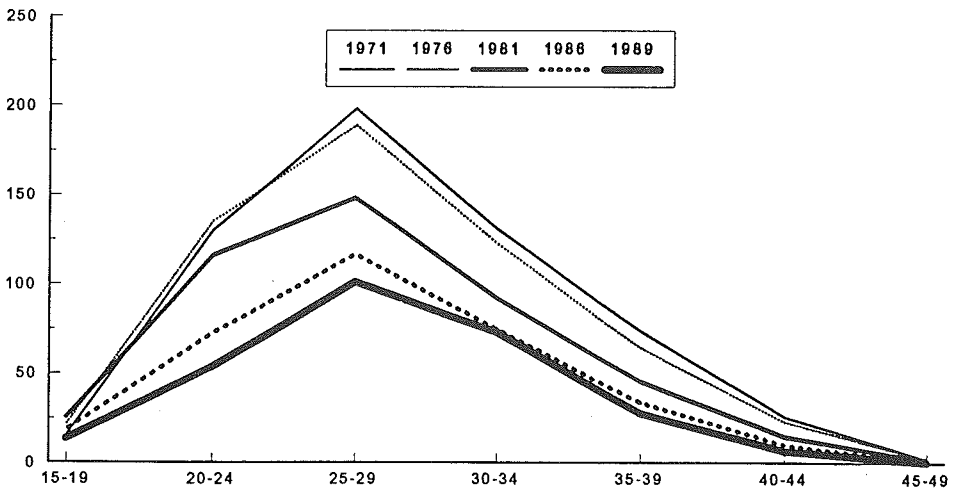
It is well known that the crucial elements influencing population projections are the assumptions made on fertility rates. Male rate at birth is assumed to be equal to 51.77%. In that respect, we used three different hypotheses: Scenario I, the most optimistic case, is obtained as the average of the fertility rate structure corresponding to the 1980-90 period; Scenario II is constructed by using the average of the second half of the eighties -the 1985-90 period-; and Scenario III uses the 1989 structure as the pattern for the projected period.

As shown in figure 3, fertility rates have dramatically dropped in Spain over the last twenty years. The 1989 curve, corresponding to Scenario III, assumes a value of total fertility equal to 1.34. Figure 4 presents the forecasted evolution of population, using the three alternative assumptions on fertility. Scenario III, the most pessimistic, shows that if the 1989 fertility rates were maintained for the next sixty years, population would peak in 2008 (40 million) and would dramatically decrease, reaching 30 million by 2051. Scenario II, based on the average fertility rate corresponding to the second half of the 80's, shows a peak in 2011, with the total population reaching a value close to 38 million by 2051. Scenario I, the most optimistic, depicts a flat area from the year 2011 until 2036, with a slow reduction in population from then on.[2]

Figure 5 displays the dependency rates derived from our projections. It is interesting to notice that the dependency rate calculated by using the intermediate ID case runs very close to our own projection and even coincides with scenario III in 2026. The dependency ratio for 2051 derived from scenario III is similar to the one derived from the IIASA study, as was shown in figure 2 above.

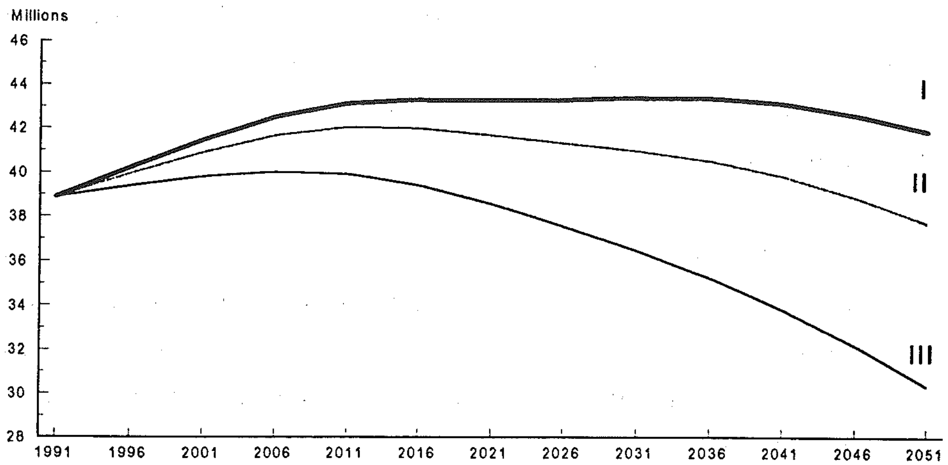
[2] Using different assumptions, De Miguel and Agüero (1986) obtain surprisingly similar results for senarios II and III.

Figure 3.
FERTILITY RATES BY AGE



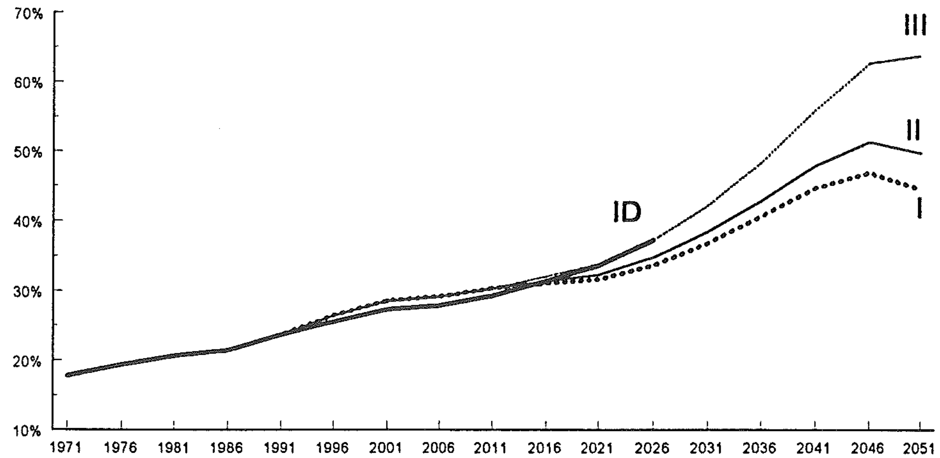
Source: INE.
Fertility rates per thousand.

Figure 4.
TOTAL POPULATION



Total Population in millions.
Scenarios I, II and III. (See the text for further details).
Source: Authors' own estimates.

Figure 5.
DEPENDENCY RATES.



Dependency rates (in percentage).
Scenarios I, II. III and ID.
Source: Authors's own estimates, ID (1994).

The inferences drawn from the intermediate cases of all the projections presented above lead us to conclude that the total population in 2051 will be close to that of 1991. However, the structure of the population will be very different; the population aged 65 and over, in relation to that between the ages of 20-65, will be around 50%, a dramatic increase.

3. DEPENDENCY RATIOS

This section assesses the burden of dependency on the Spanish economy for the 1971-2051 period. Although we are well aware of the traditional inaccuracy of long term demographic projections, we are considering quite an extended horizon, to the year 2051. This study may serve to point out the inevitable need of a future endogenous correction in order to avoid a predictably unstable trend. As time goes by, societies react to events that become more immediate in the near future by altering their behaviour pattern. Since such changes are unpredictable at the present time, we limit ourselves to pointing out the future evolution of the basic ratios under the assumption of no recovery of the past levels of fertility rates.

Dependency ratios aim at establishing a relationship between needs and resources. Total population is often used as a proxy for needs and the labor force as a proxy for resources, in such a way that their ratio becomes an indicator of dependency. A low or decreasing participation rate would financially collapse any public pension system. Participation rates are difficult to forecast because they are endogenous variables, reacting to different kinds of shock. In addition, we find this measure of dependency to be an unsatisfactory index of dependency. At least two additional factors may affect the real degree of dependency.

First, on the resource side, income may change by age, due to the income life cycle hypothesis. Earning ability depends not only on the absolute size of the labor force but, also, on the relative age composition. Taking into account the fact that the young and elderly work force tend to earn less than middle aged persons, we have weighed population by earnings. In so doing, resources may change even if total labor force is constant, due to variations in the share of newcomers or of those close to retirement in the aggregate. Secondly, to be more precise in measuring needs, we have taken into account the life cycle consumption profile. In this approach, we considered the different consumption needs according to age. More specifically, children's needs are assumed to be lower than those of middle aged persons and, in contrast, the elderly are considered more needy due to medical care costs, which grow with age at exponential rates.

Table 1 contains different measures of dependency under the three scenarios considered. They appear in panels A, B and C in decreasing grades of optimism. These definitions of dependency make use of different methods of measuring needs and resources. Columns (1) and (2) show the projected growth (in annual rates) of two measurements of resources: (i) the number of persons aged 20-65 and (ii) the same variable weighted by their

earning capacity. Under scenario I (panel A) we find a positive rate of growth from 1971 until the year 2006. Afterwards, population flattens out during the two first decades of the next century, slightly declining from then on. It is interesting to notice how the values in this column corresponding to the three scenarios are the same until the year 2006. This means that the population aged 20-65 will grow at a decreasing rate for the first fifteen years, irrespectively of the assumed hypothesis on fertility. In other words, demographic changes only affect dependency ratios with a significant lag. In contrast, the period in which the reversal of the growth trend of population is predicted is quite different in the three scenarios. In the least optimistic case (panel C), the reversal appears in the year 2006.

After making two corrections on the variable shown in column (1), we find that column (2) contains a more refined measure of resources. Of all the population aged 20-65 we consider only those willing to work, forming the total labor force. We also weigh the population by earning power according to their age, using the wage-age structure obtained from available data on family budgets.[3] Although we are aware of how inaccurate declared wages are in budget surveys, we find this corrected measure a more precise indicator of available resources in the economy than the plain labor force. It is interesting to notice that these corrections do not change the signs of the average rates of growth of the population 20-65. However, the values are somewhat greater for the corrected figures, meaning a less severe slow down on economic resources arising from the forecasted deceleration in population growth.

Columns (3) and (4) in table 1 offer two different measures of needs, the average annual rate of growth of total population and the same variable corrected for consumption patterns by respective age. Population grows at a decreasing rate in scenario I until the period ending in the year 2016, stabilizing there for a period of 20 years, and then resumes a slow reduction. In contrast with scenario I, the other two cases show a slower growth rate, a deeper and earlier reduction in the rate of growth and an earlier change of tendency towards a negative trend. Figure 4 above, shows the three projections of total population under the different scenarios. Scenario III clearly shows an unimaginable projection of a rapidly

[3] We use the survey published as the Encuesta de Presupuestos Familiares, 1991.

decreasing total population level with a final accumulated reduction of one fourth of the initial population level.

Total population, although an undisputed proxy for needs, can be corrected by different consumption patterns. More specifically, column (4) in table 1 shows a measurement of the rate of change of needs where population is weighted for consumption levels. We have assumed that the needs of persons under 20 years account for only 50% of the average consumption level of the persons aged 20-64. Similarly, the needs of the elderly -persons 65 and over- are assumed to have needs 1.34 times the average level.[4] The corrected variable shows a slightly higher rate of increase than the plain total population, reaching a maximum twenty years later in scenarios I and II. In sum, the correction introduced for needs based on consumption patterns puts forward a more difficult horizon for the coming decades.

TABLE 1 (PANEL A) Scenario I - Most Optimistic **"Dependency Ratios, Spain 1971-2051"**
average annual rates of growth

	RESOURCES: LABOR FORCE GROWTH		NEEDS: CONSUMPTION GROWTH	
	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-65	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971/76	0.64	1.22	1.08	1.44
1976/81	0.99	0.66	0.94	1.04
1981/86	1.75	1.00	0.58	0.76
1986/91	0.48	1.86	0.08	0.94
1991/96	0.85	1.38	0.69	1.06
1996/01	0.60	1.25	0.61	0.83
2001/06	0.26	0.47	0.49	0.44
2006/11	-0.20	-0.03	0.30	0.19
2011/16	0.27	-0.15	0.09	0.24
2016/21	0.28	-0.11	-0.00	0.19
2021/26	0.02	-0.22	0.02	0.23
2026/31	-0.31	-0.37	0.04	0.19
2031/36	-0.64	-0.49	-0.01	0.06
2036/41	-0.80	-0.45	-0.12	-0.06
2041/46	-0.55	-0.23	-0.24	-0.19
2046/51	0.09	0.03	-0.33	-0.35

[4] Deaton (1986) estimated this factor using a Spanish database and assuming that all individuals have equal non-medical care resources.

"INDICES OF ECONOMIC DEPENDENCE"
accumulated changes

NEEDS:	EQUAL CONSUMPTION		EQUIVAL SCALE CONS	
RESOURCES:	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971	-5.67	-9.72	1.60	-2.77
1976	-7.72	-9.10	-2.37	-3.83
1981	-7.48	-10.34	-2.60	-5.60
1986	-1.97	-8.45	2.32	-4.45
1991	0.00	0.00	0.00	0.00
1996	0.81	3.45	-1.04	1.55
2001	0.78	6.77	-2.16	3.65
2006	-0.39	6.66	-3.06	3.79
2011	-2.82	4.91	-4.92	2.64
2016	-1.95	3.65	-4.78	0.65
2021	-0.53	3.10	-4.35	-0.86
2026	-0.52	1.88	-5.32	-3.04
2031	-2.27	-0.18	-7.67	-5.69
2036	-5.33	-2.56	-10.85	-8.25
2041	-8.54	-4.19	-14.10	-10.01
2046	-9.93	-4.12	-15.65	-10.21
2051	-8.02	-2.36	-13.80	-8.50

TABLE 1 (PANEL B) Scenario II - Intermediate **"Dependency Ratios, Spain 1971-2051"**
average annual rates of growth

	RESOURCES: LABOR FORCE GROWTH		NEEDS: CONSUMPTION GROWTH	
	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-65	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971/76	0.64	1.22	1.08	1.44
1976/81	0.99	0.66	0.94	1.04
1981/86	1.75	1.00	0.58	0.76
1986/91	0.48	1.86	0.08	0.94
1991/96	0.85	1.38	0.55	0.99
1996/01	0.60	1.25	0.48	0.76
2001/06	0.26	0.47	0.37	0.37
2006/11	-0.20	-0.07	0.19	0.13
2011/16	0.05	-0.28	-0.02	0.12
2016/21	0.06	-0.35	-0.14	0.05
2021/26	-0.20	-0.49	-0.16	0.07
2026/31	-0.53	-0.66	-0.17	0.03
2031/36	-0.87	-0.79	-0.22	-0.11
2036/41	-1.11	-0.79	-0.34	-0.25
2041/46	-0.95	-0.58	-0.48	-0.40
2046/51	-0.32	-0.32	-0.60	-0.60

"INDICES OF ECONOMIC DEPENDENCE"
accumulated changes

NEEDS:	EQUAL CONSUMPTION		EQUIVAL SCALE CONS	
RESOURCES:	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971	-5.67	-9.72	1.60	-2.77
1976	-7.72	-9.10	-2.37	-3.83
1981	-7.48	-10.34	-2.60	-5.60
1986	-1.97	-8.45	2.32	-4.45
1991	0.00	0.00	0.00	0.00
1996	1.49	4.15	-0.68	1.92
2001	2.13	8.20	-1.46	4.39
2006	1.58	8.76	-2.04	4.89
2011	-0.35	7.40	-3.63	3.86
2016	-0.01	5.99	-3.96	1.81
2021	1.02	4.92	-3.91	-0.20
2026	0.83	3.20	-5.20	-2.98
2031	-0.97	0.70	-7.79	-6.23
2036	-4.12	-2.11	-11.25	-9.39
2041	-7.79	-4.30	-15.03	-11.81
2046	-9.95	-4.78	-17.34	-12.59
2051	-8.67	-3.46	-16.15	-11.36

TABLE 1 (PANEL C) Scenario III - Most Pesimistic **"Dependency Ratios, Spain 1971-2051"**
average annual rates of growth

	RESOURCES: LABOR FORCE GROWTH		NEEDS: CONSUMPTION GROWTH	
	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-65	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971/76	0.64	1.22	1.08	1.44
1976/81	0.99	0.66	0.94	1.04
1981/86	1.75	1.00	0.58	0.76
1986/91	0.48	1.86	0.08	0.94
1991/96	0.85	1.38	0.28	0.84
1996/01	0.60	1.25	0.20	0.62
2001/06	0.26	0.47	0.10	0.24
2006/11	-0.20	-0.13	-0.05	0.00
2011/16	-0.40	-0.55	-0.25	-0.14
2016/21	-0.40	-0.83	-0.42	-0.23
2021/26	-0.68	-1.09	-0.52	-0.25
2026/31	-1.01	-1.31	-0.59	-0.31
2031/36	-1.39	-1.49	-0.68	-0.45
2036/41	-1.80	-1.58	-0.81	-0.63
2041/46	-1.85	-1.39	-0.98	-0.85
2046/51	-1.28	-1.15	-1.17	-1.13

"INDICES OF ECONOMIC DEPENDENCE"
accumulated changes

NEEDS:	EQUAL CONSUMPTION		EQUIVAL SCALE CONS	
RESOURCES:	(1) POP. 20-65	(2) EARNINGS WEIG. POP. 20-	(3) TOT. POP.	(4) CONS. WEIG. TOT. POP.
1971	-5.67	-9.72	1.60	-2.77
1976	-7.72	-9.10	-2.37	-3.83
1981	-7.48	-10.34	-2.60	-5.60
1986	-1.97	-8.45	2.32	-4.45
1991	0.00	0.00	0.00	0.00
1996	2.88	5.58	0.05	2.68
2001	4.95	11.19	-0.03	5.91
2006	5.76	13.24	0.07	7.14
2011	4.99	12.77	-0.94	6.40
2016	4.22	11.10	-2.21	4.25
2021	4.29	8.80	-3.07	1.12
2026	3.47	5.74	-5.15	-3.08
2031	1.31	1.98	-8.45	-7.84
2036	-2.26	-2.09	-12.68	-12.53
2041	-7.03	-5.81	-17.71	-16.63
2046	-11.05	-7.75	-21.79	-18.90
2051	-11.55	-7.70	-22.36	-18.98

Columns (5)-(8) contain the corresponding accumulated changes of the four indices of economic dependence that can be formed by combining the two ways of measuring needs with the two ways of measuring resources. 1991 is taken as the base year. In column (8), for example, we find the accumulated index of dependency defined as the ratio between resources and needs, where the resources are the result of correcting the population 20-65 by effective participation rates and by wage differentials, and needs are measured as total population corrected for consumption age patterns. If the index grows from one year to the next, resources grow in relation to needs, and the degree of dependency falls. Looking at Scenario I, we find a lower degree of dependency for the next twenty five years and an increase from this point forward. Dependency decreases for fifteen years and starts increasing from then on. Scenario II shows a similar pattern, although with a more pronounced fluctuation. Finally, Scenario III shows a lower degree of dependency for an extended period of time, although a stronger worsening of the dependency ratio for the second half of the period under study.

4. THE MODEL

The purpose of this section is to construct an analytical framework to show the likely effects brought about by changes in population growth and dependency rates. We use a discrete version of the neoclassical growth model to derive consumer reaction to exogenous shocks in dependency rates. We analyze the transitional dynamics and conduct dynamic simulations using parameters values derived from Spanish data.

We are going to work with a version of the baseline model presented by King and Rebelo (1993)[5]. We introduce two modifications in their strategy. First, they assume that each population member supplies a fixed amount of hours of work, n. We are interested on the difference between labor force and population from a different perspective and, therefore, we distinguish between ages of the population using the dependency ratio. Second, King and Rebelo's exercise assumes that the initial situation is not a steady state and they analyze the transitional dynamics from that point to the steady state. The initial capital stock they used is such that

$$F(k^*) / F(k_0) = \sqrt{7}$$

where k^* is the stock of capital in the final steady state. We follow Cutler et al. (1991) and assume that the initial situation is a steady state deriving the transitional dynamics to the new steady state after the shocks.

The general idea is to build an economy with exogeneous technical change and to analyze the effect on consumption and capital per capita derived from changes in population growth and dependency rates.

[5]King and Robelo (1990) and Rebelo (1991) had previously studied the effects of taxation and property rights protection on edogenous growth models.

Assume that a social planner maximizes a preference function like

$$U_t = \sum_{j=0}^{\infty} \beta^j N_{t+j}^{\gamma} U\left[\frac{C_{t+j}}{N_{t+j}}\right] \qquad [1]$$

where β is the time preference rate, N_t is the population in period t, C_t is the consumption and γ is the valuation of future membership[6]. This social welfare function weights the utility of a representative individual by the size of the generation. We are assuming $\gamma=1$. $U(.)$ is a constant relative risk aversion utility function

$$U\left(\frac{C_t}{N_t}\right) = \frac{\left(\frac{C_t}{N_t}\right)^{1-\sigma} - 1}{1-\sigma} \qquad 0 < \sigma < \infty \qquad [2]$$

where s measures the concavity of the utility function.[7]

When labor force and total population are the same the capital accumulation constraint is

$$K_{t+1} - K_t = F(K_t, N_t) - C_t - \delta K_t \qquad [3]$$

where K is capital, δ is the depreciation rate and $F(.,.)$ is a Cobb-Douglas production function.

$$F(K_t, N_t) = A (K_t)^{1-\alpha} (E_t N_t)^{\alpha} \qquad [4]$$

where A will be normalized to 1.

[6] Barro and Becker (1989).

[7] When σ -> 1 the utility function becomes the logarithmic utility.

Technical progress is labor augmenting. Therefore, the model will have steady state growth when technical progress and labor input grow at constant rates.

We define the rate of population growth as n and that of productivity as g. Consequently,

$$N_t = (1+n)\ N_{t-1} \qquad [5]$$

$$E_t = (1+g)\ E_{t-1} \qquad [6]$$

We define the variables in terms of efficiency units of labor.

$$c_t = \frac{C_t}{N_t E_t} \qquad [7]$$

$$k_t = \frac{K_t}{N_t E_t} \qquad [8]$$

$$y_t = \frac{Y_t}{N_t E_t} \qquad [9]$$

The utility function can be expressed as[8],

$$U_t = \sum_{J=0}^{\infty} \beta^j\ (1+g)^{(1-\sigma)j}\ (1+n)^j\ \frac{c_{t+j}^{1-\sigma}}{1-\sigma} \qquad [10]$$

[8] Notice that E_0 and N_0 have been conveniently normalized.

The equation of accumulation will be,

$$(1+n)(1+g)k_{t+1} = f(k_t) - c_t + (1-\delta)\ k_t \qquad [11]$$

The production function can be expressed as,

$$y_t = k_t^{1-\alpha} \qquad [12]$$

However, if the dependency rate is not equal to one, which is to say labor force (L_t) is not equal to population (N_t), there are several changes we should introduce in the model. First of all, the relevant measure of consumption in the social welfare function is still consumption per capita in efficiency units. However, the relevant variable in the production function is not total population but labor force. Define Ψ as the ratio labor force over population. If we divide (3) by labor force instead of total population the budget constraint becomes

$$(1+n)(1+g)k_{t+1} = f(k_t) - \frac{c_t}{\psi} + (1-\delta)\ k_t \qquad [13]$$

where

$$\frac{c_t}{\psi} = \frac{\frac{C_t}{N_t E_t}}{\frac{L_t}{N_t}} = \frac{C_t}{L_t E_t}$$

From this equation we can derive the effects of changes in n and Ψ on the $k_t = k_{t+1}$ locus. A decrease in Ψ will lead to a reduction in the feasible level of per capita income for each k. However, a reduction in the growth rate of population will imply more consumption for a given k.

To solve this problem we need to construct the intertemporal Lagrangean

$$Max_{k,c}\ L=\sum_{j=0}^{\infty}\beta^{j}(1+g)^{(1-\sigma)j}(1+n)^{j}\frac{c_{t+j}^{1-\sigma}}{1-\sigma} + \lambda_{t+j}(f(k_{t+j})-\frac{c_{t+j}}{\psi}+ (1-\delta)k_{t+j}-(1+n)(1+g)k_{t+j+1}) \qquad [14]$$

where λ is the current-valued Lagrange multiplier. First order conditions are

$$\frac{\partial L}{\partial c_t}=c_t^{-\sigma}-\frac{\lambda_t}{\psi}=0$$

$$\frac{\partial L}{\partial c_{t+1}}=\beta\,(1+n)\,(1+g)^{(1-\sigma)}\,c_{t+1}^{-\sigma}-\frac{\lambda_{t+1}}{\psi}=0 \qquad [15]$$

$$\frac{\partial L}{\partial k_{t+1}}=\lambda_{t+1}\,(f'(k_{t+1})+(1-\delta))-\lambda_1(1+n)(1+g)=0 \qquad [16]$$

and the transversality condition

$$\lim_{j\to\infty}\lambda_{t+j}k_{t+j+1}=0 \qquad [17]$$

Plugging the first and second conditions into the third, we obtain

$$\left[\frac{c_{t+1}}{c_t}\right]=\bar{\beta}\left[\frac{f'(k_{t+1})+(1+\delta)}{(1+g)(1+n)}\right] \qquad [18]$$

where

$$\bar{\beta}=\beta\,(1+g)^{1-\sigma}(1+n)$$

This equation, together with the capital accumulation equation (13), defines the dynamic system.

Assuming $c_{t+1}=c_t$ in equation (18) we obtain the steady state capital in efficiency units of labor as

$$k^{*}=\left[\left(\frac{(1+g)^{\sigma}}{\beta}-(1-\delta)\right)\frac{1}{1-\alpha}\right]^{-1/\alpha} \qquad \textbf{[19]}$$

which does not depend on n or ψ. Therefore, if $\gamma = 1$, neither changes in population growth nor changes in dependency rates will affect the steady state k^*.

By contrast, steady state consumption in efficiency units c^* will be affected by population growth and dependency ratios because

$$c^{*}=\psi\left[k^{*(1-\alpha)}-(1+n)(1+g)k^{*}+(1-\delta)k^{*}\right] \qquad \textbf{[20]}$$

It is interesting to notice that recent demographic changes have two opposite effects. First, an increase in the index of economic depedence reduces consumption because, as shown in equation (20) above, consumption is a proportion of output minus investment that is smaller than one when the labor force is smaller than the total population. Second, when population growth decreases, the investment needed to maintain the level of capital per capita is reduced. This liberates production that can be consumed. In terms of a phase diagram, an increase in dependency ratios implies a vertical downward movement of the locus (c^*,k^*), while a reduction of population growth implies a similar upward movement of the same locus.

As explained above in section 3, forecasted demographic changes in Spain indicate a higher dependency rate and a severe slow down of population and labor force growth. These facts imply that the steady state continuously moves up and down. As a reaction to these exogenous shocks, agents respond by selecting the optimal trajectories to the new equilibrium. We want to describe this transition process of the consumption and capital variables from one steady state equilibrium to the next.

There are many possible cases that can be analyzed depending on the demographic scenario or the parameters chosen. As a benchmark, and with the sole intention of considering this simulation as a simple application in order to evaluate the impact on consumption and capital accumulation of predicted demographic shocks, we have chosen Scenario II from our projections described in section 2.2. and the following parameter values

Parameter	Value
s	1.000
$(1 - \alpha)$	0.255
β	0.990
g	0.015
δ	0.080

For computational simplicity we have assumed $s = 1$, which transforms our CRRA utility function into the logarithmic function. The share of income in national income - $(1-\alpha)$ - and the average growth rate of productivity -g- are taken from the Annual Report of the Bank of Spain. β is taken from Hansen and Singleton (1982)[9].

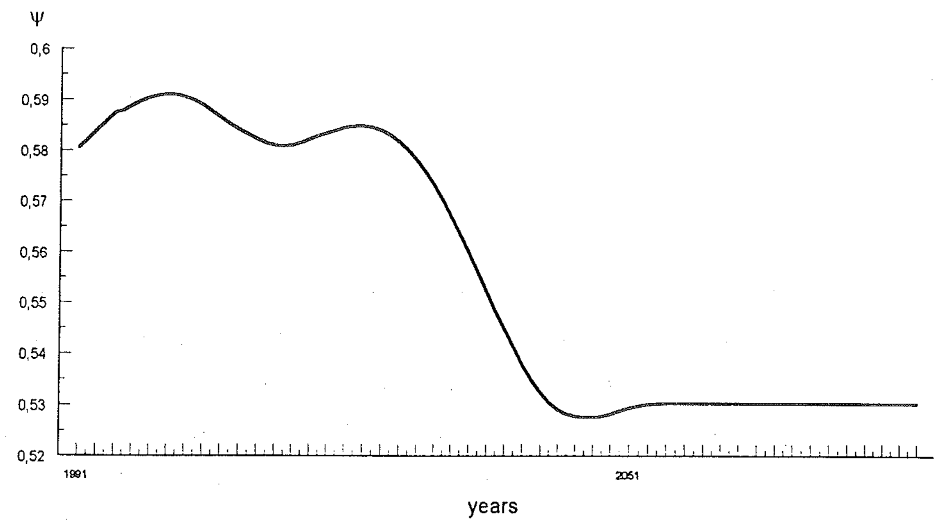
[9] As far as we know there is no estimation of the rate of time preference obtained with data from the Spanish economy. King and Rebelo (1993) use 10% as the depreciation rate. The estimations of the depreciation rate for the Spanish economy lead to smaller rates (Hernando and Valles (1993) and Corrales and Taguas (1989)). Based on those studies we set the depreciation rate to 8%.

To start the simulation exercise we assume as initial values for population growth and for the dependency ratio, the corresponding average values for the eighties.[10] In 1991 the demographic transition takes the economy to the year 2051, the year in which the transition is supposed to end. Therefore, after the year 2051, the values for population growth and dependency ratios are assumed to be constant and equal to those calculated in section 2.2 and 3 above for that year.

Figure 6 displays the index of economic dependence, Y. Given that projections are made using five year age groups, yearly observations are obtained by applying a moving average filter. In this economy, agents are supposed to have rational expectations and, therefore, the sequence of n and Y belongs to their informational sets.[11]

Figure 6.

LABOR FORCE/TOTAL POPULATION.



Ratio: labor force/total population

[10] If γ is not equal to 1, there is no need to assume that the economy is initially in a steady state equilibrium. However, the fact that there are no good estimates for this parameter lead us to take 1 as a satisfactory compromise. In fact, this value is also adopted by Cutler et al (1991).

[11] Details of the simulation are presented in the appendix.

Figure 7 presents the combined effect of the change in population growth and the dependency rate on the evolution of consumption. This variable has been normalized with respect to the value of consumption in the initial steady state.

Figure 7.
CONSUMPTION.

As displayed by the graph consumption initially jumps up by 7% and starts going down since that point. When the system reaches the new steady state consumption has fallen around 6%. This means that at the new steady state the effect of the increase of population over 65 over working age population overcomes the impact of the decreasing growth rate of the labor force. It is interesting to notice that the level of consumption goes below the 1991 benchmark, initial steady state, around the year 2031-36 which coincides with the same period at which the accumulated changes in the index of economic dependence based on the earning weighted equal per capita consumption described in section 3 (table 1 panel B scenario II) goes below the level of 1991.

Figure 8.
SAVINGS RATE

On the other side, as figure 8 shows, the savings rate goes from 18,5% up to almost 21.5% in the new steady state. Initially, the decline in labor force growth causes an increase in the savings rate that reaches the level of 22.2% in the year 2013. The effect of the increase in the index of economic dependence, specially quick after 2041, will lead to a smooth reduction of the savings rate afterwards.

5. CONCLUDING REMARKS

Recent significant changes in demography occurring in Spain question the long term sustainability of growth and of the public pension scheme. However, the public pension problem is just one of the possible problems posed by the dramatic increase in the dependency ratio. A quick look at the available information allowed us to reach several conclusions.

Population projections predict, in intermediate scenarios, an absolute level for 2051 quite similar to the 1991 level. In the period between 1991 and 2051 population grows steadily, reaching a maximum around the middle of the interval and decreasing after that point in time. However, if recent trends in fertility rates do not change substantially, the population will dramatically decrease by 2051, so much so that we would expect an endogenous reaction in social behaviour, once the problem becomes more immediate.

The dependency ratio will increase in the future no matter which scenario or projection is adopted. In fact, the quick increase in dependency also appears in all alternative definitions proposed in this paper. However, in the short run, we will see decreasing dependency ratios, until they turn around to significantly increase in the last decades analyzed. The use of better defined dependency ratios allowed us to be more precise in forecasting periods of likely unbalances between needs and resources.

Finally, the simulation exercise points out that the increase in dependency and the reduction of population growth rates will also have important effects on consumption per capita. Therefore, the problems posed by the increase of the dependency ratio will not only question the sustainability of the public pension plan but are transmitted to the economy as a whole.

APPENDIX

This appendix covers the method used to simulate the model presented in section 4. The general idea is to solve the system of difference equations

$$(1+g)^{\sigma}(c_t)^{-\sigma}=(c_{t+1})^{-\sigma}\beta\left[f'(k_{t+1})+(1-\delta)\right] \quad [21]$$

$$(1+n)(1+g)k_{t+1}=f(k_t)-\frac{c_t}{\psi}+(1-\delta)\,k_t \quad [22]$$

subject to the boundary conditions k_0, the initial value of capital, and $c_T = l(k^*)$, where $l(.)$ is given by (21).[12]

The procedure to obtain the solution is based on finding initial jump in consumption, such that $c_T - l(k^*) < \epsilon$, where ϵ is a very small number set as the tolerance level.

There are many possible methods to simulate a system of difference equations subject to boundary conditions.[13] The usual procedure is the so called "shooting algorithm" which implies to guess an arbitrary initial value for c and then obtain the implied c_0^+ and compare it with $l(k^*)$. If the difference is larger than a tolerance level try a new guess and proceed iteratively until the difference is very close to zero. The shooting algorithm does not work very well in growth models because some arbitrary guesses for c_0^+ lead to negative values of k_t.

[12] This second boundary is equilvalent to the transversality condition since paths that satisfy the *TC* converge to the steady state. Although this is a condition at infinity the usual way to deal with it is to set a number for *T* large enough. In this case, *T=200.*

[13] For a discussion of these methods applied to economics see Judd (1992).

shooting. From the phase diagram of the typical growth model we know that, if the guess for c_0^+ is too big the sequence of k_t explodes, while if the jump in c_0^+ is too short the value of k_t goes quickly to 0. For this reason, the strategy adopted was the following: find a c_0^0 that generates an explosive path and a c_0^2 that leads to an imploding path for k_t. Compute $c_0' = (c_0^0 + c_0^2)/2$. Simulate the trajectories for the difference equations.

* If $l(k^*) > c_T$ then make $c_0^0 = c_0^1$ and update the value of c_0^1.

* If $l(k^*) < c_T$ then make $c_0^2 = c_0^1$ and update the value of c_0^1
  Iterate until $l(k^*) - c_T < \epsilon$.[14]

[14] The GAUSS program that contains the code used to make the simulation presented in this paper is available from the authors upon request.

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