The implications of an ageing population for the UK economy

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Abstract

This paper considers the likely development of aggregate living standards in the United Kingdom over the course of this century and some of the risks to this outlook. It argues that even under relatively cautious assumptions about technological progress and capital accumulation, aggregate living standards (as measured by GDP per head) are set to double over the next 50 years. While there are clear risks to this aggregate outlook, these would be present even without demographic change. The paper also discusses the risks to the living standards of individuals and individual cohorts. These risks have changed in three main ways as a result of demographic change. First, ageing has been a factor throughout the world in encouraging a shift from public to private provision for old age, increasing the proportion of retired people exposed to risks to market prices and rates of return. Second, the size of the group exposed to such risks is growing larger as a direct result of ageing. Third, any adverse effects of demographic change are most likely to be felt in old age; one of the effects of people living longer is that they have to spread their lifetime incomes over more years of life, implying a need for more saving when working. If this does not occur, then consumption has to be a lot lower in old age than would have been the case had proper provision been made for retirement.

JEL classification: D91, E27, G12, H55, J11.

Key words: Demographic change, overlapping generations, savings.

Summary

This paper discusses the impact of demographic change on the UK economy, looking at effects on GDP growth and GDP per head, saving and capital investment, interest rates, asset prices and the distribution of national income. It also considers the risks associated with demographic change. A key finding, widely supported in the academic literature, is that even under relatively cautious assumptions about technological progress and capital accumulation, aggregate living standards (as measured by GDP per head) are set to double over the next 50 years. While there are clear risks to this aggregate outlook, these would be present even without demographic change.

The impact of ageing on the rate of saving and capital accumulation is one of the key uncertainties surrounding any projection of long-term growth. The paper analyses this in the context of a model where people are reliant on their own saving for their retirement income and considers three different types of demographic shocks: a baby boom, an increase in longevity and a decline in fertility. The overlapping generations model used for this purpose makes it possible to assess the impact of these shocks on the welfare of different generations under different assumptions about household behaviour. It finds that a baby boom has an adverse effect on the baby boom generation for the obvious reason that when they are of working age their abundance drives down wages and when they are of retirement age the abundance of their saving drives down the rate of return. The impact of a baby boom on other generations is largely beneficial. Increases in longevity, not accompanied by changes in labour supply, have a detrimental effect on annual consumption per head for the obvious reason that people have more years over which to spread their consumption. Changes in fertility appear to have very little effect on individual consumption per head, although they clearly affect aggregate quantities because of changes in the number of people.

An important conclusion of these models is that while individual consumption over the life cycle may not be strongly affected by demographic change, there can be large effects at particular parts of the life cycle when individuals do not attempt to spread their consumption evenly. For example, the analysis of greater longevity suggests that this might reduce individual life-time consumption by about 2% if the change is spread evenly over time. But if individuals follow rule-of-thumb behaviour prior to retirement and do not accumulate enough assets, the reduction in their life-time consumption will be concentrated into the years when they are old. This is particularly important at the current juncture since many people in prime saving age will observe their own pensioner parents living longer without any obvious adverse effect on their consumption. This could be misunderstood as suggesting that their own saving for retirement is adequate. Yet the formal model suggests that the early generations to benefit from greater longevity do not have to reduce their consumption since the capital accumulated by previous generations is not affected by their longevity. But their children will receive smaller bequests. Moreover, the current generation of pensioners has benefited from extraordinarily high asset returns which are unlikely to be repeated.

The implications of this analysis for interest rates are modest. This is consistent with other research which suggests that the effect of demographic change on asset prices more generally is

likely to be small. This leads on to the second conclusion of this paper, that the risks to the living standards of individuals and individual cohorts are large. While the impact of demographic change on asset prices is small, the historical volatility of asset prices and rates of return is significant. This is unlikely to be affected by demographic change, but it means that those relying on financial market returns for their retirement income could be much less lucky than those who enjoyed the high returns of the 1980s and 1990s.

Moreover, the projected increase in the number of people in this position raises the risks of large numbers suffering the effects of financial shocks, as well as the risks to macroeconomic and financial stability. Recent experience with endowment mortgages emphasises that the returns on long-term investments can turn out to be substantially different to expectations. In a similar way, a period of very low rates of return on capital would leave people with much lower pension entitlements than had been anticipated. This can occur even when overall asset returns have been strong if investors have poorly diversified portfolios, but the adverse effect of it occurring for a substantial group of savers could be severe. Such an outcome would have macroeconomic repercussions if lower expenditure by the retired was intensified by lower spending by those of working age who become concerned about their own retirement income. It would have systemic implications if lower asset returns meant that debts could not be paid.

Given the lack of financial sophistication of many households, there is a clear educational role for financial regulators in informing people of the risks they face and what action they might take.

1. Introduction

In common with most OECD countries, the demographic characteristics of the United Kingdom are expected to change sharply in the current century. This reflects a number of factors including the ageing of the baby boom generation, lower fertility rates and increased longevity. One of the main changes is that the UK population will get older with the mean age rising from 38.6 years in 1998 to 41.9 years in 2021, stabilising on current projections at 44 years by 2040. Perhaps more significantly, the number of old people is expected to rise sharply with those over the age of 75 increasing from about 4.4 million in 2000 to 8.3 million in 2040.

Such changes are likely to have profound economic effects as the number of people at different stages of the life cycle changes over time. In the future, any ageing-related increase in the number of consumers relative to the number of workers will create pressures on living standards. In the present, any attempt by those currently of working age to provide for their retirement is influencing both the future supply of capital and current asset prices, affecting the market value of the assets of those who are currently retired. Thus demographic change has an impact across generations affecting those not yet born and those who will no longer be alive to see it.

Despite a growing literature analysing the economic effects of these demographic trends, there does not yet appear to be a clear consensus on the likely size of the possible effects, at least for the United Kingdom. One of the purposes of this paper is to survey the existing literature, stating where there is consensus and pinpointing where there are areas of difference. While much of the existing literature is concerned with the issue of reform of state pension systems, this paper focuses on the impact on aggregate living standards and the risks to the welfare of individuals in an economy like the United Kingdom where the state is expected to provide only a minimum level of retirement income. In such an economy the rate of return on lifetime savings is a key factor in determining the level of welfare in retirement.

In this context, it is important that any changes expected to emerge as a direct result of demographic change are contrasted with general uncertainty over the macroeconomic outlook. It is likely that the main risk of an ageing population is not from any change that it induces in the behaviour of the economy, but from the increased number of people reliant on private savings who are vulnerable to the risks that are always present.

The next section briefly summarises the extent of demographic change anticipated in the United Kingdom and describes a possible scenario for GDP growth consistent with it. This is contrasted with similar exercises for other countries. So long as technological progress continues to drive productivity growth, this analysis provides a relatively comforting description of continued growth in average living standards in the United Kingdom over the course of this century. But the rate of growth of living standards in the future is likely to be heavily dependent on the rate of saving and capital accumulation. This section also discusses some of the evidence on the relationship between saving and ageing, but stresses the difficulty in applying this to future periods when the demographic structure is expected to be different.

The third section sets out a dynamic general equilibrium model of a closed economy with overlapping generations that can be used to assess the impact of different demographic shocks. This is used to assess the impact of a baby boom, increased longevity and reduced fertility, the main causes of expected population ageing.

The fourth section considers the impact of demographic change on asset prices and rates of return. While it is possible to make predictions about changes in the rate of return in response to demographic shifts, this section draws attention to its historical volatility suggesting that any predicted changes need to be large to be practically important. It goes on to assess the evidence on the impact of demographic change on asset prices and rates of return in the last century. Some authors have claimed that the increase in equity prices in the 1990s was a response to the maturing of the US baby boom generation. The implication has been drawn from this that there will be an asset price 'meltdown' when this generation sells its shares as it reaches retirement. This section sifts out realistic claims for an effect of ageing on asset prices from wilder assertions not supported by available theory or evidence.

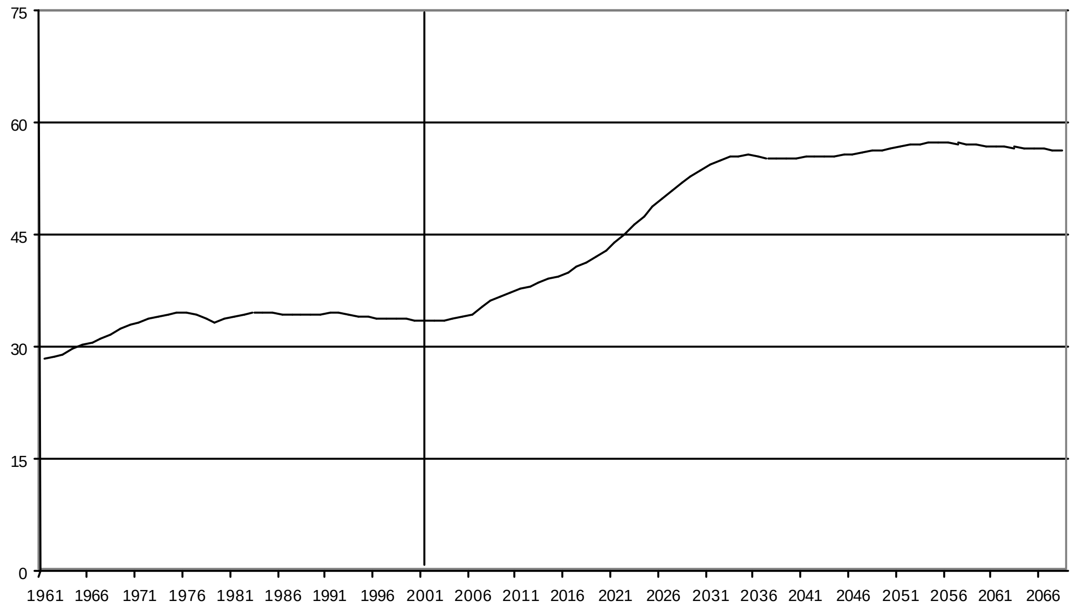
The final section summarises the key findings of this review of the literature, puts them into context and identifies where the main vulnerabilities lie.

2. Demographic change in the United Kingdom

Demographic change and population ageing is a global phenomenon that has attracted considerable attention throughout the world. While a large number of reports and research papers have been published on this subject, there is relatively little existing analysis of the impact of demographic change on the United Kingdom. This section sets out in broad terms how the UK economy might develop as the population changes in line with official population projections. It compares these trends with those set out elsewhere for other countries and highlights some of the key sensitivities.

Chart 1 illustrates the anticipated extent of demographic change in the United Kingdom in the coming 60 or so years. It shows that the number of people over 60 is expected to rise from 33% of those aged between 15 and 60 in 2001 to around 55% in the early 2030s and then, on current projections, to remain at around that level. In other words, taking 60 as the retirement age, the number of working age people per pensioner is due to fall from around 3 now to about 2 in 30 years' time.

Chart 1: Ratio of over-60s to 15-to-60s in the United Kingdom



Source: Government Actuary’s Department.

At a simple level, such change affects living standards because it raises the number of people with a claim to the country’s resources relative to those involved in producing them. But the level of living standards themselves is affected by how much capital the old people accumulated when they were young as well as the extent of continuing technological change. The relationship between output and factor inputs is determined by the aggregate production function showing the dependency of output on available labour supply and accumulated capital. This can be written in Cobb-Douglas form as:

$$Y_t = AK_t^a L_t^{1-a} \qquad \textbf{(1)}$$

where Y is aggregate output, K is the capital stock and L is the effective labour supply; A is a constant and a is a parameter, usually taken to be equal to the capital share in national income (around a third).

The effective labour supply is affected by a number of factors including the size of the population of working age, labour force participation rates, hours of work supplied per worker, the skills of the workforce and the extent of labour augmenting technical progress. In the next section, these are summarised by the following function:

$$L_t = \sum_{i=1}^{m} e_{it}\, p_{it} N_{it} \qquad \textbf{(2)}$$

where N_i is the number of people in any group of the population, p_i is the labour force participation rate of the group and e_i is a measure of the effectiveness or productivity of that group that changes due to improvements in skills and advances in labour saving technology. This productivity term, which can subsume trends in hours per worker, usually trends upward over time.[1]

Table A shows trends in the population in different age groups over recent and future ten-year periods. It also shows how this translates into aggregate output and output per head of population under specific assumptions about participation rates and effectiveness per worker. Here capital is cautiously assumed to grow at 10% per ten-year period, while productivity grows at 1.75% per annum consistent with the average over the past 40 years. Participation rates are assumed not to change and are set at their recent levels. Under these cautious assumptions, the growth in living standards, as given by output per head of population, slows down sharply but continues at a sufficient rate that by 2060-68 the level of living standards is two and a half times greater than in the 1991-2000 period.

[1] Note that measured labour productivity growth may differ from the growth rate in the productivity term in equation **(2)** because of changes in capital intensity.

Table A: Demographic trends and living standards

	Population of age group (millions)						*L*	*K* (£ bn)	*Fitted Y* (£ bn)	*Actual Y* (£ bn)	*Y/N* (£thou per head)
	0-14	**15-29**	**30-44**	**45-59**	**60-74**	**75+**					% growth in (.)
1961-70	12.82	11.15	10.30	10.40	7.32	2.40	15.8	843	368	371	6.8
1971-80	12.86	12.24	10.15	9.93	8.12	2.45	19.0	1198	470	477	8.6 (26.5)
1981-90	11.01	13.29	11.45	9.33	8.08	3.66	24.1	1451	587	578	10.2 (18.6)
1991-2000	11.31	12.08	12.87	10.42	7.89	4.17	30.1	1795	730	731	12.4 (21.6)
2001-10	10.94	11.61	13.46	11.86	8.33	4.56	37.3	1974	868		14.3 (15.3)
2011-20	10.56	11.81	12.03	13.34	9.86	5.02	43.9	2172	997		15.9 (11.2)
2021-30	10.63	11.2	12.37	12.40	11.32	6.33	51.3	2389	1141		17.8 (11.9)
2031-40	10.4	11.15	11.99	11.92	11.84	7.55	59.6	2628	1301		20.1 (12.9)
2041-50	10.18	11.11	11.62	12.13	10.86	8.80	69.9	2891	1492		23.1 (14.9)
2051-60	10.13	10.81	11.69	11.55	11.04	8.43	81.8	3180	1709		26.8 (16.0)
2061-68	9.98	10.72	11.50	11.50	10.76	8.32	94.5	3498	1940		30.9 (15.3)

Notes: L is constructed assuming participation rates of 0.75, 0.85, 0.70 and 0.1 for 15-29, 30-44, 45-59 and 60-74 year old age groups respectively, productivity is assumed to grow at 1.75% per annum and 30-44 year olds are assumed to be 40% more productive than others. Output (GDP at constant market prices) and the capital stock (constant 1995 prices) are averaged over each ten-year period. The future capital stock is cautiously assumed to grow at 10% per ten-year period. Future output is generated by equation ***(1)*** *in the text with A=5.8 and* ***a****=0.35.*
Source: Population projections from Government Actuary (supplied by FSA), capital stock from Office for National Statistics and output from Economic Trends Annual Supplement (code: ABMI).

The projected broad increase in living standards is consistent with similar projections made for other countries. For example, the OECD has produced a number of papers on the effects of ageing.[2] One of the key papers is Turner *et al* (1998) which presents a number of long-term scenarios illustrating the likely domestic and international macroeconomic effects of ageing across the OECD and policies which might ameliorate or reverse underlying tensions. It is useful to list some key figures from their 'reference case scenario' in Table B.

Table B: Living standards and real interest rates in OECD reference case

	Living standards		Real interest rate
	Average growth 2000-2050	Level by 2050 1995=100	By 2050
United States	1.1	176	5.5
Japan	1.1	176	5.4
European Union	1.3	195	4.9

Note: Living standards measured by GNP per capita adjusted for terms of trade.

These figures offer a similarly comforting aggregate picture. While living standards are projected to grow at a relatively slow rate over the next 50 years, they are projected to be considerably higher in 2050 than in 1995, almost doubling in the European Union.

The OECD study notes that the largest positive contribution to growth comes from labour efficiency growth. This contributes about 1½% per annum in all regions from 2020 onwards. The main negative contribution to living standards derives from the projected rise in the dependency rate, the ratio of those not of working age to those who are, as the output produced by the employed labour force is progressively shared among larger populations. For the European Union, there is little or no effect before 2010, but thereafter growth in living standards is damped by about ½% per annum between 2020 and 2040 due to this factor. By 2050, the direct cumulative effects of the rise in the dependency ratio is to reduce per capita living standards in the EU by about 18% relative to a situation where dependency ratios remain at current levels.

One of the early analyses of the effects of ageing is Cutler, Poterba, Sheiner and Summers (1990), focusing on the possible effects on the US economy. In terms of the effects on living standards, they find that while increasing dependence reduces living standards in the long run (relative to levels without a change in dependence) this would be fully reversed by only a 0.15% a year increase in productivity growth. Further, they argue that diminished fertility will make labour more scarce and so possibly induce technical change.[3] Overall, they find little to cause major concern.

Faruqee and Muhleisen (2001) examine the effects of ageing in Japan with a special focus on its effect on fiscal sustainability. The projected increase in the dependency ratio is greater in Japan than in the United States or United Kingdom. They proceed by building a reference scenario with a stationary population and then simulating the effects of more realistic population paths. They find that GDP is actually higher in 15 years' time relative to the base case due to increases

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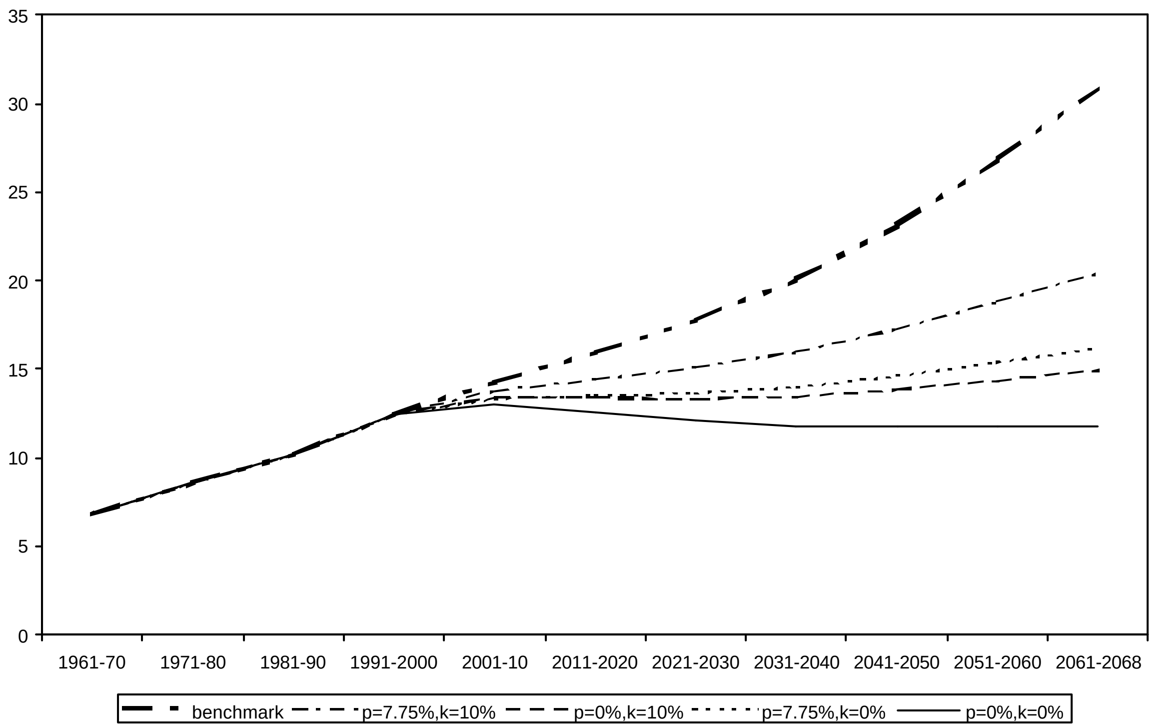
[2] These are available on a *Maintaining Prosperity in an Ageing Society* website at www.oecd.org/subject/ageing/
[3] Elmendorf and Sheiner (2000) re-examine the Cutler *et al* analysis.

in the effective labour supply and the fact that the effects of ageing do not occur until after 2015. By 2050 GDP is lower than in the base case by 11%, but GDP per head is reduced by only 1.4%.

Thus, a range of international studies support the view that aggregate living standards will continue to improve over the coming years despite ageing populations. Clearly, this is dependent on a number of uncertain factors. Chart 2 shows the sensitivity of projected living standards in the United Kingdom to different stylised assumptions about productivity growth and capital accumulation. In the benchmark case productivity grows at 19% per decade (equivalent to 1.75% per annum) and the capital stock grows at 10% per annum. Combinations of lower productivity growth (7.75% and 0% per decade) and lower capital stock growth (zero growth) are shown.

Chart 2: Projected living standards under different assumptions

Output per head of population, £ thousands, 1995 prices



These figures suggest that future living standards would be adversely affected by sharp falls in either productivity growth or the rate of capital accumulation. While either is possible and therefore a source of general uncertainty, their possible link to demographic change needs to be clarified. There is very little theoretical argument or empirical evidence to link productivity growth to demographic change apart from the effect on average productivity as large cohorts move through different stages of the productivity life cycle.(4) There is however a direct

(4) Cutler *et al* (1990) is one of the few papers in the literature which tries to link productivity growth to demographic change.

relationship between demographic change and capital accumulation through the effect on national saving. However, the direction of this effect is not clear-cut.

The OECD study projects a negligible contribution to growth from changes in the capital intensity in all three regions covered. This result is said to reflect the *downwards* pressures which ageing populations place on both private and public savings and the consequent crowding out of the capital stock by higher interest rates. In the Faruquee and Muhleisen (2001) analysis of Japan, saving rates *increase* as the population ages. This is stated to arise for two reasons; first, because there are fewer low-saving young people, second, greater longevity increases saving by old people.

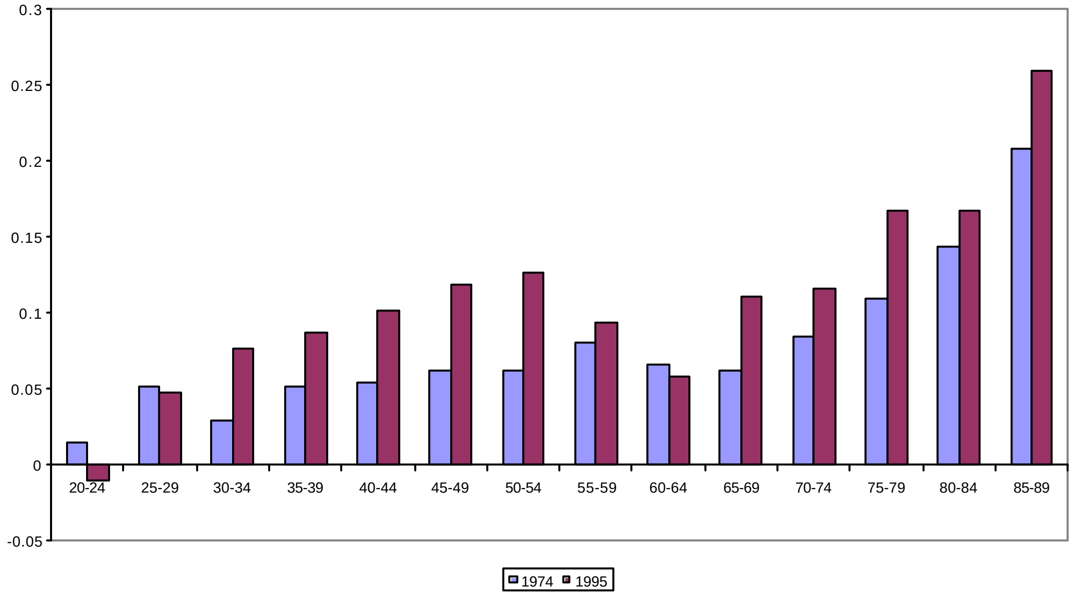
This raises the question of how aggregate saving and hence capital accumulation in the United Kingdom might respond to ageing. This issue has been approached in the literature by considering saving over the individual life cycle. If, as seems logical, people tend to save most in their middle age and dis-save in their old age, then aggregate saving might be expected to increase when the proportion of middle-aged people in the population increases and decline when the proportion of old people increases. However, there are at least two difficulties with this analysis.

First, aggregate saving cannot be identified simply with saving by the household sector. For the United Kingdom, household saving in 2000 amounted to 3½% of GDP, corporate saving to 9% of GDP and government saving to 3½% of GDP. It could be argued that ageing will have less impact on corporate and government saving. But these different sectors are clearly linked in that households ultimately own the corporate sector and are responsible through their taxes for the financial obligations of the government. As such household saving is substitutable to some extent with the saving of the other sectors. For example, if companies increase their saving by reducing dividend payments, then household dividend income will be reduced. To the extent that this does not affect their consumption, it directly reduces household saving. Similarly, government can increase its saving by raising taxes on dividends. Again, if this does not affect household consumption then it reduces saving. Nevertheless, it is unlikely that saving is sufficiently substitutable across sectors that aggregate saving reflects only the preferences of households.

Second, the observed pattern of saving across different age groups does not match up easily with the predictions of life-cycle theory. Chart 3 shows measured saving rates by age group in the United Kingdom in 1974 and 1995 based on data from the *Family Expenditure Survey* (FES) presented in Banks and Rohwedder (2000). Saving is here defined as the residual between household income and consumption, where the former takes no account of employers' contributions to employee pension schemes and the latter includes expenditure on durable goods and housing. This definition of saving therefore represents the accumulation of *financial* assets and does not take account of the accumulation of housing assets or any pension fund built up by employer contributions. It also fails to take account of wealth accumulated through capital gains on assets.

Chart 3: Saving rates by age group

As a proportion of household income



One of the striking features of this chart is the high median rate of saving by the retired at a time of life when they might be expected to be running down assets. This is the so-called 'retirement savings puzzle' analysed by Banks, Blundell and Tanner (1998). They show that this cannot be accounted for by mortality risk, the removal of work-related costs or demographic factors. Partly, it can be accounted for by noting the complexities in measuring pensioner income. As Miles (1999) has pointed out, household surveys like the FES incorrectly measure pensioner income because all 'receipts are counted as income when a large proportion is really distribution of capital which depletes the remaining fund'.

Hussain (1998) adjusts the saving rate of pensioners for this form of mis-measurement and suggests that the 'true' saving rate of pensioners, taking account of the depletion of the fund, is minus 8% of disposable income. From this he predicts a decline in the personal saving rate from a peak of around 12% in 2005 to a low of around 9% by 2040 as a consequence of demographic change. Miles (1999) projects a fall in the UK national saving rate of 8 percentage points as a consequence of ageing.

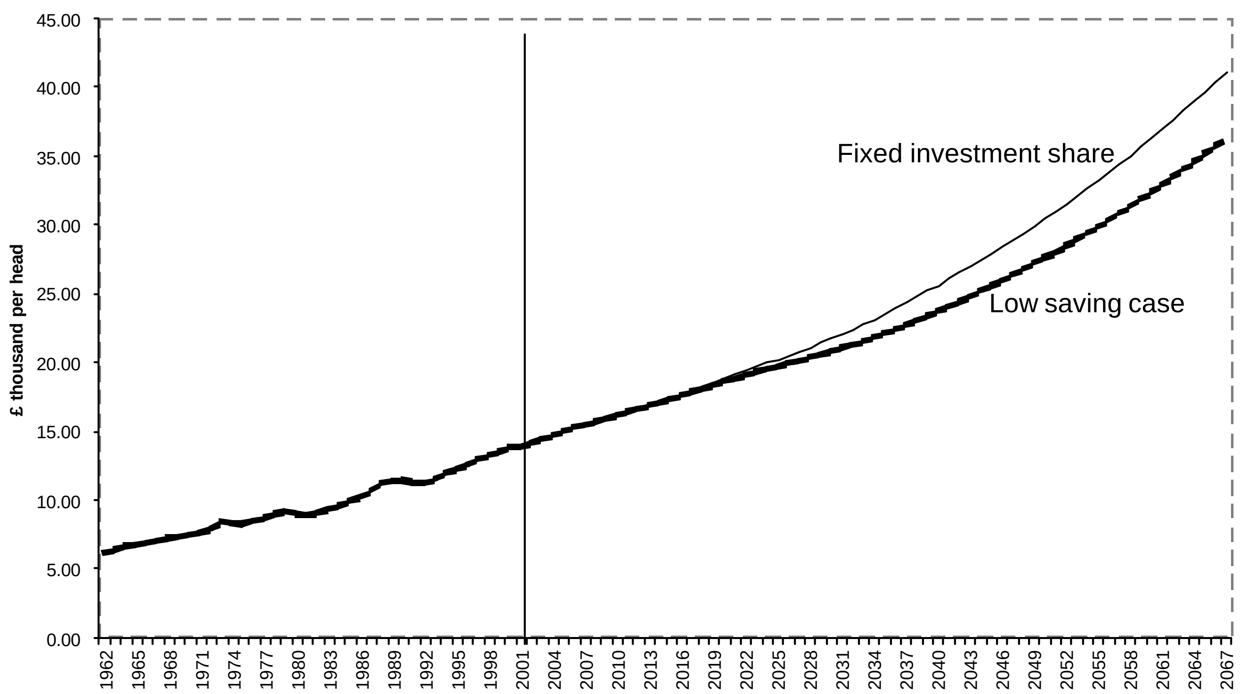
For illustrative purposes, a similar approach is used here to assess the impact of ageing on aggregate saving assuming that the saving rate of different cohorts is fixed. In recent years, the national saving rate in the United Kingdom has been around 16% of GDP taking account of saving by the household, corporate and government sectors. This is about 2 percentage points less than the investment rate, with the difference reflecting the current account deficit on the balance of payments. In order to quantify the possible effect of ageing on aggregate saving and hence the development of living standards, we suppose that aggregate saving *and* investment are determined by the cohort specific savings rates for 1995 shown in Banks and Rohwedder (2000) with the pensioner saving rate adjusted in line with Hussain (1998). The specific functional form is:

$$\frac{I}{Y} = 4(0.02.n0 + 0.085.n1 + 0.12.n2 - 0.05.n3 - 0.02.n4)/(n0 + n1 + n2 + n3 + n4)$$

where $n0$ is the size of the 15-29 year old cohort, $n1$ is the size of the 30-44 year old cohort, $n2$ is the 45-59 year old cohort, $n3$ is the 60-74 year old cohort and $n4$ is the 75 plus cohort; multiplying the overall saving rate by four is necessary for the investment-output rate to be of the right order of magnitude in 2000 (this effectively adds in saving by corporations and government).

This relationship predicts a decline in the investment output ratio from around 18% now to 14% in the early 2030s. The impact of this can be quantified by extending the equations underlying Table A to take account of the effect of a lower rate of capital accumulation on the capital stock and hence output and subsequent saving. Chart 4 shows projections of output per head in the baseline case where the investment output ratio is fixed at 18½% and in an alternative case where aggregate investment responds to exogenously determined cohort-specific savings rates. The impact is large as not only is saving lower out of a given level of income, but national income is itself reduced relative to what it would otherwise have been because of the lower capital stock. In this case, living standards show slower growth so that by 2060 they are 135% higher than in 2000 compared with 160% higher in the fixed investment rate case. The difference is substantial, but does not alter the expectation that living standards in the future will be substantially higher than they are now.

Chart 4: Output per head under different assumptions about the saving rate



Aside from the problem in estimating age group specific saving rates, there are a number of other difficulties with the forgoing illustration. In particular, it cannot be assumed that the age-specific saving rates will remain constant over time. As Chart 3 illustrates, the saving rates of different age groups have changed over time reflecting different behaviour over time as well as factors specific to particular cohorts.[5] It is likely that demographic change will have a number of effects on saving rates at particular points in the life cycle depending on what is causing the demographic shift. These are examined in detail in Section 3, which surveys some of the recent literature and describes a dynamic general equilibrium model that allows for endogenous changes in aggregate savings in response to certain demographic shocks.

3. Assessing the impact of demographic change

A number of economic models have been developed to analyse the impact of demographic change. These fall into two broad classes depending on whether they take account of the overlapping generations structure of the population. The first group includes the extensive US analysis of Cutler *et al* (1990) which is based on a calibrated growth model of a closed economy and the estimated cross-country model of Turner *et al* (1998). The second group includes a number of calibrated models that make explicit allowance for the birth and death of different age cohorts. These overlapping generations (OLG) models were first introduced in this context by Auerbach and Kotlikoff (1987) and have now become the standard tool for analysing the implications of demographic change (see De Nardi *et al* (2001) for a recent discussion).

The overwhelming advantage of the OLG approach is that it takes explicit account of how the behaviour of individuals changes as they age and respond to change in prices caused by demographic shocks. It may also be used to assess the impact of economic shocks on different age groups within the population. This is of crucial importance when assessing changes, such as those arising from demographic shifts that are thought to have different effects on different age cohorts. Despite this general advantage to OLG models, they have been implemented in a number of different ways that make them more or less useful. Moreover, the models themselves are usually strongly theoretically based without any serious attempt at fitting any empirical evidence other than a few stylised facts. This means that no single model can be generally taken to be more reliable than any other on empirical grounds and choices between them need to be based on other criteria, such as plausibility.

A state-of-the-art example of an OLG model is that applied to the United Kingdom and Europe by Miles (1999). This is based on the assumption that at any moment in time there are 60 cohorts of adults alive. It is assumed that there are no differences between adults within a cohort and that each adult lives for 60 years. In contrast to Auerbach and Kotlikoff (1987), Miles allows for technical change which raises productivity over time and variation in productivity over an individual's life cycle. People are assumed to maximise a utility function that depends on the discounted value of utility they receive from consumption of goods and leisure. There are assumed to be no bequests. Choices are determined by a perfect-foresight path of wages and interest rates over the whole life cycle. Wages and interest rates are assumed to be determined

[5] The difficulty in identifying age, time and cohort effects is discussed by Gourinchas and Parker (1999) among others.

competitively and given by the marginal product of labour and capital respectively via a Cobb-Douglas production function. It is assumed that people receive the state pension after retirement, where the maximum retirement age is set by the government. The pension is financed by a tax on current labour income, where the contribution rate is set to balance the pay-as-you-go (PAYG) scheme in every period.

The model has a number of limitations that are typical of this general approach. One of the key assumptions of the Miles model is that the real interest rate is determined endogenously within the closed economy by the competitive equilibrium condition that the marginal product of capital be equal to the user cost of capital given by the real interest rate plus the rate of depreciation of capital. As Miles clearly acknowledges, this assumption is inconsistent with the view that interest rates are determined internationally in the global capital market. With perfect international capital markets, real interest rates would be equalised throughout the world and an increase in saving would be reflected in capital outflows rather than lower domestic interest rates. While a number of arguments can made to justify the closed-economy assumption, it limits the applicability of the model in the context of a world of highly integrated capital markets and justifies the efforts of the OECD and others to investigate the effects of demographic change using a multi-country approach. This is discussed further in the next section. Nevertheless, closed-economy OLG models are important in understanding the impact of world-wide demographic change since the real interest rate is clearly endogenous globally.

A further limitation of Miles' model and most others of this type is the inconsistency between the implied life-cycle saving behaviour of individuals and that observed in practice.(6) The model implies that people smooth their consumption over the life cycle, saving when in work and running down their saving until they die with no assets to pass on to their children. This is apparently at odds with the evidence on saving by the retired described in the previous section.

Miles uses official projections of demographic change to assess its impact on the UK economy. These produce relatively large fluctuations in the aggregate saving rate from around 14% in 2000 to a low point of about 6% in 2040. While not defined on the same basis as the UK national accounts (where the household saving rate was 5% in 2000), the changes in the saving rate are indicative of how saving on the official definition might change. The simulated change in the saving rate reflects the rise in the number of people in the dis-saving older age groups. This in its turn contributes to a changing capital labour ratio which peaks in about 2030, after which lower saving reduces capital relative to labour. The real interest rate falls to 4.2% at the same time, having peaked at 4.6% at the end of the 1990s.

Hviding and Merette (1998) present a similar analysis for seven OECD economies, each assumed to be closed in the sense that interest rates are endogenously determined in each country without reference to those in other countries. In contrast to Miles, labour supply is exogenous. However, a bequest motive is included by assuming that households derive utility from leaving some of their savings to their children. The model generates predictions for the United Kingdom very similar to those of Miles. The aggregate saving rate falls from about 15% in 2000 to about 8% in 2040. The real return on capital falls from about 7½% in 2000 to about 7% in 2030.

(6) See Kohl and O'Brien (1998) for a survey of the literature linking saving and ageing.

Much of the literature cited above assesses expected demographic change without drawing a distinction between ageing due to the maturing of the baby boom generation, falling fertility rates and ageing due to an increase in people's survival to old age. Partly, this is because it is not obvious how to take account of the latter within an OLG framework. In this section, a model is developed which builds on the OLG approach referred to above, but also allows for changes in longevity. This is achieved by assuming that people live as adults for a maximum of five 15-year periods (that is from 15 to 90 years of age), but that a fraction of them do not survive to old age. It is assumed, however, that the lack of well functioning annuity markets makes people plan their life-time consumption *as if* they were going to survive to old age and so build up savings for their possible old age. This means that those who do not survive die before they have exhausted their savings and leave bequests to a following generation. Thus, bequests are not the result of a 'bequest motive' but are accidental in the sense of Abel (1985). This provides a rationale for bequests from people without descendants.

Households are assumed to supply labour exogenously in varying amounts and to varying degrees of effectiveness over their life cycle. Each effective unit of labour supplied is paid a wage given by w_t, so that the labour income of somebody becoming an adult at date t is given by the sequence $\{ w_{t+i} p^i_{t+i} e^i_{t+i}, i = 0,.,4\}$, where p^i_{t+i} is the age-dependent proportion of time spent participating in the labour market and e^i_{t+i} is the age-dependent productivity level. Throughout the analysis, it is assumed that people only participate in the labour market in the first three periods of their life (ie periods 0, 1 and 2). In addition to labour income, households can hold assets paying a rate of return given by r_t and receive a bequest, b_t. It is assumed that bequests are received at the end of the second period of their lives from those dying at the end of the fourth period of their lives. There are no taxes or transfers including state pensions.

Two separate models are used depending on the way in which household saving behaviour is determined. In the first case optimising households are assumed to choose their life-cycle consumption so as to maximise a well-defined utility function, forming rational expectations of future incomes and asset prices. In the second case, households are assumed to follow 'rules of thumb' where they consume their current resources according to a fixed pattern.

Optimising behaviour

Households are assumed to maximise a standard inter-temporal utility function:

$$U_t^0 = \sum_{i=0}^{4} b^i \left(\frac{c^i_{t+i}}{1-g} \right)^{1-g} \qquad \textbf{(3)}$$

subject to the flow budget constraints:

$$c^i_{t+i} = e^i_{t+i} p^i_{t+i} w_{t+i} - a^i_{t+i} + (1 + r_{t+i}) a^{i-1}_{t+i-1} + b^{i-1}_{t+i-1} \qquad \textbf{(4)}$$

where a is asset holdings and b is any bequest received.

The first-order (Euler) conditions (i=0,..4) are that

$$\frac{c_{t+i}^{i}}{c_{t+i+1}^{i+1}} = \left(b\,(1+r_{t+i})\right)^{-1/g} \qquad \textbf{(5)}$$

These may substituted into the inter-temporal budget constraint derived from **(4)** to give optimal consumption throughout the life cycle. The optimal consumption of a new adult at date t (who retires at the end of period t+2) is:

$$c_t^0 = \frac{\left[(1+r_{t+1}^4)\,p_t^0 e_t^0 w_t + (1+r_{t+2}^3)\,p_{t+1}^1 e_{t+1}^1 w_{t+1}(1+r_{t+3}^2)(p_{t+2}^2 e_{t+2}^2 w_{t+2} + b_{t+2}^2)\right]}{(1+r_{t+1}^4) + c_t^1(1+r_{t+2}^3) + c_t^2(1+r_{t+3}^2) + c_t^3(1+r_{t+4}^1) + c_t^4} \qquad \textbf{(6)}$$

where $(1+r_{t+1}^j) = \prod_{i=0}^{j}(1+r_{t+1+i})$ evaluates rates of returns over different terms and $c_t^j = \prod_{i=1}^{j}(b\,(1+r_{t+1+i}))^{1/g}$ is a measure of patience or impatience. All future dated variables are expectations conditioned on information at date t.

Thus optimal consumption is a function of current and future variables, including wages and interest rates which are endogenous. Similar specifications can be derived for optimal consumption at different dates over the life cycle using **(5)**.

Rule-of-thumb behaviour

Clearly, choosing optimal consumption is computationally demanding and, because life is short, households may instead behave sub-optimally by following simple rules of thumb in determining consumption over the life cycle.[7] Here it is assumed that households consume all of their labour income in the first period of their life, 90% of it in the second period and 80% of it in the third. In addition, they consume some of the bequest they expect to receive from the second period of their adult lives. In the fourth period, they consume 70% of their resources and use up all of their resources if they survive to the fifth period of their life.

Population structure

It is assumed that N_t people reach adulthood at date t. They all survive for four periods, but only $1-drate_{t+4}$ of them survive to the fifth period. Thus the population at any date is given by $N_t + N_{t-1} + N_{t-2} + N_{t-3} + (1-drate_t)N_{t-4}$.

Bequests

Whether households are optimising or basing their behaviour on a rule of thumb, they will leave a bequest if they do not survive to the fifth period. The aggregate bequest at date t is given by

[7] Boersch-Supan *et al* (2001) suggest that the assumption of optimality is one of the limitations of their model, but argue that departures from optimality do not have first-order effects on the aggregate behaviour of the economy.

$B_t = drate_t.(1+r_t).a^3_{t-1}N_{t-4}$, where $(1+r_t).a^3_{t-1}$ is the period t value of the assets of each member of the generation born at t-4. The bequest received by each member of the middle-aged generation at date t is then B_t/N_{t-2}.

Aggregate consumption and asset holding

Aggregate consumption is simply the sum of the consumption of each generation and is given by $C_t = N_t c^0_t + N_{t-1}c^1_t + N_{t-2}c^2_t + N_{t-3}c^3_t + (1-drate_t)N_{t-4}c^4_t$. Similarly aggregate asset holding at the end of period t is $ASSET_t = N_t a^0_t + N_{t-1}a^1_t + N_{t-2}a^2_t + N_{t-3}a^3_t$ where note that the oldest generation have no remaining assets at the end of the final period of their life.

Production

The production side of the model is given by the production function shown earlier as equation **(1)** with labour input given generally by equation **(2)**, these are repeated below with labour input written to take account of assumptions about the length of the working life:

$$Y_t = AK^a_t L^{1-a}_t \qquad \textbf{(1)}$$

$$L_t = \sum_{i=0}^{2} e^i_t p^i_t N_{t-i} \qquad \textbf{(2')}$$

Unlike the models of Abel (2001) and Bütler and Harms (2001), there are no capital stock adjustment costs and the stock simply reflects the assets accumulated by households. In view of the fact that each period represents 15 years, an average of the assets at the beginning and end of the period is used:

$$K_t = 0.5(ASSET_t + ASSET_{t-1}) \qquad \textbf{(7)}$$

Factor prices

In competitive factor markets, the prices of factors are determined by their marginal products. As such, the rate of return on capital and the wage rate are given by:

$$r_t = a\frac{Y_t}{K_t} - d \qquad \textbf{(8)}$$

$$w_t = (1-a)\frac{Y_t}{L_t} \qquad \textbf{(9)}$$

where d is the rate of capital depreciation.

Parameters and calibration

A range of parameter values have been chosen in line with those common in the literature. These are described for a main case. Some sensitivity analysis has been carried out to assess whether the results are dependent on the values chosen.

Production function parameters: in the main case, A = 140 (scaling parameter), a = 0.25 (the capital share). The value of the capital share parameter is the same as that used by Miles (1999). Values of 0.3 and 0.15 have also been used in sensitivity analysis.

Capital depreciation: d = 0.5. This is equivalent to about 5% per annum. A value of 0.4 has also been used in sensitivity analysis.

Preferences: g = 2.5, b = 1. Miles (1999) surveys values in the literature of the coefficient of relative risk aversion (g), ranging from 0 to 4, and settles on a value of 1.33 for his study. Auerbach and Kotlikoff (1987) use a value of 4, while Deaton (1991) and Carroll (1997) use a value of 3. A value of 1.5 has also been used in sensitivity analysis. The discount factor (b) is usually taken to be less than one, implying household impatience. Miles (1999) uses 0.985 in an annual model, equivalent to 0.8 in a 15-year model. Values of 0.8 and 1.18 are used in sensitivity analysis.

Labour efficiency: grows at 30% per (15-year) period. Prime age workers (i=2) are 40% more efficient than others.

Population: a constant population is assumed in the base case, with 12.5 million adults born per period.

Model solution

The model is similar to other dynamic general equilibrium models with overlapping generations, although with a number of added complexities. Diamond (1965) and Blanchard and Fischer (1989, Chapter 3) discuss the solution of these models and point out that a stable solution is not guaranteed for an arbitrary choice of parameters. Moreover, there is no guarantee that the solution will be dynamically efficient with the equilibrium rate of interest greater than the growth rate. For the parameters selected, the steady-state equilibrium in the case where households are optimisers turns out to be one where the rate of interest is less than the growth rate of the economy given by the sum of population and productivity growth.[(8)] The equilibrium interest rate in this case is lower than has been observed in recent years and, equivalently, the capital-labour ratio is higher than that seen historically. This reflects the high levels of private saving in the model that arise mainly because of the assumed absence of a state pension scheme and the presence of accidental bequests which add to aggregate saving.[(9)] This sort of equilibrium

(8) The model is solved over a hundred periods using the Winsolve package. Details on Winsolve are available from Richard Pierse's homepage at www.econ.surrey.ac.uk/people/index.htm

(9) This contrasts with Miles' (1999) model which uses similar parameters but results in an equilibrium rate of interest that is greater than the growth rate. Miles' model does include a state pay-as-you-go pension scheme, but does not allow for intergenerational bequests.

may be more relevant in a world where people face long periods of retirement which have to be funded out of private saving. It should be noted that households do not choose to borrow in this model so a low rate of interest is not to their advantage.[(10)] In the case where household savings are determined by rules of thumb, the steady-state equilibrium interest rate is greater than the growth rate and the capital-labour ratio is consistent with that observed historically.

The model is now used to evaluate the implications of a changing demographic structure. This is achieved by simulating the model about a steady-state solution. Three types of demographic shocks are considered. First, a baby boom which traces out the consequences of a particularly large cohort. Second, an increase in longevity. Third, a reduction in fertility.

The effects of a baby boom

The first case considered is that of a baby boom. Here the number of people becoming adults at date 0 is raised by a million (about 8%) relative to the base case, broadly in line with the UK 'boom' generation born in the late 1950s and early 1960s who entered work in the mid-70s to early 1980s. The size of all other cohorts is unaffected so that the fertility rate of the boomers is lower (since more of them do not produce additional progeny).

The main immediate effect of the baby boom is to increase labour supply and lower the capital-labour ratio thereby raising the marginal product of capital and the interest rate and reducing the marginal product of labour and the wage rate. The impact on the interest rate is shown in panel A of Chart 5. Whether households are optimisers or followers of rules of thumb, the 15-year interest rate is higher by 1 to 2 percentage points (equivalent to a tenth of an annual percentage point) while the baby boomers are at work. During this time, aggregate saving is raised reflecting mainly the life-cycle behaviour of the boomers. Thus, by the time the boomers leave the workforce, the capital stock has been raised (as shown in panel B of Chart 5), and this drives down the rate of interest on their retirement so that it is about 1 to 2 percentage points lower than it would have been in the absence of a baby boom.

The changes in factor prices as a consequence of the baby boom are clearly to the disadvantage of the baby boom cohort, reflecting their relative abundance. But the impact on other generations is generally beneficial. Higher interest rates when the baby boomers enter the labour market is to the advantage of preceding generations living off capital at the time. While a higher capital stock when the boomers retire is to the benefit of the succeeding generations. These effects are shown in panels C, D and E of Chart 5. The general pattern is not greatly affected by whether households are optimisers or followers of rules of thumb, although the profiles are smoother when households are optimisers.

[(10)] Different steady-state equilibria can be found by varying the parameters of the model, but in no case does this model of household behaviour produce a stable equilibrium where the interest rate is greater than the growth rate. The model is unstable for many combinations of parameters. This arises from the assumed intertemporal substitution by households since there is no instability in the case where households are assumed to follow rules of thumb.

The effects of greater longevity

According to the data underlying Table A, 53% of those aged 60-75 in 1970-85 survived to the 75 plus age group in 1985-2000, but 73% of those aged 60-75 in 2000-15 are expected to survive to 75 plus in 2015-30. Here, the effect of a permanent increase of 20 percentage points in the survival rate from date 0 is evaluated. This would raise the old age dependency ratio depicted in Chart 1 by about 7 percentage points.

In principle, increased longevity and better health alongside it might encourage greater labour force participation among older age groups. However, this possibility is not allowed for here. In the absence of increased labour supply, the response of output and living standards depends on the response of overall saving to changes in longevity. In fact this is dependent on assumed household behaviour. In the optimising case, households are anyway assumed to plan on the basis that they will survive to old age even though they know that this may not happen. As such, the main consequence of increased longevity is that there are fewer accidental bequests. Anticipating this, optimising households save more when they are working so that they spread fewer lifetime resources more evenly over their life cycle. In the rule-of-thumb case, there is no additional saving by the young to take account of smaller bequests and the main impact of greater longevity is that resources are used by those who would otherwise have died instead of a succeeding generation. Since all of these resources will now be spent whereas some would otherwise have been saved, there is a fall in aggregate saving.

Panel A of Chart 6 shows the different response of interest rates in the two cases. With optimising households, there is a small permanent fall in 15-year interest rates of about 1 percentage point (less than 0.1 percentage points per annum); with rule-of-thumb households there is a more substantial permanent increase of about 10 percentage points in the 15-year interest rate (about 0.75 percentage points per annum). Panel B of Chart 6 shows the response of the capital stock in each case. It is permanently higher by about 2% in the case where optimising households increase their saving, but is lower by almost 10% in the case of rule-of-thumb households.

In the optimising case, *aggregate* consumption is eventually hardly affected by increased longevity: but *individual* consumption is reduced sharply because a similar amount of lifetime resources are shared out over longer lives. In the rule-of-thumb case, aggregate and individual consumption are reduced more substantially.

The life-cycle response of consumption to increased longevity is very different under the two approaches to household behaviour considered here. When households are optimising, consumption is reduced by a similar amount throughout the life cycle, although with lower interest rates the decline is slightly larger late in life. When households follow a rule of thumb, the response of consumption depends largely on the timing of when resources are received. The change in longevity affects the size of bequests, reducing them by about 25% in line with the greater number of people reaching old age. The changing size of bequests has little impact on rule-of-thumb behaviour early in life and so most of the reduction in individual consumption is concentrated in later life. This is offset to some extent by the effect of higher interest rates in this case. The changing patterns of consumption are shown in panels C to E of Chart 6.

Panel C shows the response of those born at the time of increased longevity, lengthening the lives of their parents. In an economy of optimising households, consumption is smoothed over the life cycle and is reduced immediately by 2 to 3%. But when households follow a rule of thumb, there is only a small change in consumption when they are working. It is the lack of saving during their working lives that accounts for the need for consumption of this group to fall substantially on retirement.

Panel D shows the response of the parents of those born at the time of changed longevity. These are a relatively fortunate generation in that they benefit from increased longevity themselves, but receive bequests from their parents who do not. As such increased longevity has a negligible effect on their lifetime resources. In the rule-of-thumb case, they benefit in old age from much higher interest rates.

Panel E shows the response of the children of those born at the time of changed longevity. Their bequest will be lower, reflecting the greater longevity of their parents, so that their consumption will be lower over the life cycle. While the optimising households smooth this over their life cycle, the rule-of-thumb households do not reduce their consumption enough when young and so have to reduce consumption more when they are old, particularly in the first period of their retirement.

Panel F shows the sensitivity of the results in the optimising case to different parameter values. In all cases the interest rate response is small, and it is smaller for low values of the coefficient of relative risk aversion.

The effects of lower fertility

In this simulation it is assumed that fertility falls permanently by half a percentage point per period. This is sufficient to reduce the number entering the population in each 15-year period by about 3 million over the course of a century, broadly in line with projected trends. This would raise the steady-state old age dependency rate (as plotted in Chart 1) by about 5 percentage points.

This demographic shift has relatively modest implications for welfare in the steady state, although aggregate consumption and income are substantially affected by the reduced population. The rise in the old age dependency ratio raises the equilibrium capital labour ratio and this reduces the equilibrium real interest rate and raises the equilibrium wage rate. These changes lead optimising households to increase consumption in the early part of their life at the expense of later consumption, with no substantial impact on lifetime consumption. Panel A of Chart 7 shows the interest rate effect.

Some cohorts lose out in the transition to the steady state. In particular, those born in the four periods up to and including the period in which the birth rate falls. This is a reaction to a lower interest rate in the part of their lives when they are net savers. This is not a problem for households in the steady state since higher wages counteract lower interest income. Panels B and C of Chart 7 show consumption per head of the first generation experiencing lower fertility and their children.

As before, the results are different in the case where households follow rules of thumb rather than optimising their consumption over the life cycle. In this case, the shift to a new equilibrium with higher wages and a lower rate of return on capital, encourages these households to consume more when they are young, but they need to compensate for this by consuming less when they are old.

Summary of model results

The model suggests that the welfare implications of ageing depend upon the nature of the demographic shock. A baby boom is a temporary demographic shock with no impact on the length of life of individuals. It is shown to reduce the welfare of the baby boom generation while improving the conditions of their parents and children. This inter-generational welfare implication arises simply from the fact that the baby boom generation are less scarce than others and this reduces the value of their labour when they are working and the value of their capital when retired. The impact of greater longevity is different since it affects the average length of life of individuals. It is shown to have an adverse impact on the consumption of all generations. This arises partly out of the property of the model that people do not work for longer when they expect to live longer. With longer life-spans but no change to labour supply, households have to spread their resources over more time and hence must consume less. Lower fertility is a permanent demographic shock that has no impact on the length of life of individuals. It has no apparent long-run effect on individual welfare, although the induced change in interest rates does encourage households to schedule more of their consumption early in their life. Lower fertility does however have an adverse impact on those generations alive when it occurs. This derives from the fact that these generations lose from having lower interest rates when they are old without benefiting from having higher wages when they are young.

Many of these changes reduce optimal consumption in retirement relative to what it would have been without a demographic shock. These effects are compounded when households determine their consumption by following rules of thumb since in this case they do not make the necessary adjustment to their consumption when they are young.

The implications for interest rates are dependent on the model of household behaviour used. In the case of a baby boom and lower fertility, interest rates move in a qualitatively similar way in both the optimising and rule-of-thumb models although the magnitude of the effects is different. When households are optimisers the effects are generally small as saving responds to changes in interest rates and so dampens their movement. In the case of increased longevity, the models have different predictions about the direction of change in interest rates, reflecting different responses in saving. When households are optimisers, aggregate saving rises in response to increased survival rates and this depresses interest rates mildly. But when households make no provision for increased survival, aggregate saving falls, raising equilibrium interest rates.

4. The likely impact of demographic change on asset prices and rates of return

The previous section analysed the impact of demographic change in a closed-economy model where there is a single rate of interest which is determined by the rate of return on capital (after depreciation). One of the key implicit assumptions of such models is that consumption goods can be costlessly transformed into capital goods. Because of this, the relative price of assets does not vary over time since there is no essential difference between consumption goods and capital goods. A number of recent papers have extended this type of model in three different directions. First, some authors have considered the impact of capital adjustment costs which cause a wedge to develop between the price of consumption goods and capital goods. In these models, increases in the demand for capital raise the price of existing capital goods relative to consumption goods. Second, other authors introduce a range of different financial instruments which allow more risk averse households to reduce their exposure to risk. These models generate an equilibrium risk premium on risky assets which may be sensitive to demographic change. Third, some recent research has considered the impact of demographic change on capital flows in open economies, generating possible effects on the exchange rate. This section considers each of these separate strands of the literature before discussing the empirical evidence.

Asset prices and demographic structure

The seminal paper in this area is Poterba (2000). It is motivated by popular claims that the ageing of the US baby boom generation is a key factor in explaining the recent rise in asset values, and by predictions that asset prices will decline when this group reaches retirement age and begins to reduce its asset holdings. In order to analyse this issue, Poterba develops 'projected asset demands' based on the actual saving behaviour of different cohorts and the projected future age structure of the US population. Part of Poterba's contribution is to note that since people do not dissave sharply in retirement, then projected asset demands will not drop sharply when the baby boomer generation retires and, as a consequence, a sharp prospective decline in asset values is not bound to occur.

Poterba's argument has been contested by Abel (2001) in a paper entitled 'Will bequests attenuate the predicted meltdown in stock prices when baby boomers retire?' Abel presents an OLG model similar to that presented in Section 3 above with the addition of costly capital adjustment to show that the dynamic behaviour of the price of capital is not affected by a bequest motive. Here the bequest motive is used to account for Poterba's evidence on the lack of significant dissaving in retirement. Intuitively, Abel's argument is that while a bequest motive makes the demand for capital higher than it would otherwise be, it also makes the supply of capital higher and that what matters for predicting *changes* in asset prices is changes in demand relative to supply. In effect, the only way in which a bequest motive could insulate asset prices from the effects of demographic shifts is if it were stronger when the number in retirement is larger.

Abel's argument is an important one, but it does not overturn the main thrust of Poterba's case, that projecting future asset demands is of key importance in assessing the likely response of asset prices to changing demographic structure.

Abel’s model has a relatively simple structure with two overlapping generations of optimising households and fixed labour supply behaviour. The adverse impact of a baby boom falls heavily on the baby boom generation; their wages are reduced when they are at work and the return on their saving is low when they retire. The simplicity of the model means that there is very little that households can do to avoid the consequences of a baby boom. The model has been extended by Bütler and Harms (2001) who allow for more generations and flexible labour supply behaviour. They find that by adding more flexibility to the model, the swings in factor prices are substantially reduced. This means that the adverse impact of the baby boom on the baby boom generation is much smaller when labour market activities can be shifted across time. This comes about as the boomers’ parents save more when young in anticipation of rising asset values when they are middle aged and work less in middle age. Both of these effects support the wages of the boomers when they are young. Conversely, the children of the boomers postpone their entry into the labour market when they are young to benefit from higher wages when they are middle aged.

Asset returns and demographic structure

An important point made by Poterba in commenting on the debate about the effect of demographic change is that in efficient markets asset prices should change to reflect predictable factors when they first become known. Forward-looking investors should have anticipated the rising demand for capital from the baby boomers at least two decades earlier and bid up share prices at that time. Looking forward, forward-looking asset markets should already be pricing the effects of future changes in asset demands due to demographic shifts. Consequently, there should be no meltdown when the baby boomers retire.

Brooks (2000a) addresses the issue of the effect of demographic change on asset returns in a forward-looking model, similar to that discussed in the previous section with the addition of a riskless asset that can be held in zero net supply. This allows him to explore the consequences of demographic change for the premium on risky over riskless assets. His main finding is that changes in the age distribution have significant effects on asset returns, even when investors are rational and forward looking, and that these effects have important implications for the welfare of baby boomers and surrounding cohorts. A key ingredient of the model is that although agents’ risk aversion is constant over time, agents invest *as if* they are increasingly risk averse as they get older because they are no longer able to benefit from the imperfect correlation between the returns on equity and human capital. Thus people prefer to hold risky assets when they are young and safe assets when they are old. As a consequence, demographic shifts affect the risk premium. However, the effects are quantitatively small. A simulation approximating the effects of the US baby boom shows the riskless return rising from 4.5% per annum to 4.8% per annum when the large cohort is in its peak saving years, falling to 4.3% per annum when the cohort reaches retirement. The risky return moves in the same direction but by less than the riskless rate which is more sensitive to demographic shifts in this model.

International capital flows and demographic structure

As has been noted, most of the models considered in the literature assume that rates of return are determined domestically and so are inconsistent with international capital mobility. Once capital mobility is allowed, capital will flow to countries where the rate of return is highest, equalising rates of return where mobility is perfect. For small open economies, purely domestic demographic shocks would have no effect on the domestic rate of return and countries would export capital when the domestic saving rate is high and import it when it is low.

Cutler *et al* (1990) discuss how the results of their analysis are amended by allowing capital mobility. They find that because the United States is ageing more slowly than other OECD countries, the United States would run a current account deficit until about 2010 with surpluses beyond that until 2020 when rapid increases in the number of elderly again bring about deficits.

Brooks (2000b) outlines the implications of population ageing in a ‘parallel universe’ that is calibrated to look similar to the real world. His simulations show that there will be a turning point in regional savings investment balances between 2010 and 2030 when the European Union and North America will experience a substantial decline in savings relative to investment as their populations age rapidly. This shift will be financed by capital flows from less developed regions which are projected to become capital exporters.

More substantially, this model predicts large changes in interest rates over the next 100 years, falling gradually from around 10% in 2000 to about 6% at the end of the century. This contrasts with the analysis of Boersch-Supan *et al* (2001) who show the rate of return on capital rising in a simulation model from about 7.5% in 2000 to around 8% in 2050.

These papers discuss net capital flows as countries build up wealth in other countries when desired saving exceeds the investment opportunities that are available domestically at the global interest rate. They do not discuss the gross capital flows that emerge from a desire to diversify risk. It is well known that portfolios suffer from ‘home bias’ as they are not diversified internationally by as much as standard international asset pricing models predict (see French and Poterba (1991)). This lack of diversification means that portfolio returns are currently more risky than they need be. One implication of this is that international portfolio diversification is likely to increase as fund managers become more aware of its benefits.

While there is a literature discussing the impact of demographic change on capital flows, there is no discussion of how this might affect exchange rates. Generally, the exchange rate would be expected to appreciate in countries that are building up foreign assets, but there are no formal models linking this to demographic change.

Empirical evidence on asset returns and demographic structure

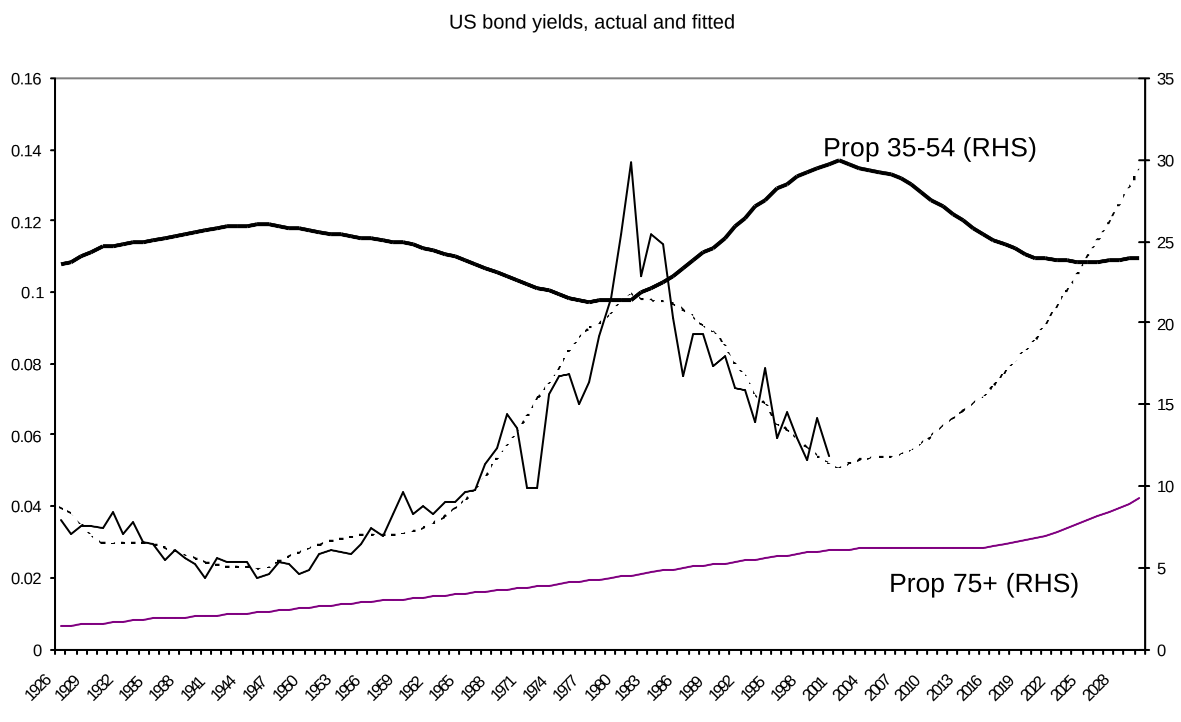
It is important to recognise that shifts in the demographic structure have occurred in the past and this may be used to test predictions about its link to asset prices. This includes house prices as well as the prices of financial assets.

Mankiw and Weil (1989) analysed the relationship between house prices and the age structure of the US population. Their key demographic variable explaining owner-occupation is the number of households between 25 and 40. The study forecast that reduced housing demand would result from ageing of the US population after 1990 and this would lead to house prices in the ensuing years lower than 'any time in recent years'. Of course, house prices did not fall as predicted over the 1990s. This does not refute the thrust of the Mankiw-Weil analysis since other factors have undoubtedly changed so as to offset the impact of demographic changes on house prices over the past decade. Nevertheless, it does emphasise the need for caution in making predictions about asset prices on the basis of known demographic trends without acknowledging the wider uncertainty that exists.

Similar trends in the house-buying population were suggested as a cause of the lacklustre state of the UK housing market in the late 1990s (Wallace (2001)), but the subsequent recovery in the housing market again suggests that demographic trends are not the only cause of house price growth.

Chart 8 is based on analysis reported in Barclays Capital (2001) showing the US long bond yield and its predicted value based on a demographic model of yields. The demographic model is estimated using data from 1926 to 2000. The fitted bond yield depends negatively on the proportion of the population in the prime saving years from 35 to 54 and positively on the proportion who are over 75. The chart suggests that the fit of the model is good as is confirmed by re-estimation of the model using data kindly supplied by Barclays Capital.

Chart 8: A demographic model of US bond yields



However, there are a number of reasons to doubt the Barclays Capital estimates.[11] First, the model attempts to explain nominal returns in terms of real demographic factors when the theoretical relationship would be between real returns and demographic factors. This model implausibly implies that inflation is being accounted for by demographic changes. Second, the

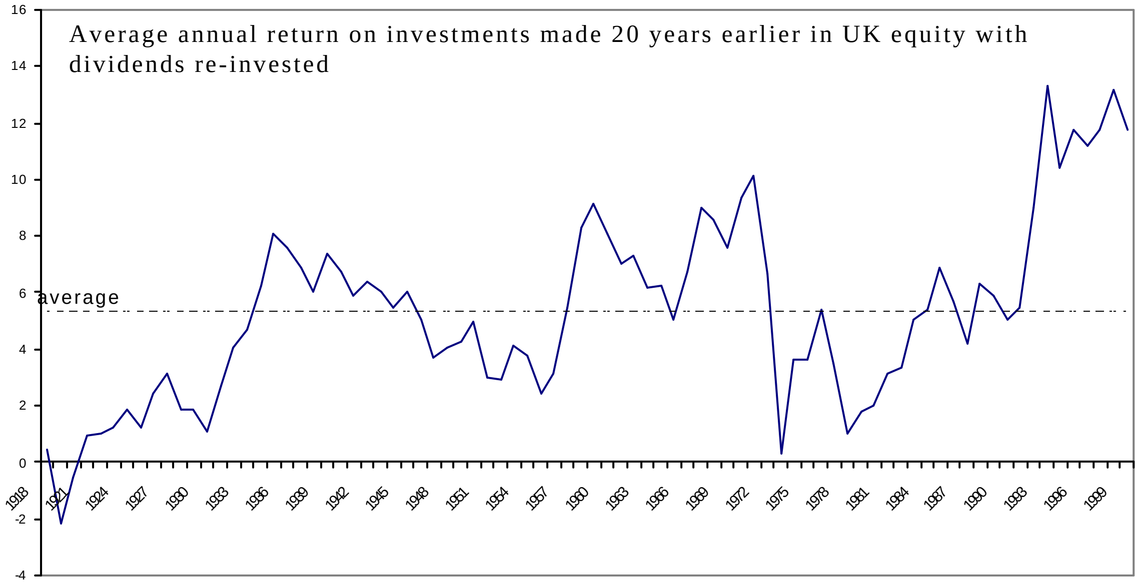
(11) Booth *et al* (2000) are similarly sceptical of the Barclays Capital analysis.

estimated relationship is overfitted in that all possible demographic variables are included on the right-hand side of the equation to be estimated. Third, the estimated coefficient on the high saving 55-65 age group is very low relative to that of the 35-54 year old group. Fourth, the out-of-sample predictions of the model (shown in Chart 8) look implausibly large.

Despite these points the Barclays Capital evidence is consistent with the existence of an effect of demographic change on asset returns and suggests that further empirical analysis is worthwhile. However, Poterba (2000) questions whether there are sufficient degrees of freedom to test for low-frequency patterns in asset prices, 'There is one Baby Boom shock in the post-war US demographic experience, and as the Baby Boom cohort has approached fifty, real stock market wealth has risen rapidly. This is consistent with some variants of the demographic demand hypothesis. Whether fifty years of prices and returns on this experience represent one observation, or fifty, is however an open question.' Despite this caveat, Poterba goes on to analyse the empirical evidence. He concludes that 'it is difficult to find a robust relationship between asset returns on stocks, bonds, bills and the age structure of the US population over the last seventy years.'

This negative result is consistent with the small effects on asset returns generated by the theoretical models and suggests that Poterba is unable to isolate it in the data because of other influences on asset prices. That is, these possible changes need to be set against the normal levels of volatility that exist in asset prices. Chart 9 shows the *ex post* annual average rate of return on equity in the United Kingdom on investments held for 20 years at a time with dividends re-invested.

Chart 9: Long-run asset returns



Likely responses of asset prices to demographic change

Poterba's analysis has implications for future trends in asset prices. The variable that is most successful in explaining past trends in asset prices is the 'projected asset demand' variable that takes account of the observed saving behaviour of different age groups and changes in the size of these groups. However, he is not expecting this to change sharply when the baby boomers retire since asset decumulation takes place much more slowly in retirement than accumulation occurs during working years. Whether this continues in the future is not clear and is likely to be dependent on the path of asset prices themselves. If, for whatever reason, future asset prices are weak, then the old generation may be forced to run down more of their asset holdings than was the case when asset prices were strong.

5. Conclusion

This paper has discussed the likely development of aggregate living standards in the United Kingdom over the course of this century and some of the risks to this outlook. It has suggested that even under relatively cautious assumptions about technological progress and capital accumulation, aggregate living standards (as measured by GDP per head) are set to double over the next 50 years. While there are clear risks to this aggregate outlook, these would be present even without demographic change. The paper has also discussed the risks to the living standards of individuals and individual cohorts. These risks have changed in three main ways as a result of demographic change. First, ageing has been a factor throughout the world in encouraging a shift from public to private provision for old age, increasing the proportion of retired people exposed to risks to market prices and rates of return. Second, the size of the group exposed to such risks is growing larger as a direct result of ageing. Third, any adverse effects of demographic change are most likely to be felt in old age; one of the effects of people living longer, is that they have to spread their lifetime incomes over more years of life, implying a need for more saving when working. If this does not occur, then consumption has to be a lot lower in old age than would have been the case had proper provision been made for retirement.

Consider first the impact of demographic change on the economy as a whole as measured by GDP growth and GDP per head. GDP growth is determined ultimately by three factors: the available labour supply, the capital stock and technological progress. The UK population between the ages of 15 and 60 is expected to peak in 2014 before declining gradually over time. The impact of this on the supply of labour is difficult to quantify because of possible changes in participation rates of those of working age and those beyond it and changes in the number of hours worked. In 1930, Keynes speculated that the average working week 100 years hence would be 15 hours per week.[12] In fact, since 1950 average hours per worker have fallen from 2,135 hours per annum to 1,597 hours in 1996 (O'Mahony (1999)). A relatively modest correction in this downward trend would offset the effect of changing demographics on labour supply.

Perhaps more important than possible changes in average hours per worker is the effect of technological change on the productivity of each worker. Technological change has been the main driver of growth in the post-war period and is likely to make a similar contribution over the future. Cutler *et al* (1990) calculated that a rise in the productivity growth of 0.15% per annum would completely reverse the impact of demographic change on living standards in the United States.

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(12) Quoted by Visco (2001).

Simple illustrative calculations in this paper suggest a relatively comforting picture of continued growth in UK living standards implying that the ageing of the UK population is unlikely to be the cause of a downturn in economic prospects. But this does not mean the upbeat projection is any way guaranteed to happen. The main proximate risks are a halt to technological progress and capital accumulation. There is little to link technological progress directly to demographic change, but the outlook for capital accumulation is closely linked to saving behaviour which is in turn affected by ageing.[13] Miles' (1999) analysis suggests that the aggregate saving rate in the United Kingdom will fall by about 8 percentage points between 2000 and 2030 as the population ages. Such a large change in the rate of capital accumulation would slow down the rate of growth of output, although living standards would continue to rise in the absence of other shocks.

The impact of ageing on the rate of saving and capital accumulation is one of the key uncertainties surrounding any projection of long-term growth. There are at least two dimensions to this uncertainty. First, how the saving behaviour of old people will develop in the new environment. Second, whether domestic saving matters in determining domestic investment in competitive international capital markets.

On the first issue, there is a puzzle concerning why old people do not consume more. There are a number of possibilities including bequest motives, accidental bequests, and capital market imperfections which prevent old people realising fair values for their investments. There is a clear possibility that whatever obstacle has prevented people from spending all of their resources in the past will be cleared out of the way when their numbers and their political and market power increase. This raises the risk of a larger fall in aggregate saving than would be anticipated on the basis of existing models of aggregate saving.

On the second issue, any decline in saving and so capital intensity would put upwards pressure on the rate of return on domestic capital. To the extent that this rises relative to that available in other countries, it would tend to attract capital from abroad and this would make up for the lower level of domestic saving. The risk here though is that the global ageing problem will reduce domestic saving by more in other countries and that this will put upward pressure on international interest rates. Since the ageing problem is more severe in other countries, it is possible that capital will flow out of the United Kingdom even though domestic saving is being reduced by ageing. Nevertheless, most calculations of the impact of ageing on rates of return show small changes of less than a percentage point.

This discussion points to the risks associated with the long-term outlook for saving and investment in the United Kingdom. But there is a danger in looking at these issues in isolation as if changes in the demographic structure had a definite impact on saving and could not respond in any way to changes in economic incentives. The analysis of this paper and others shows that aggregate saving responds endogenously to a range of factors. This paper considers three different types of demographic shocks: a baby boom, an increase in longevity and a decline in fertility. The overlapping generations model used for this purpose makes it possible to assess the impact of these shocks on the welfare of different generations under different assumptions about

[13] According to some growth models, technological progress could be indirectly retarded by a slowdown in capital accumulation.

household behaviour. It finds that a baby boom has an adverse effect on the baby boom generation for the obvious reason that when they are of working age their abundance drives down wages and when they are of retirement age the abundance of their saving drives down the rate of return. The impact of a baby boom on other generations is largely beneficial. Increases in longevity, not accompanied by changes in labour supply, have a detrimental effect on annual consumption per head for the obvious reason that people have more years over which to spread their consumption. Changes in fertility appear to have very little effect on individual consumption per head, although they obviously affect aggregates because of changes in the number of people.

An important conclusion of these models is that while individual consumption over the life cycle may not be strongly affected by demographic change, there can be large effects at particular parts of the life cycle when individuals do not attempt to spread their consumption evenly. For example, the analysis of greater longevity suggests that this might reduce individual life-time consumption by about 2% if the change is spread evenly over time. But if individuals follow rule-of-thumb behaviour prior to retirement and do not accumulate enough assets, the reduction in their life-time consumption will be concentrated into the years when they are old. This is particularly important at the current juncture since many people in prime saving age will observe their own pensioner parents living longer without any obvious adverse effect on their consumption. This could be misunderstood as suggesting that their own saving for retirement is adequate. Yet the formal model suggests that the early generations to benefit from greater longevity do not have to reduce their consumption since the capital accumulated by previous generations is not affected by their longevity. But their children will receive smaller bequests. Moreover the current generation of pensioners have benefited from extraordinarily high asset returns which are unlikely to be repeated.

The implications of this analysis for interest rates are modest. This is consistent with other research which suggests that the effect of demographic change on asset prices more generally is likely to be small. This leads on to the second conclusion of this paper, that the risks to the living standards of individuals and individual cohorts are large. While the impact of demographic change on asset prices is small, the historical volatility of asset prices and rates of return is significant. This is unlikely to be affected by demographic change but it means that those relying on financial market returns for their retirement income could be much less lucky than those who enjoyed the high returns of the 1980s and 1990s.

Moreover, the projected increase in the number of people in this position raises the risks of both large numbers suffering the effects of financial shocks as well as risks to macroeconomic and financial stability. Recent experience with endowment mortgages emphasises that the returns on long-term investments can turn out to be substantially different to expectations. In a similar way, a period of very low rates of return on capital would leave people with much lower pension entitlements than had been anticipated. This can occur even when overall asset returns have been strong if investors have poorly diversified portfolios, but the adverse effect of it occurring for a substantial group of savers could be severe. Such an outcome would have macroeconomic repercussions if lower expenditure by the retired was intensified by lower spending by those of working age who become concerned about their own retirement income. It would have systemic implications if lower asset returns meant that debts could not be paid.

Given the lack of financial sophistication of many households, there is a clear educational role for financial regulators in informing people of the risks they face and what action they might take.

Throughout the paper it has been assumed that demographic change is one of the few things that people can be certain of, but this too is uncertain. Population projections have tended to be relatively cautious with lives turning out to be longer than had been anticipated. The risk of even greater longevity than has been assumed is a real one and points to the need for more information on the risks faced by those planning for the long term.

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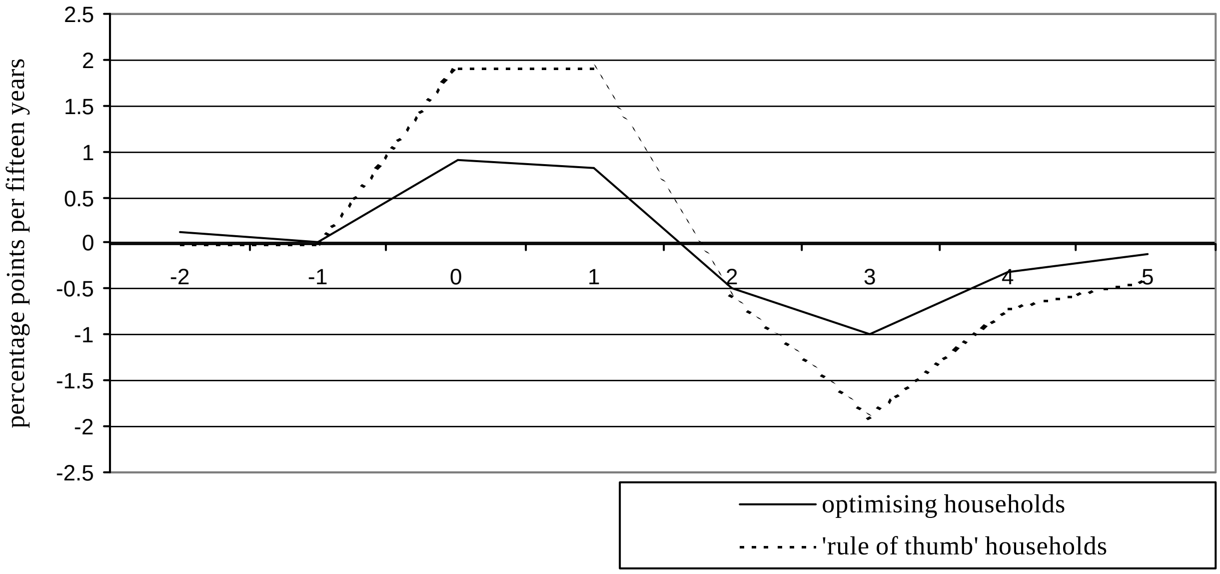
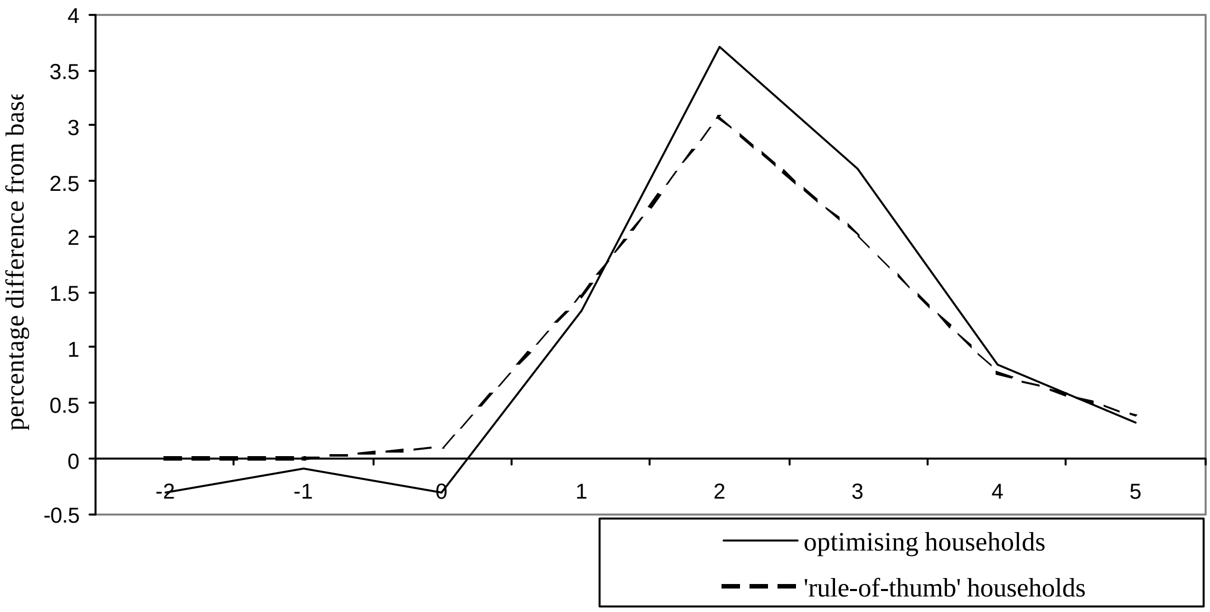
Chart 5: The implications of a baby boom

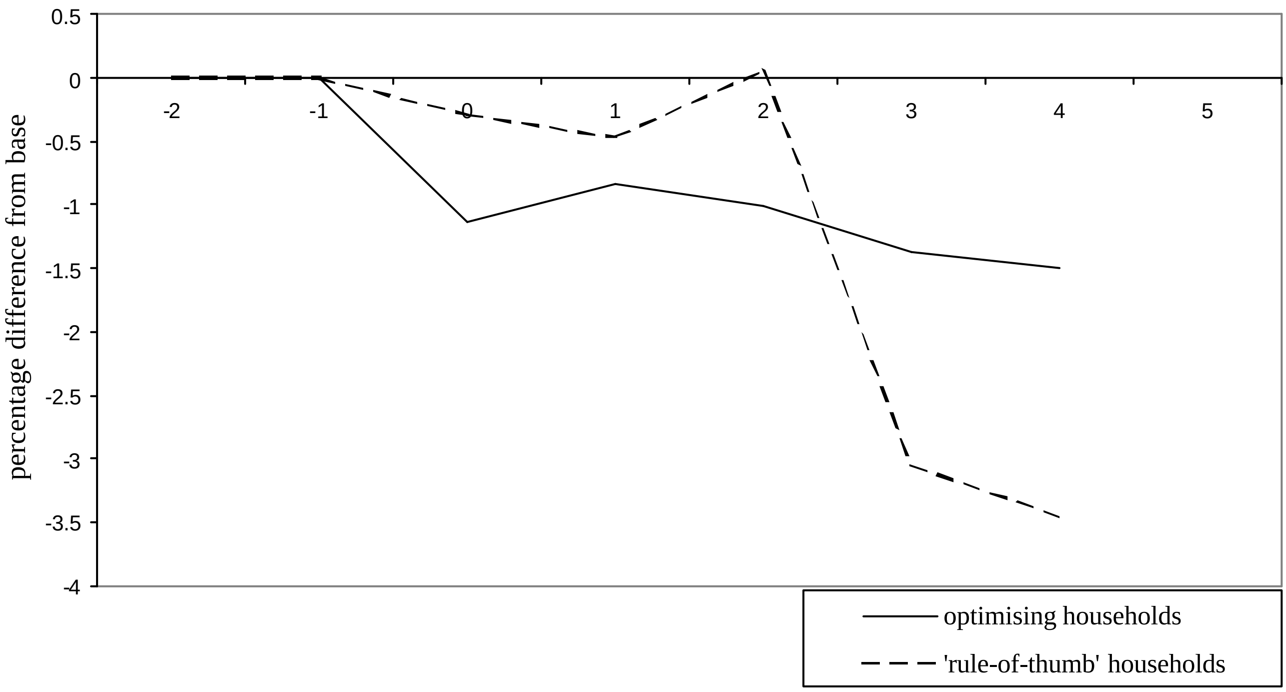
A. Interest rate response to baby boom at date 0



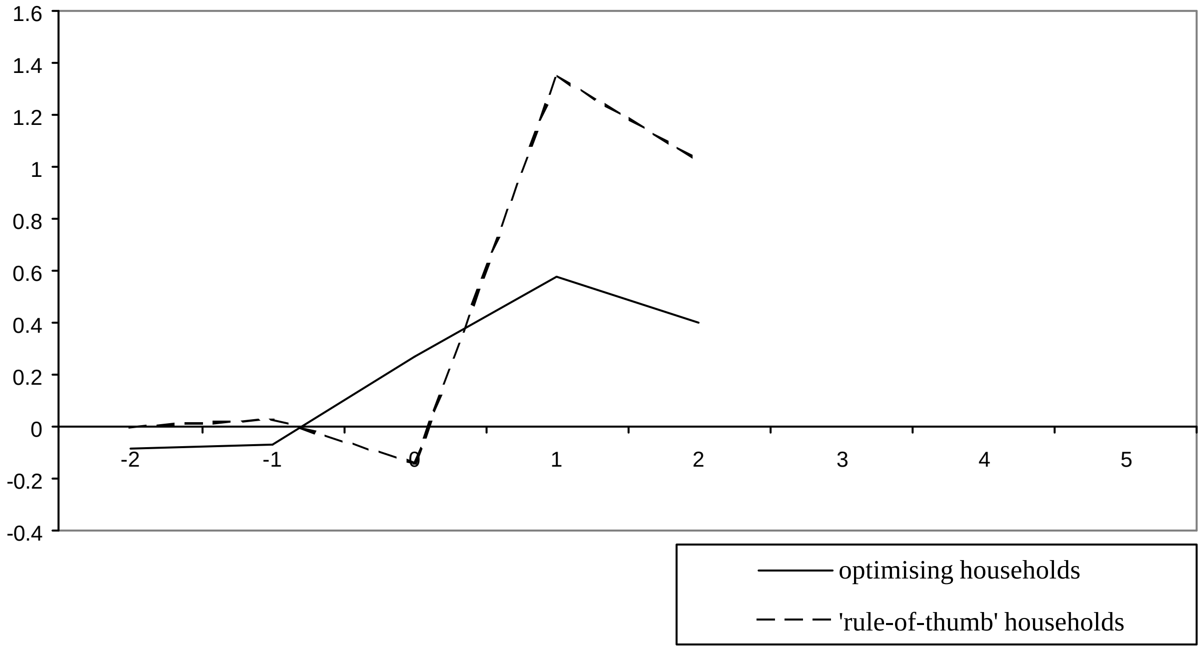
B. Response of capital stock to baby boom at date 0



C. Effect of baby boom at date 0 on consumption per head of boomers



D. Effect of baby boom at date 0 on consumption per head of boomers' parents



E. Effect of baby boom at date 0 on consumption per head of boomers' children

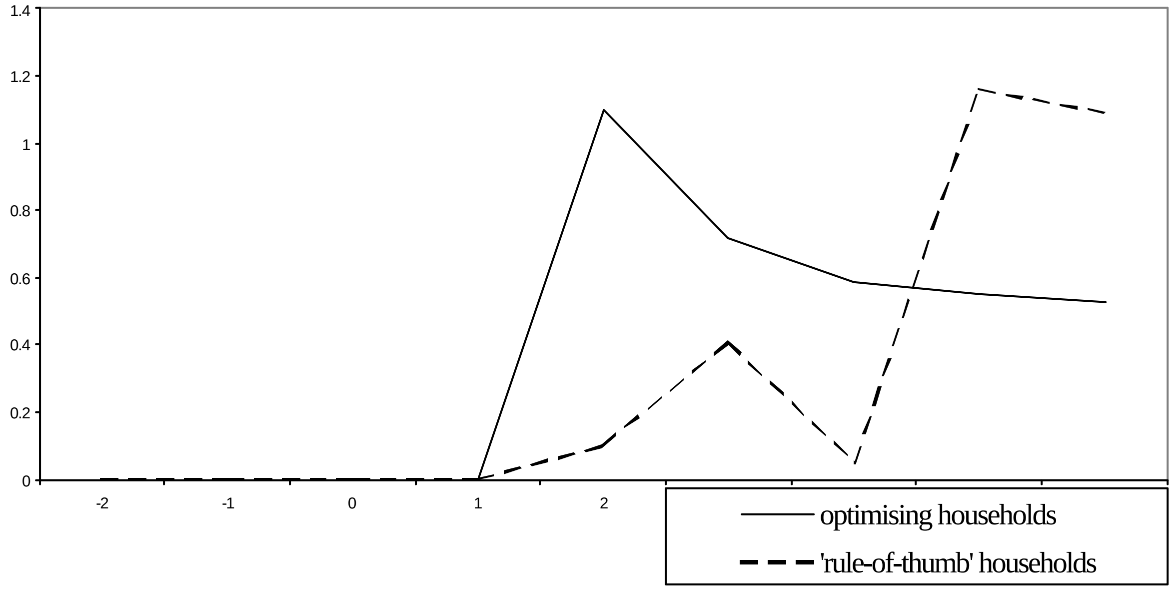
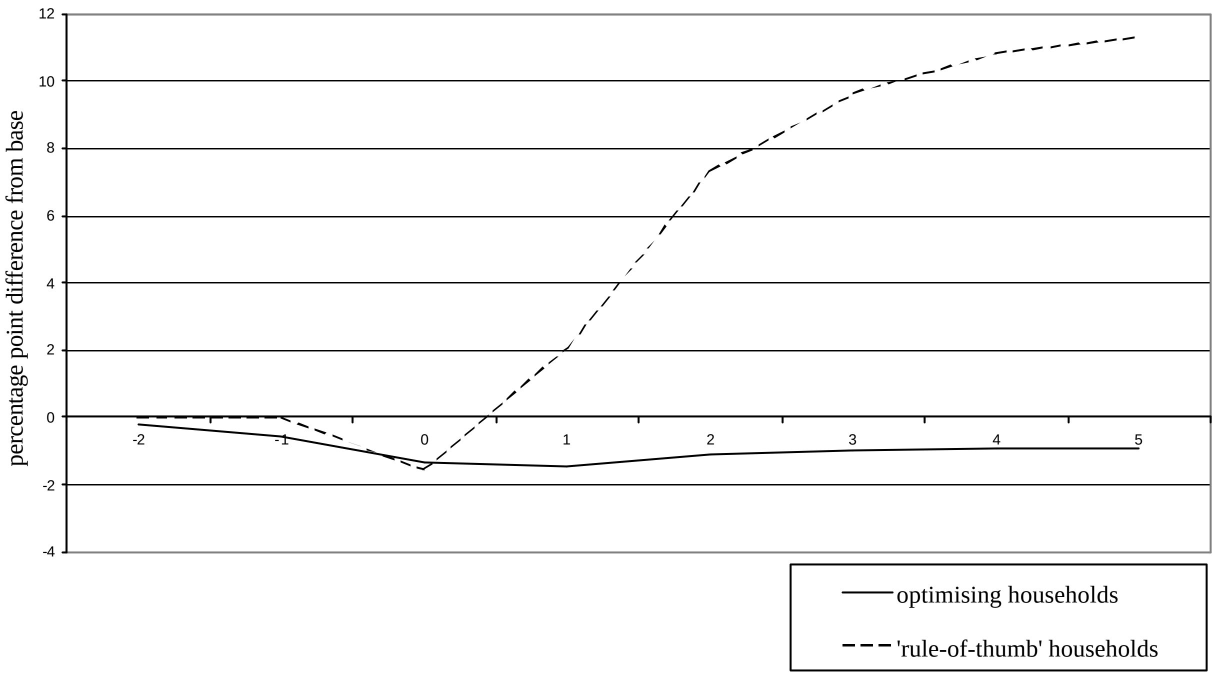
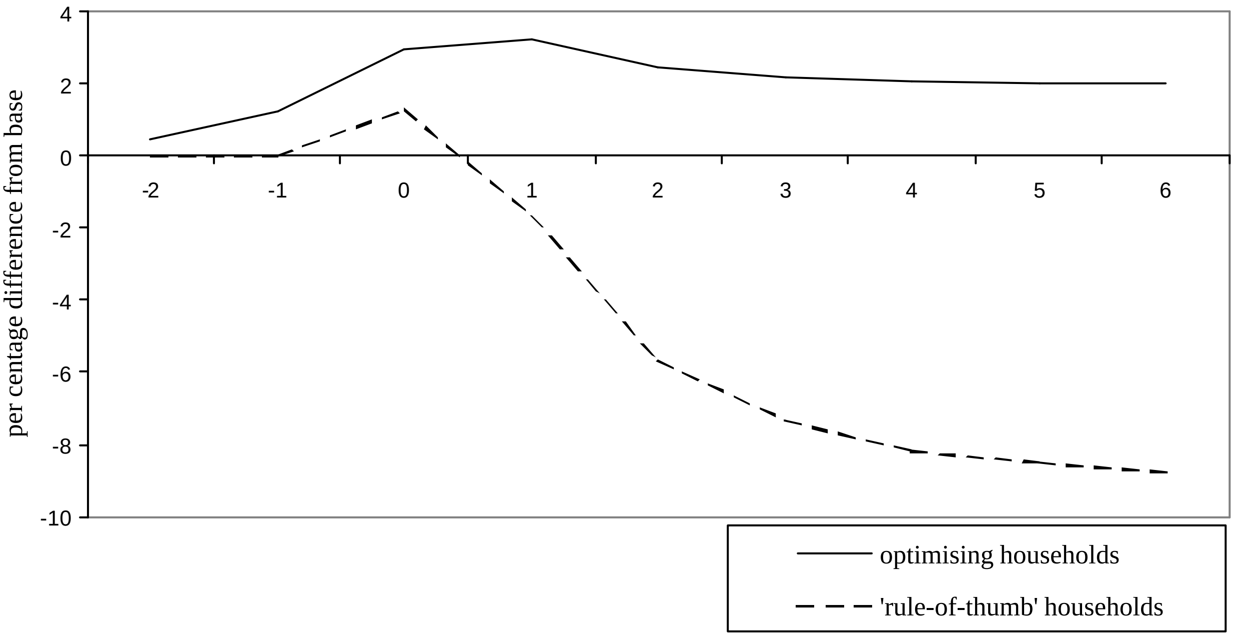


Chart 6: The implications of increased longevity

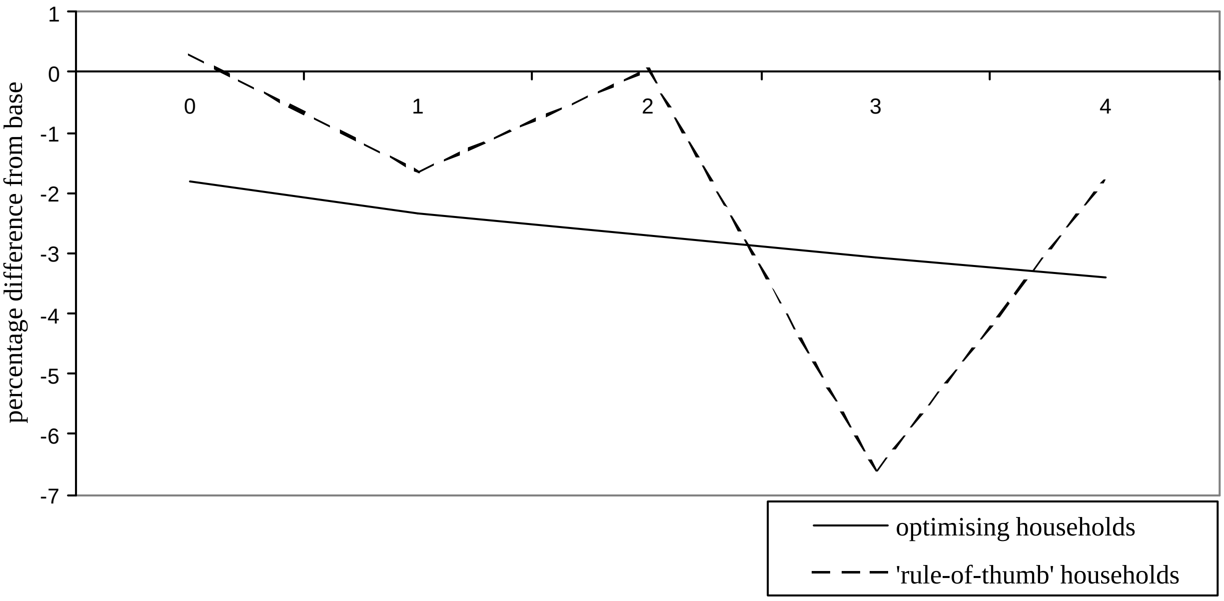
A. The response of interest rates to increased survival to old age from date 0



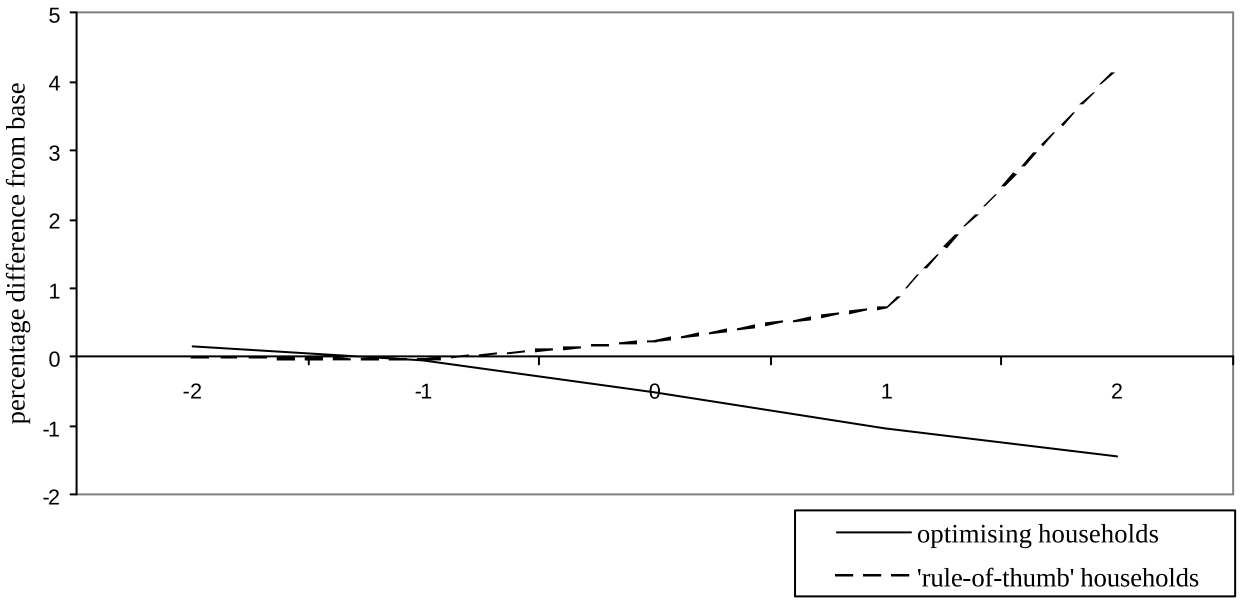
B. Capital stock response to increased survival to old age from date 0



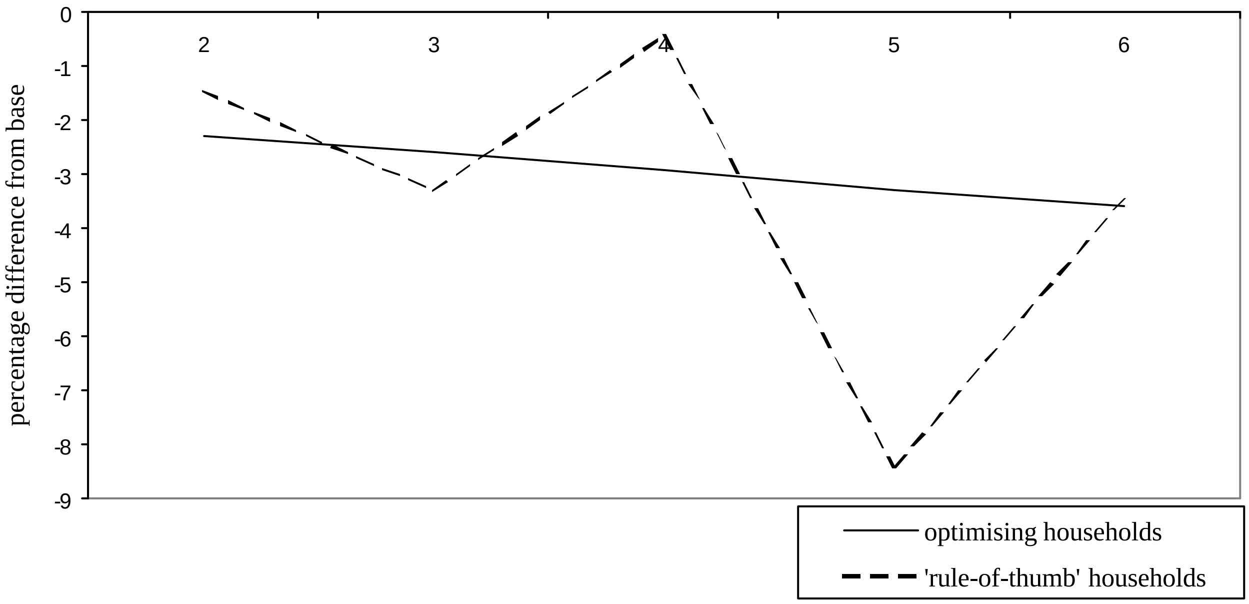
C. The effect of an increase in survival to old age from date 0 on consumption of generation 0



D. The effect of an increase in survival to old age from date 0 on consumption of parents of generation 0



E. The effect of an increase in survival to old age from date 0 on consumption of children of generation 0



F. Interest response to increased survival: sensitivities

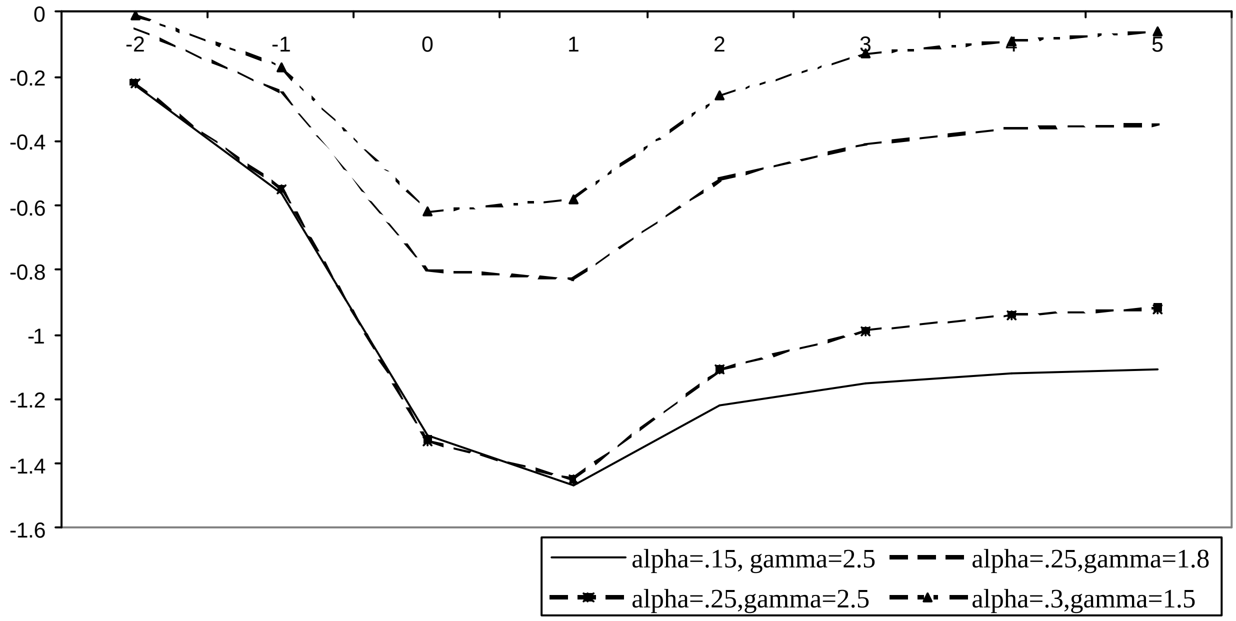
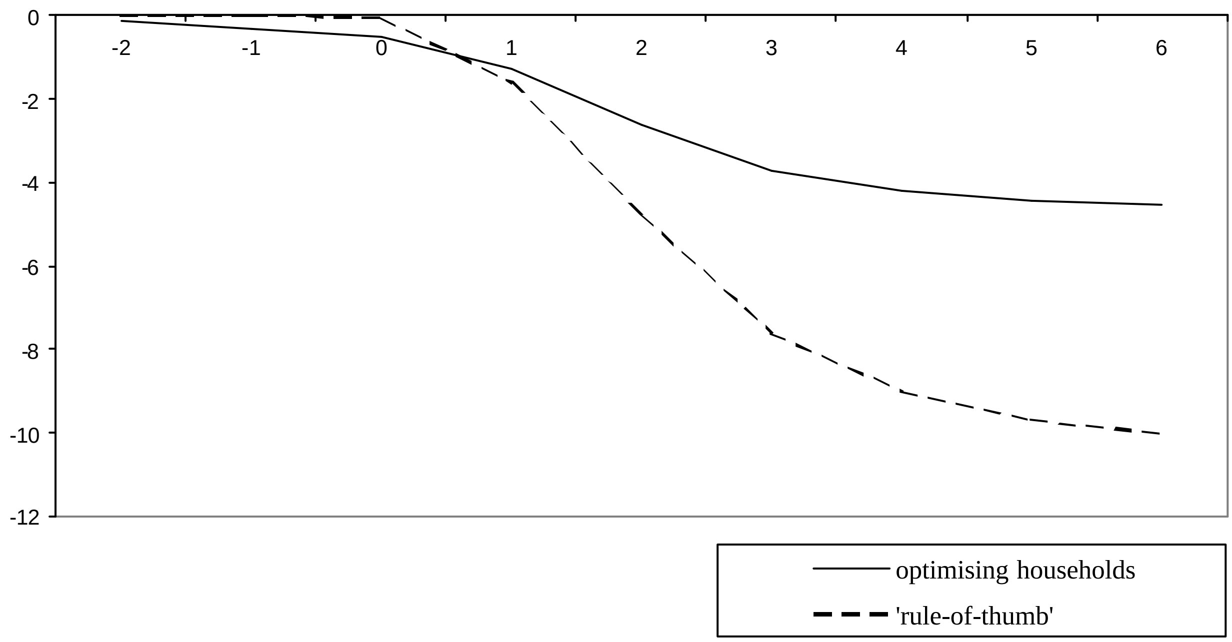
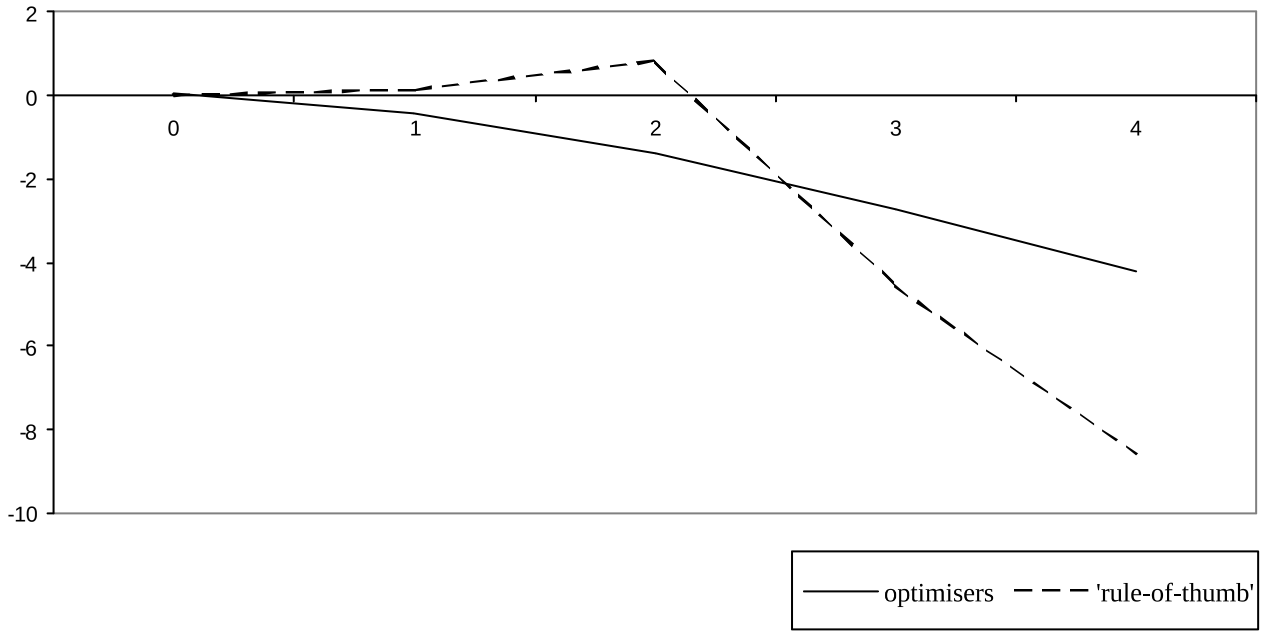


Chart 7: The implications of reduced fertility

A. Effect of lower birth rate on rate of interest



B. Effect of lower birth rate on generation 0



C. Effect of lower birth rate on consumption of children of generation 0