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The Effect of Alternative World Fertility Scenarios on the World Interest Rate, Net International Capital Flows and Living Standards

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ABSTRACT

This paper applies a multi-region Ramsey model to the question of the impact of alternative fertility scenarios on the world interest rate, net international capital flows and living standards. The world economy is divided into nine regions consisting of the eight regions in the United Nations long run demographic projections (1998 Revision) plus Japan as a separate region. Age-specific consumption demands and age-specific labour productivity levels are applied. The model is simulated for the low, medium and high fertility scenarios as projected for all regions by the United Nations. Population ageing in five of the nine regions – Japan, Europe, North America, China and Oceania - over the next few decades causes a fall in the world interest rate, which is greater the lower the fertility scenario. The size of net international capital flows is smaller for the low fertility scenario and higher for the high fertility scenario. This is due to the different effect on optimal saving of a change in the world interest rate for borrowing and lending regions. For lending regions the income effect is positive but for borrowing regions it is negative. This causes lending regions to reduce their lending, and borrowing regions to reduce their borrowing, in response to lower fertility; the result is smaller current account deficits and surpluses. Higher fertility results in bigger current account deficits and surpluses. Lower fertility results in an initial boost in living standards followed by reduced living standards later on. Borrowing regions are better off, in terms of living standards, than lending regions following a lower fertility shock.

1. Introduction

There is currently, in OECD countries in particular, a vigorous debate about the role that policy makers can, and ought to, play in influencing the fertility rate. Public concern is widespread that lower fertility rates imply lower living standards, yet the theoretical and empirical evidence is ambiguous. The transition to lower population growth yields a short term dividend for living standards in the form of lower youth dependency and lower capital widening requirements. This dividend is offset later on by higher old age dependency. For a discussion along with simulation results see Weil, 1999; Elmendorf and Sheiner, 2000; and Guest and McDonald, 2002.

These models are, however, single region models. In a multi-regional framework the effect on living standards depends on the effects of lower fertility rates on net international capital flows, through the effect on saving and investment flows, which in turn alters world interest rates. The effect of changing world interest rates on living standards differs for borrowing and lending regions. For borrowers the income effect is negative while for lenders it is positive.

This paper quantifies the impact of alternative fertility rates on international capital flows, world interest rates and living standards by simulating a multi-regional Ramsey model. The model incorporates the changing demographic structure implied by UN population projections for the 21st century under three different fertility assumptions – low, medium and high.

There are several classes of multi-regional macroeconomic models that can be used to analyse the macroeconomic implications of population ageing. The model in this paper belongs to the class of multi-regional Cass-Ramsey-Solow models. This is a single good model. Although generations are not overlapping in this framework, heterogeneity of workers and consumers is captured by weighting for age-specific productivity and consumption needs, respectively. Other examples of this class of models is the OECD model in Borsch-Supan (1996) and the two region open economy model in Cutler et al. (1990). A variation on this approach is the international overlapping generations models of Turner et al. (1998) using the OECD's Minilink model, the models of the Ingenue Team (2001) and Fougere, M. and Merette, M. (1999), and the macroeconometric model of Masson and Tryon (1990). A third and newer class of models is the multi-good general equilibrium models such as the G-cubed model (McKibbin and Wilcoxen, 1995). However, we were unable to find any specific applications of this class of models to the impact of population ageing.

2. Demographic projections

In this model, the world economy is divided into nine regions consisting of the eight regions in the United Nations (2000) long run demographic projections plus Japan as a separate region. The nine regions are: Africa, Asia (excluding China, India and Japan), China, Europe, India, Japan, Latin America, North America and Oceania. This is a larger number of regions than has been adopted in other models listed above. We choose for comparison the low, medium and high fertility scenarios in the United Nations projections (up to 2150). The medium scenario assumes that fertility in all major areas stabilizes at replacement level around 2050; the low scenario assumes that fertility is half a child lower than in the medium scenario; and the high scenario assumes that fertility is half a child higher than in the medium scenario. For each of these population scenarios, employment projections by age and sex are calculated from the International Labour Organisation (ILO, 2001) database: Key Indicators of the Labour Market (KILM). These data provide labour force and population by age group and sex for each country in the world for the latest year – typically 1999 or 2000. From these data the aggregate labour force participation rates (LFPR) for each of the nine regions, by age group, are calculated. These age and sex-specific LFPRs are assumed to be the age-specific employment to population (L/N) ratios. Employment projections for each region are calculated by assuming that the age-specific L/N ratios (for both sexes) converge toward those of North America according to the following formula:

$$\left(L/N\right)_{j,a} = \left(L/N\right)_{j-1,a}\left(\frac{\left(L/N\right)_a^{NA}}{\left(L/N\right)_{j-1,a}}\right)^{\gamma} \qquad (1)$$

where *j* is the year from 2001 to 2150, *NA* is North America, *a* is the age group, γ is the convergence parameter set equal to 0.025.

Following Cutler et al. (1990) and Elmendorf and Sheiner (2000) the employment and population numbers are weighted to account for, respectively, age-specific differences in labour productivity and consumption needs. The age-productivity relation in Miles (1999) is adopted, where the productivity weight is a quadratic function of age: $0.05\text{age} - 0.0006\text{age}^2$. The consumption weights are those applied in Cutler et al (1990); that is 0.72 for 0-19 year olds, 1.0 for 20-64 year olds and 1.27 for over 64 year olds. Both productivity weights and consumption weights are non-gender specific.

The aggregate weighted L/N ratio for each region is the support ratio (Cutler et al., 1990). A decrease in the support ratio implies a diminished capacity to meet a given level of consumption needs per capita. An increase in the support ratio implies the opposite. Chart 1 plots the support ratios for the nine regions. The three regions that face imminent steep declines in their support ratios are Japan, Europe, China and North America. The first three of these are large net lenders to the rest of the world and it will be seen below that it is optimal for this to continue in the next few decades. This will enable them to build up wealth to provide for their reduced capacity to meet future consumption needs.

3. The model

The simulations are based on a multi-region Ramsey model of optimal saving, with heterogeneous workers and consumers, habit formation in consumption, and a vintage production function.[1] A social planner maximises, for each region, a social welfare function (see Table 1 for a list of variable names).

$$V = \sum_{j=1}^{h} \left\{ N_j \left(\frac{C_j}{P_j} - \frac{C_{j-1}}{P_{j-1}} \right)^{1-\beta} \frac{(1+\rho)^{1-j}}{(1-\beta)} \right\} + N_h \omega \left(\frac{W_h}{N_h} \right)^{1-\psi} \frac{(1+\rho)^{1-h}}{(1-\psi)} \quad \text{j=1,..,h} \tag{2}$$

where C_0 is exogenous and equal to actual consumption for the region. Equation (2) is maximised subject to the evolution of foreign debt

$$D_j = I_j + C_j + D_{j-1}(1+r_j) - Y_j \qquad j = 1,..,h \tag{3}$$

the vintage production function,

$$Y_j = Y_{j-1}(1-\delta) + A_{j-1} I_{j-1}^{\alpha} (L_j - (1-\delta) L_{j-1})^{1-\alpha} \qquad j = 2,..,h \tag{4}$$

and the definition of terminal wealth

$$W_h = K_h - D_h \quad where \quad K_h = K_0 (1-\delta)^h + \sum_{j=1}^{h} I_j (1-\delta)^{h-j} \tag{6}$$

$$\sum_{i=1}^{9} S_{i,j} = \sum_{i=1}^{9} I_{i,j} \qquad \text{j=1,..,h} \tag{7}$$

The social welfare function (2) includes a reference level of consumption, C_{j-1}, which captures habit formation where the “memory” in habit-formation lasts for only one period. Fuhrer (2000) finds empirical evidence to support such a low degree of persistence in habit formation, using aggregate consumption data for the U.S. over the period 1966 to 1995.

The world interest rate is determined such that world investment equals world saving, condition (7). However, the path of the world interest is exogenous to the social planner for each region, which implies that no region has market power in the world capital market and that indebted regions do not face risk premia on their borrowings. This assumption ensures that the solution is a global optimum.

The initial value of total factor productivity, A, in production function (4) is calibrated for all regions such that optimal investment is equal to actual investment in the initial year. Thereafter, total factor productivity growth is exogenous and constant at 1% per annum for all regions. This implies two things – first, that there is no influence of ageing on technical progress and, second, that there is no convergence of labour productivity among the nine regions. On the effect of ageing on technical progress both the theoretical and empirical evidence is ambiguous, as discussed by Cutler et al. (1990, p. 38). On the one hand slower population growth makes innovation less profitable by reducing the gains from economies of scale through the spreading of fixed costs; and a smaller youth share of the population may reduce innovation through a loss of "dynamism". Also, in endogenous growth models with human capital, the effect of ageing on productivity growth is ambiguous. In the model in Steinman et al. (1998) lower population growth results in less human capital accumulation and therefore a lower growth rate of labour productivity. On the other hand, the model in Fougere and Merrete (1998) shows that ageing will increase human capital formation, through tax effects. Furthermore, slower labour force growth implies

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[1] The rationale for adopting a vintage production function in simulating the impact of population ageing,

a higher relative price of labour and therefore greater incentive to innovate through capital investment. Also, diseconomies of higher population growth, through congestion for example, can reduce labour productivity growth. The empirical evidence on the effect of fertility on labour productivity is relatively scarce - see for example Galor et al. (1997), Ahituv (2001) and Hondroyiannis and Papapetrou (1999) - and somewhat conflicting. Hence the assumption here of zero net effect of ageing on total factor productivity growth seems to be a reasonable starting point.

With respect to the zero convergence assumption, Barro and Salai-Martin (1995, p.26) report that the hypothesis of absolute convergence – where poor countries catch-up with rich countries in their GDP per capita, without allowing for any control variables – has received mixed empirical support.[2] Nevertheless, most multi-regional macroeconomic models adopt some form of productivity convergence. Using the OECDs multi-regional "Minilink" model, Turner et al (1998) assume slow convergence in the rates of technical progress of their five world regions, as distinct from convergence in their productivity levels. The Ingenue Team (2001) assume extremely slow convergence in levels of productivity – the gap between rich and poor countries appears to close by about 20% over 100 years. Dynamic intertemporal general equilibrium models, such as the G-Cubed Model, also typically incorporate some form of technology catch-up (McKibbin, 1999). In this paper, zero convergence in total factor productivity is assumed because, in our initial simulations, we found that all but a very small rate of convergence tended to swamp the effects of differences in fertility rates that we were attempting to isolate. As a result of this, and the uncertainty

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is discussed in Guest and McDonald, 2002(a) (available from the authors).

[2] The hypothesis of conditional convergence, which controls for various characteristics of economies, has received stronger empirical support. However, even the testing of this weaker hypothesis faces some serious econometric problems. See Durlauf and Quah in Taylor and Woodford eds. (1999) for a comprehensive discussion of the theory and empirical tests of convergence hypotheses.

in the empirical literature about productivity convergence, we felt that zero convergence was a reasonable assumption for our purposes.

The parameter ω is set such that the ratio of terminal wealth to consumption is equal to the actual ratio of wealth to consumption in 2000. This prevents a rundown of wealth in the simulations. The simulation length, h, is equal to 150 years which is length of the United Nations demographic projections and also long enough that optimal values in the first 100 years – the period of interest - would not be changed significantly by increasing h. The rate of time preference, ρ, is set equal to 0.025 for each region, which is approximately the rate such that in a steady state the share of consumption in output approaches a constant value.

Table 1. Definition of variables

j	year of the planning period that runs from 1 to h
i	region , from 1 to 9
Y	real GDP
C	aggregate consumption
W	wealth=capital stock plus overseas assets
I	aggregate investment
D	overseas debt
K	capital stock
r	world interest rate
δ	rate of depreciation (5%)
ρ	rate of time preference (2.5%)
β	reciprocal of intertemporal elasticity of substitution (2.0)
ω	weight attached to bequest of terminal wealth in the social welfare function
L	aggregate employment in relative efficiency units
h	terminal period of the maximisation problem (150 years)
N	population
P	population in effective persons
A	efficiency parameter – the initial value is set such that the optimal level of investment is equal to the actual level of investment. Thereafter A grows at 1% p.a.

National accounts data for the initial year are from IMF International Financial Statistics Yearbook (2000). The capital stock to GDP ratio is assumed to be unchanged from their latest values available from the Penn World Tables (Summers and Heston, 1993).

4. The world rate of interest and net international capital flows

Figure 2 shows the impact of the future patterns of demographic change on the world rate of interest. The base case is the medium fertility scenario. Under all fertility scenarios, the world interest rate falls. The regions that face imminent population ageing and hence falls in their support ratios – Japan, Europe, China, North America and Oceania – find it optimal to increase saving and reduce investment. Higher saving allows these regions to smooth consumption and therefore smooth the burden of ageing over time. At the same time their lower employment growth reduces both the marginal product of new capital and capital widening requirements, implying lower optimal investment to output ratios. The relative size of the regions facing these forces puts downward pressure on the world interest rate. The lower is the fertility rate the greater are these forces, and hence the bigger the drop in the world interest rate.

The effect of alternative fertility scenarios on net international capital flows works through the effects on investment, saving and hence current account balances. The direction of these effects is ambiguous in a model in which the world interest rate is endogenous. As noted above, lower fertility reduces the optimal investment ratio. However, this is a first round effect. There is a second round effect that works in the opposite direction, increasing investment through the lower world interest rates that result from lower fertility. Our simulations show that these effects approximately cancel out for at least several decades after which the negative employment dominates. This is illustrated in Figure 3. There are minor differences in the magnitude of these effects between regions.

The effect of lower fertility on saving is also ambiguous. The higher saving described above arising from lower fertility is also a first round effect only. A second round effect occurs through the effect on saving of a changing world interest rate. Here the effect is different for borrowing and lending regions. Lending regions face a positive income effect (lower income) and a negative substitution effect from the lower interest rate that results from lower fertility. Both of these effects tend to lower saving in response to lower fertility and therefore work in the opposite direction to the first round effect on saving. Simulation showed that the second round effect dominates the first round effect for lending regions leading to lower saving. See Figure 3. Hence lending regions face an initial small increase in investment and a larger decrease in saving. The result is lower current account surpluses for lending regions as a result of lower fertility. The opposite occurs for higher fertility. That is, the higher interest rate leads to higher saving and an initial small fall in investment – the net result being an increase in the current account surpluses for lending regions.

For borrowing regions, the second round effect on saving is different to that for lending regions as shown in Figure 3. The sign of the income effect is negative for borrowing regions because they gain income from lower interest rates. Hence the income and substitution effects work in the opposite direction on saving. The net of the income and substitution effects is small enough that the first round effect on saving dominates the second round effect of the lower interest rate. The result is higher saving for borrowing regions in response to lower fertility. Combining with the small initial effect on investment – and large negative effect later on - the outcome is a reduction in current account deficits for borrowing regions. Again, higher fertility has the opposite effect – an increase in current account deficits for borrowing regions.

To summarise, lower fertility leads to lower current account surpluses for lending regions and lower current account deficits for borrowing regions. Hence net international capital flows are lower under the lower fertility scenario. The opposite occurs for higher fertility – an increase in net international capital flows. This is illustrated in Figure 4 which shows the size of net international capital flows for the three alternative fertility scenarios over the next 100 years.

5. Living standards

Living standards are defined as aggregate consumption per effective person, C/P. In considering the impact of fertility scenarios on living standards the analysis above suggests the need to distinguish between borrowing and lending regions. In addition, we compare the case where the whole world experiences lower fertility with the case where only one region experiences lower fertility.

The effects of population ageing on optimal consumption are discussed in (Elmendorf and Sheiner, 2000). The new steady state level of consumption in response to an ageing shock is lower as a result of the net of two effects: the dependency effect and the "Solow" effect. Higher overall dependency (the combination of youth and old age dependency) implies fewer workers per person which lowers consumption possibilities. The Solow effect refers to the gains from the lower capital widening requirements that come with lower employment growth. The path to this lower level of consumption is determined by the changes in the return to saving during the demographic transition. In the closed economy this is determined by the effect of changes in the capital labour ratio on the marginal product of capital. In the open economy it is determined by changes in the interest rate at which the economy borrows and lends from overseas.

Within an overall scenario of population ageing, the effect of lower fertility on living standards in a single economy Ramsey model has been simulated by Guest and McDonald (2002b, 2002c).[3] They show that, in the case where the interest rate is constant, lower fertility is likely to result in an improvement in living standards throughout the planning period. The reason is that there are two consumption dividends that accrue as soon as fertility drops. These are the dividend from lower youth dependency and from lower capital widening requirements. These are eventually offset by higher old age dependency. The net effect is a gain which can be smoothed out over the planning period resulting in higher living standards throughout. Where the interest rate is endogenous the result is somewhat different in that optimal consumption is initially higher, but subsequently lower, under lower fertility (Guest and McDonald, 2002c). However, for a range of reasonable discount rates and parameter values there remains a small net discounted gain from lower fertility.

The difference in the effect of the fertility rate on living standards between the endogenous and exogenous world interest rate models arises through the second round effects of a change in the interest rate on the return to saving and on the cost of capital. Two cases are simulated here. One where a different rate of fertility is experienced by all regions in the world and another case where only one region experiences a different fertility scenario. The latter case is described as the “own region” effect of lower fertility. The own region effect is much smaller because the effect on the world interest rate is much smaller.

Figure 5 illustrates the effect of fertility on living standards for both a representative lending region (Europe) and a representative borrowing region (Africa). Taking the lending region first, lower fertility results in an initial rise in living

[3] The first reference assumes a constant exogenous interest rate and the second reference allows for a

standards as consumption is brought forward by the lower interest rate. This implies lower consumption later, which is reinforced by the income effect of lower interest rates (implying lower income). The outcome is much lower living standards later in the planning period. The reverse story applies in the case of higher fertility. The higher interest rate causes consumption to be postponed early on, relative to the base case, but the effect of higher income enjoyed by the lending country eventually allows for higher living standards.

For the borrowing country, the pattern is somewhat different. For lower fertility, the initial rise in living standards as consumption is brought forward is reinforced by the income effect of lower interest rates (implying higher income) which allows higher living standards. Hence the initial rise in living standards is higher and there is no subsequent fall in living standards for the borrowing country. By the same token, the borrowing country suffers lower income from higher world interest rates under higher fertility. Hence living standards are lower under the high fertility scenario. The own region effect remains relatively small for both the borrowing and the lending country.

Table 1 shows, for each of the 9 regions, the average annual loss in living standards between the year 2000 and 2100 from experiencing lower fertility throughout that time period. The average losses are all less than 0.15% which can be considered to be very small.

Table 1. The effect on living standards of lower fertility

	Average annual % loss
Japan	0.09
Europe	0.12
North America	0.06
Oceania	0.07
Asia	0.02
China	0.14

risk premium in the interest rate.

Africa	-0.01
India	0.06
Latin America	0.06

Finally, we found that the effect of alternative fertility scenarios on living standards is almost entirely accounted for by the dependency effect. This is illustrated in Figure 6 for the case where Europe, as an example, faces a lower fertility scenario. The gap between the total effect and the dependency effect represents the net of two effects described above – the Solow effect and the capital intensity effect. These effects are clearly dominated by the dependency effect which is itself the net of a youth dependency effect and an old age dependency effect.

6. Conclusion

From the simulations of a global model of optimal consumption, investment and saving in this paper, three major conclusions stand out. First, the lower the fertility rate the lower the world rate of interest. This is due to both lower demand for new capital implied by slower employment growth, and higher saving implied by smoothing of the reduced consumption possibilities. To equilibrate the world capital market, the equality of world saving with world investment requires a lower equilibrium rate of interest. Second, lower fertility tends to reduce the size of international capital flows. Lending regions lend less and borrowing regions borrow less. This is largely due to the fact that the income effects of lower interest rates are of opposite sign for borrowers and lenders. Third, lower fertility reduces the average growth in living standards over time. This loss is greater for lenders as a result of the lower income that they earn on overseas assets as a result of lower interest rates.

There are several simplifying assumptions that have been adopted in this analysis in order to quarantine the effect of fertility on the outcomes. For example, all regions experience in the 21st century the same rate of growth of total factor productivity and there are no risk premia faced by borrowers. These assumptions could - perhaps ought - to be relaxed in future work.

APPENDIX

The first order conditions for the maximisation problem for each region, described by equations (2) to (6) are:

$$\frac{\partial V}{\partial C_j} \Big/ \frac{\partial V}{\partial C_h} = \prod_{k=j}^{h-1}(1+r_k) \qquad \text{for j=1,..,h-1} \qquad (A1)$$

$$\frac{dY_{j+1}}{dI_j} = \frac{1}{\sum_{k=1}^{h}\left[\frac{(1-\delta)^{k-1}}{\prod_{\tau=j}^{j+k-1}(1+r_\tau)}\right]} \qquad \text{for j=1,…,h-1} \qquad (A2)$$

The terminal first order condition is

$$\frac{\partial V}{\partial C_h} = \frac{\partial V}{\partial W_h} \qquad (A3)$$

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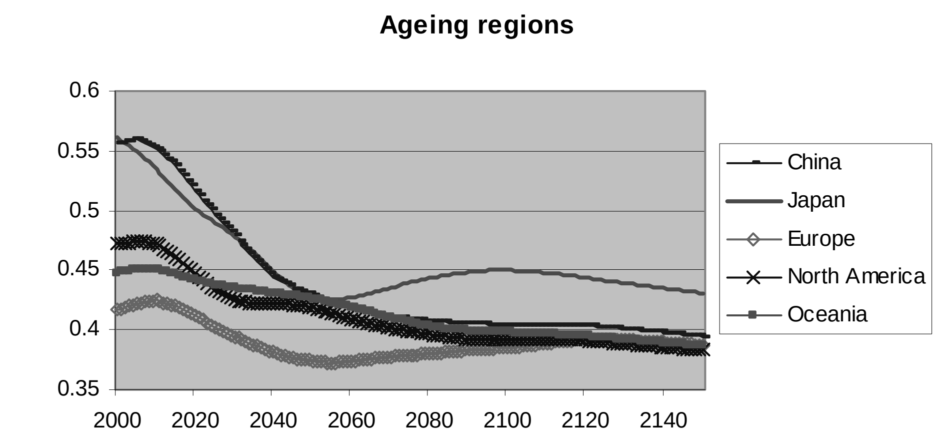
Figure 1. Support ratios - 2000 to 2150. Base fertility.



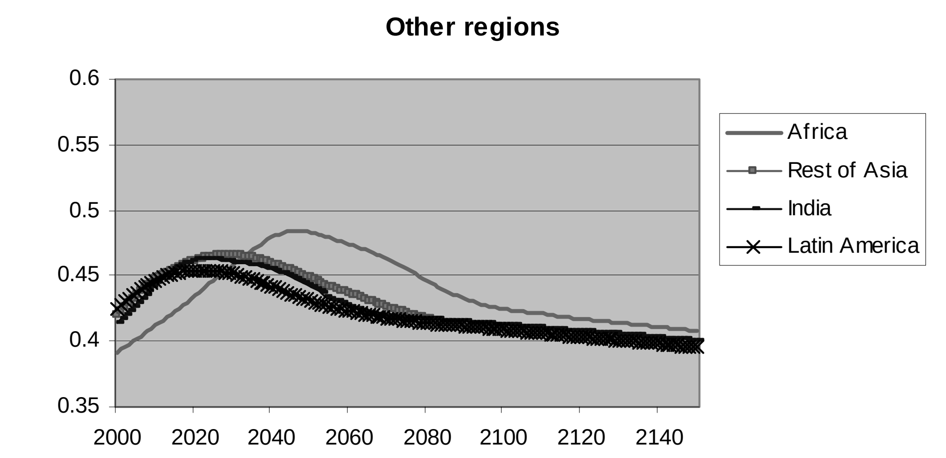


Figure 2. World Interest rate - 2000 to 2100

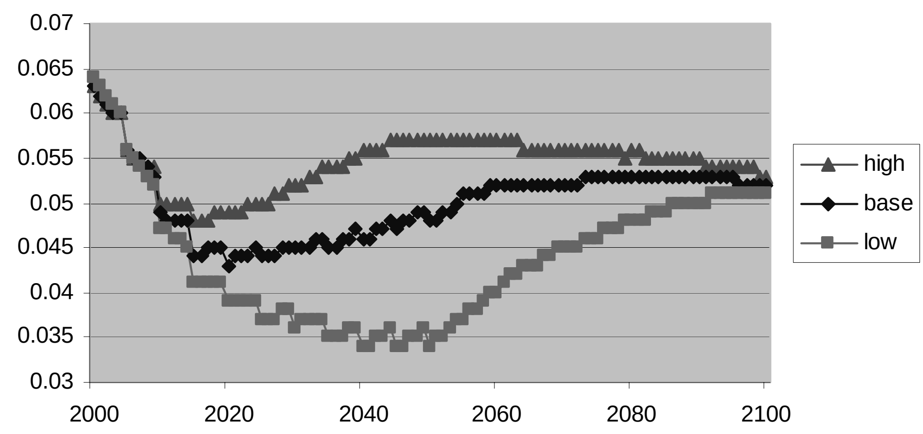
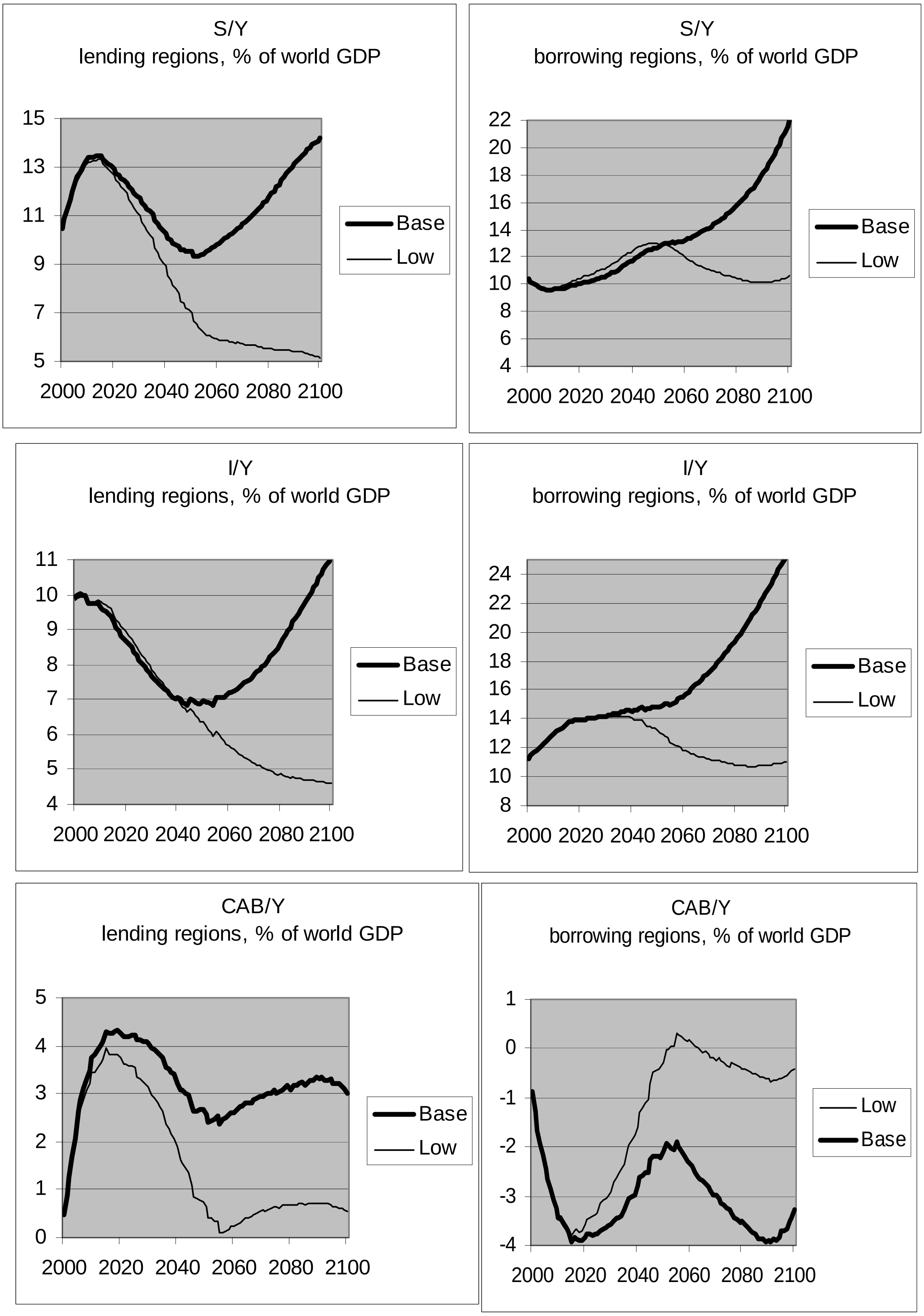


Figure 3. Saving, investment and current account balances



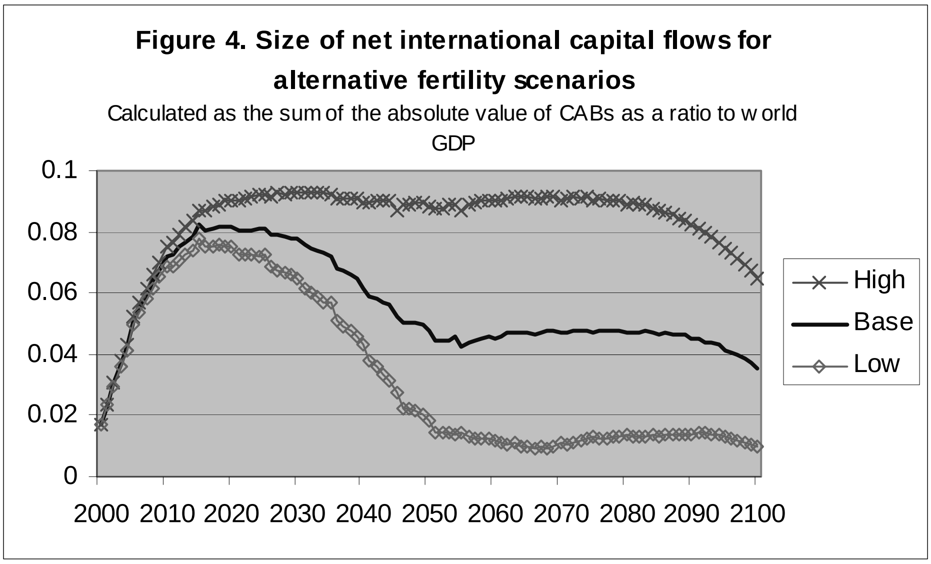
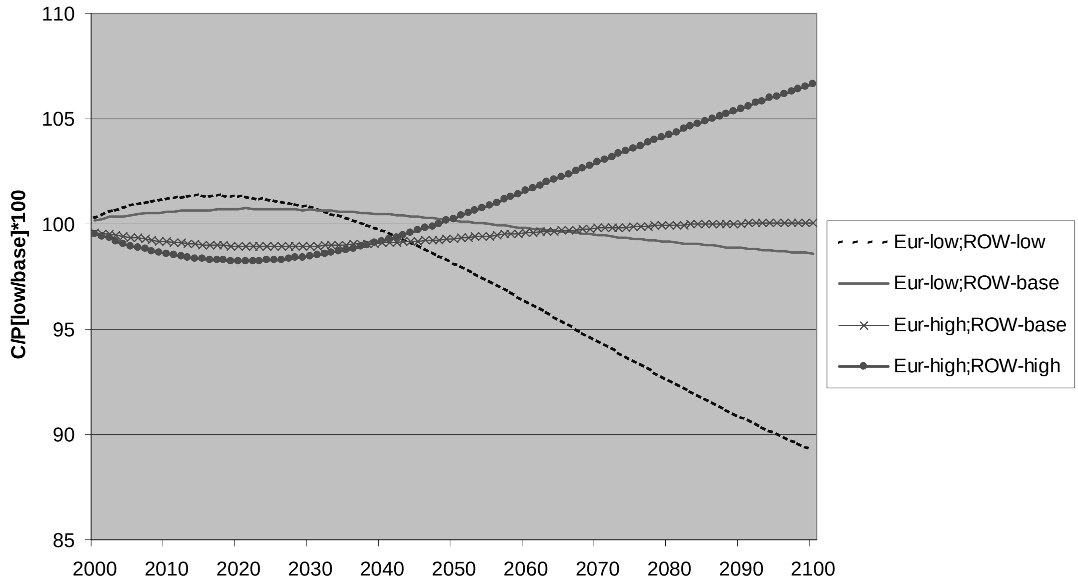
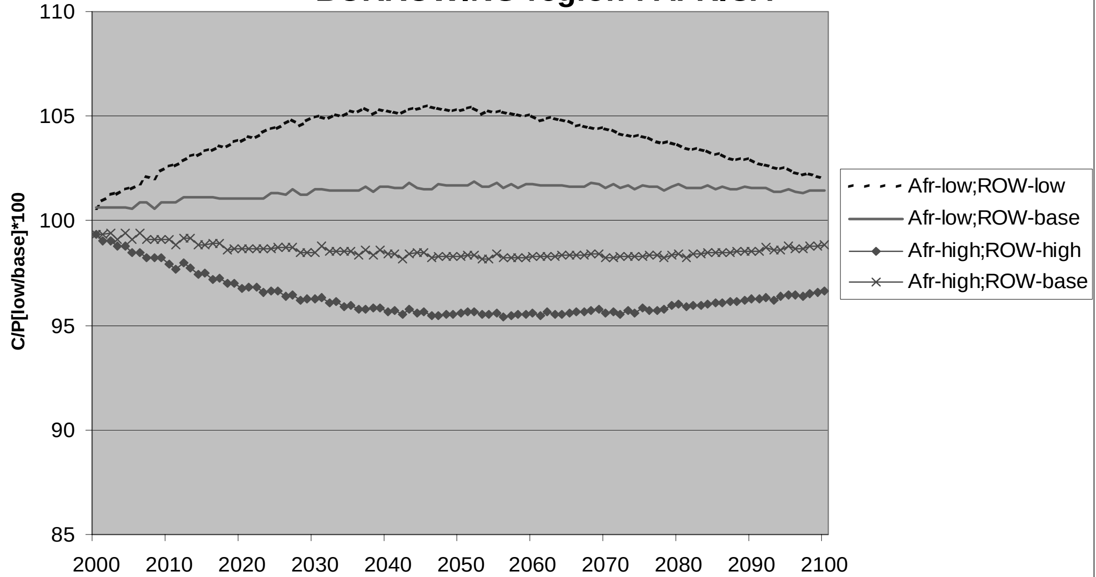


Figure 4. Size of net international capital flows for alternative fertility scenarios
Calculated as the sum of the absolute value of CABs as a ratio to world GDP
0.1
0.08
0.06
0.04
0.02
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
High
Base
Low

Figure 5. Impact of fertility rate on living standards for a LENDING region : EUROPE



Impact of fertility rate on living standards for a BORROWING region : AFRICA



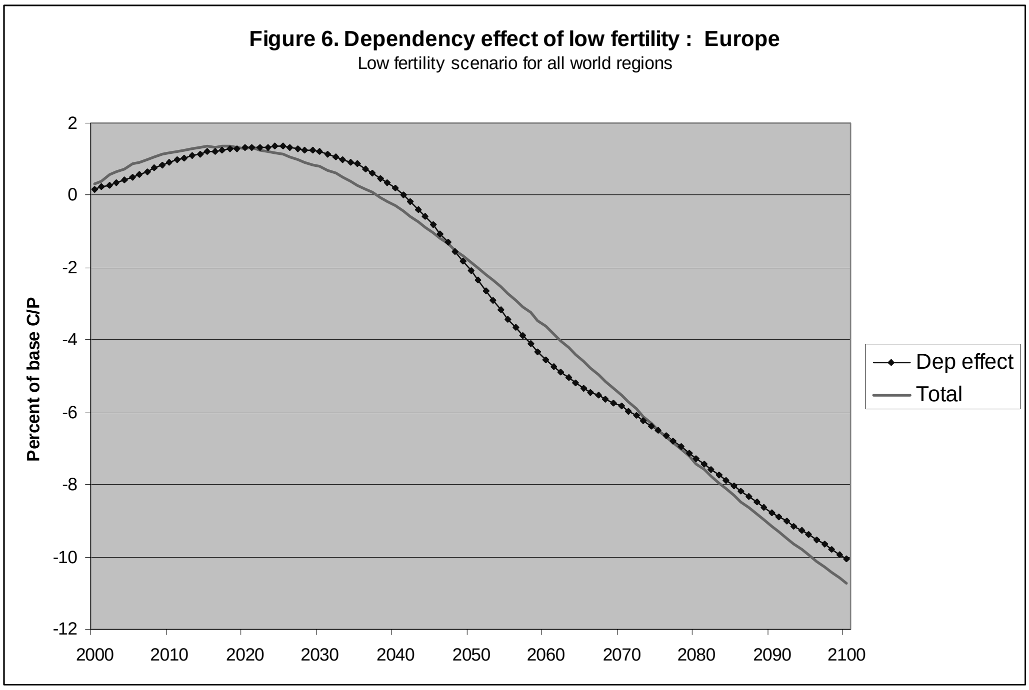


Figure 6. Dependency effect of low fertility : Europe
Low fertility scenario for all world regions
Percent of base C/P
2
0
-2
-4
-6
-8
-10
-12
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Dep effect
Total