Social Determinants of Productivity: Demographics, Human Capital and Social Diversity

Population Aging, Productivity and Living Standards

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INTRODUCTION

The productivity challenge is gaining attention among policy-makers. One reason for this is that the deficit has been "defeated." The new finance minister can afford to shift the focus to other initiatives that address the same long-run objective — to increase the living standards of Canadians over time. A second reason is the warning issued by demographers. For example, Denton and Spencer (1998) note that the rate of growth of per capita GDP is certain to fall significantly over the coming decades unless either the immigration rate or the productivity growth rate increases rather dramatically. It is the aging of Canada's population that lies behind this concern. The purpose of this paper is to evaluate some of the economic analyses that have attempted to put the concern about aging into perspective. As we shall see, it is possible that aging will lead to increases in productivity growth — even if no policy initiative is taken. In other words, population aging may create both a problem and the solution to that problem.

In the remainder of this introduction I describe more fully the basis for the concern about aging. Then, in three separate sections, I summarize research that focuses on why it is reasonable to argue that our economy possesses mechanisms that insulate living standards (at least to some extent) from the adverse effects of an aging population. In the first section I consider how an aging population affects society's incentive to invest in physical capital accumulation. The focus then shifts to an open-economy setting, where variations in the level of foreign indebtedness are just as important as changes in the capital stock. Finally, I consider how aging affects investment in human capital. A brief appendix provides a fuller explanation of some of the material in the last section.

Demographers certainly do predict that there will be dramatic growth in Canada's elderly dependency ratio — the number of individuals over 65 years of age divided by the number between 15 and 64 years of age. This ratio will essentially double, from 19.2 percent in 1996 to 38.5 percent in 2040. The most common reaction to this development is that, with so few workers trying to support so many dependants, it is obvious that our living standards will have to fall. Indeed, many studies (such as a World Bank 1994 report) have referred to this development as a "crisis." Other studies (see, e.g., Emery and Rongve 1999; Mérette 2002) reach much more optimistic conclusions, sometimes referring to the aging-population phenomenon as "much ado about nothing." How are non-specialists to react when there is such a dispersion of views in the field?

First, it should be noted that Canadians have already experienced an *overall* dependency ratio that was just as high as the level to which overall dependency will rise in the coming decades. In the 1950s, when the baby boom generation was too young to work, the youth dependency ratio was extremely high. But that overall dependency ratio was pulled down by the fact that there were relatively few older Canadians. With the passage of time, and given the dramatic drop in birth rates (the so-called baby bust), things have been in the process of switching. The youth dependency ratio has been falling while the old-age dependency ratio has been rising. The overall dependency ratio fell as the baby boomers entered their working years, and now it is rising again as the boomers begin to retire. We managed to cope quite well with the high overall dependency ratio before. Optimists presume that we can do so again.

Less optimistic individuals stress the fact that it costs a lot more to provide health care to the elderly than to provide education for the young. Numerous studies (such as Office of the Auditor General of Canada 1998 and Robson 2001) have estimated that, when the baby boomers retire, Canadian governments will need another 3 percentage points of GDP in revenue to finance existing programs for the elderly — despite some savings on other programs. Since adequate health is needed for people to enjoy consumption goods, and since an aging population requires a shifting of resources away from the production of consumption goods and towards the health sector, there may well be grounds for concern about average living standards.

Despite these estimates, optimists draw attention to several factors. First, with increased life expectancy and growing acceptance of flexible working arrangements (such as job sharing), baby boomers may choose to remain in the work force to a more advanced age than their predecessors. In addition, Canadian immigration rates may rise. Both of these developments may limit the predicted labour shortage. Second, even if these developments do not occur, and labour does become scarce, that scarcity should cause the price of labour to rise. After all, with each scarce worker having more capital to work with, her productivity will be higher. The resulting increase in pre-tax wages may make it possible for governments to tax the generation that follows the baby boomers more (to cover the extra health and pension costs for the boomers) and still leave the young better off. The next section explains how economists evaluate this possibility.

AGING, RELATIVE FACTOR PRICES AND INVESTMENT IN CAPITAL

Economists use models of overlapping generations to estimate the effects of demographic changes on living standards. The simplest framework (Diamond 1965) involves just two generations living at any point in time, the "young" and the "old." The young work with the existing stock of capital to produce output, and they decide how much of their income to consume during their working years (and how much to save so that they can supplement the public pension benefits they will receive in their old age). Saving takes the form of capital accumulation, and the decision to save is affected by the after-tax return that the individual can expect when the capital is employed during retirement.

To derive numerical predictions from a model of this sort, economists need to specify how individuals make their consumption-savings choice and how firms make their labour-capital choice when producing goods. Household decisions depend on how impatient people are, how constrained they are in their attempts to borrow, and how accurately they can predict future wages and interest rates (the yield on capital). Decisions made by firms depend on how easily labour can be substituted for capital in production processes, how rapidly capital depreciates, and the degree of competition among firms. Standard practice is to consult the empirical studies on all of these issues and, using the results of those studies as a guide, select representative parameter values for the model economy. The model economy is then used to simulate various developments, and numerical estimates of what will occur are calculated.

Many economists have constructed model economies of this sort and reported simulation results. I summarize the results of one such study here, that by Scarth and Souare (2002). This study is relatively easy to understand since it uses the simplest, baseline version of the overlapping model to examine the aging phenomenon. Fortunately, its results are representative of many of the more involved studies. To simulate the aging population, we need a base for comparison. Initially, therefore, the model economy is in equilibrium, with each generation the same size as all the others. Then a larger cohort arrives, the baby boomers, so that the economy comprises more young than old for an entire generation. The post-boomer cohort is the same size as the pre-boomer cohorts, so when the baby boomers become the old generation the model economy goes through conditions that are designed to be representative of what Canadians will confront in the next few decades. What are the results?

When the baby boomers are young, their large numbers push down both pre-tax wages and the tax rates faced by each person. In most simulations, the former effect dominates the latter, so living standards for this cohort fall somewhat. The pre-baby boom generation is better off, however. Since they own the capital that has become relatively scarce when they are old, and since they also benefit from lower tax rates, their incomes and living standards rise. Overall, consumption of the average person rises by close to 2 percent. This analysis is consistent with what we observed in Canada from the mid-1970s to the mid-1990s, when baby boomers flooded the labour market and contributed to very slow growth in wages, and older Canadians enjoyed very high interest income.

When the baby boomers constitute the old generation in the model economy, capital is the relatively abundant factor of production, so interest rates fall and wage rates rise. As a result, the old suffer a drop in their living standards, while the young — the post-boomers — enjoy an increase in consumption. The model confirms the proposition that the wages of the young rise more than their taxes, so they should welcome the aging of the generation that has preceded them. Nevertheless, we should not make too much of this result, since — considering both young and old as one group — it turns out that average living standards fall by about 2 percent. Furthermore, when the baby boomers are retired they constitute the majority of the population and thus have the political power to increase the benefits paid to the old. In this way, part of the drop in their living standards can be passed on to the post-boomer generation. Overall, then, the main outcome is that average living standards fall by about 2 percent.

This set of results is surprisingly unaffected when major changes in the model economy are considered: whether households are liquidity-constrained, whether individuals within the model accurately anticipate demographic changes and their effects, and whether governments offer favourable tax treatment for household saving. This latter issue has been stressed in the literature (especially by Mérette 2002). As the baby boom generation ages, the RRSP system shifts from being an arrangement that can limit government revenue (when the majority of the population is working and receiving tax breaks by contributing to retirement savings plans) to one that can increase government revenue (when the majority of the population is retired and paying tax on the income generated by those savings). But the model economy has two important features: both government debt and per capita government spending are fixed. Thus, when government revenue would otherwise be affected by variations in the proportions of the population that are paying into and receiving payments from their RRSPs, tax rates are adjusted. This is one of the reasons why the predictions of the model economy are unaffected by a major specification difference such as the existence (or not) of tax-sheltered savings plans.

AGING AND FOREIGN INDEBTEDNESS

Other, rather different, versions of the overlapping-generations model support the general conclusion reported above. In some specifications, there are many generations alive at the same time. Instead of just two cohorts, the young and the old, with the period of analysis covering an entire generation (roughly 30 years), there are dozens of cohorts co-existing at each point in time (with a new cohort born every year). Scarth and Jackson (1998) use this version of the model economy to investigate an alternative way of increasing the old-age dependency ratio. Instead of a temporary, but long, period involving an older population (as discussed above), they consider a permanent reduction in the average retirement age. In this scenario, the aging population occurs because the average person spends a greater portion of her life in retirement. Another important feature of this analysis is that it is designed to represent a small, open economy.

The model economy discussed in the previous section assumes that the ratio of the wage rate to the interest rate is determined by the relative scarcity of labour and physical capital. There is no constraint that factor prices bear any relationship to what labour and capital earn elsewhere in the world. For this reason, that model is best applied to the entire North American economy. Since the Canadian and American old-age dependency ratios are increasing at roughly the same rate, this is a natural application of the model.

If we want to consider an analysis that applies exclusively to Canada, we must recognize that there are serious limits on how much the factor prices of any one small country can depart from what is observed elsewhere. In the modern, "globalized" world, capital is very mobile internationally. Indeed, many studies assume that the option of moving capital elsewhere makes it impossible for domestic interest rates to depart, in any lasting way, from the yield available in the rest of the world. With the most common specification for the input-output process, the fact that the interest rate is determined in the rest of the world is sufficient to make the wage level of the domestic economy determined in the rest of the world as well. Within this framework, then, it is possible to break the effect of a rising old-age dependency ratio on average living standards into two components, one that occurs because the domestic population is aging and one that occurs because the population in the rest of the world is aging. Only the second of these developments changes relative factor prices in the domestic economy.

An older population brings down the living standards, but — as with the simpler, closed-economy overlapping-generations specification discussed in the previous section — living standards decrease by a smaller percentage than does the labour force. In this setting, the cushion is provided partly by a change in factor prices and partly by a change in the economy's foreign indebtedness. In simulations using Scarth and Jackson's specification, living standards are reduced by a little over 4 percent if the retirement age falls sufficiently to increase the dependency ratio by what we anticipate for the several decades after 2030. Faced with the prospect of a longer retirement, individuals save more. As a result, the country pays off some of its pre-existing foreign debt. Since higher savings mean less consumption for a while, there is "short-term pain." Eventually, though, with smaller interest-payment obligations to foreigners, individuals can consume more and there is "long-term gain." This gain counteracts — at least partially — the drop in living standards that occurs when there is less labour available to produce consumption goods. Living standards fall by 3 percent if an aging population occurs in the domestic economy only. The additional 1 percent drop occurs if there is an equivalent increase in the dependency ratio in the rest of the world (an event that causes the domestic interest rate to fall). Some readers may find this last outcome surprising, since it is usually assumed that lower interest rates are "good" for the economy.

It is true that lower borrowing costs make it profitable for firms to hire more capital, and more capital to work with makes labour more productive. But this favourable effect on domestic incomes competes with an unfavourable effect. With lower interest rates, individuals choose to save less. As a result, foreign debt (and the associated level of interest-payment obligations) is higher. In short, GDP is higher but the ratio of GNP to GDP is lower. Since domestic income is GNP, not GDP, this unfavourable effect cannot be ignored. It turns out that the unfavourable effect *dominates*.

Before ending this section, I touch on two issues. The first is that aging will affect the economy in ways other than by raising the dependency ratio. The second is that other important developments, such as government debt reduction, will likely continue as aging proceeds. Also, we indicate how estimates of *one-time* effects on the *level* of living standards can be converted to equivalent changes in the productivity *growth rate*.

One of the reasons for an aging population is increasing life expectancy. The models discussed above have been used to examine this aspect of aging, and favourable effects have emerged. People who live longer have an increased incentive to save. Individuals acquire more capital and achieve lower foreign indebtedness as a result, and (other things being equal) these developments raise living standards.

An additional feature of an aging population is a falling birth rate, since a population with a large proportion of old people has a correspondingly smaller proportion of individuals in the child-bearing phase of life. As a result, Canada's population growth rate is expected to fall.

According to standard growth theory, low population growth is associated with high living standards — since less of each year's output must be withheld from consumption and used to provide each worker with an adequate supply of capital. There is tension between this proposition and recent discussions of our aging population. For example, the Office of the Auditor General of Canada (1998) predicts a large drop in government revenue (and therefore in the living standards of those who are dependent on government transfers) when lower population growth causes GDP growth to fall. Scarth (2001) examines these competing effects using a small, open-economy version of a standard growth model — with overlapping generations, lifecycle features, and both forward-looking and liquidity-constrained consumers — and finds that the "rich" are better off with lower population growth (as predicted by standard theory), while the "poor" are worse off (as predicted by analysts such as the Auditor General). The model permits us to calculate the present value of all gains and losses. The conclusion is that the rich gain much more than the poor lose. Thus — as long as the rich and the poor are given equal weight, and the economist's standard rule for evaluating alternatives, the hypothetical compensation criterion, is applied — the analysis supports the proposition that lower population growth is "good."

So, the lower-population-growth dimension of the aging population is cause for optimism regarding how *average* living standards will fare as the population ages. Nevertheless, the incomes of those who are dependent on government transfers will be squeezed slightly, and income redistribution may become increasingly difficult in a global economy where mobile "rich" individuals can escape taxes that exceed international norms. Furthermore, since skilled-biased technical change will likely continue to increase the inequality of pre-tax-and-transfer incomes, it would be imprudent to give too much weight to this consideration. In short, in the face of rising demands for governments to address growing inequality, both within Canada and throughout the world, policy-makers may feel constrained to increase immigration rates by enough to avoid a significant drop in overall population growth.

There is a big difference between the model-economy simulations that have been discussed and Canada's future economy. The simulations assume that the aging population is the only shock to hit the economy, but other significant developments will very likely be occurring simultaneously as Canada's population ages. One such development is government debt reduction. Many studies (such as Scarth and Jackson) have found that if the federal debt-to-GDP ratio continues its downward trend and reaches its post-war low of about 20 percent, we can expect average living standards to increase by some 3 percent.

This is roughly what is needed to allow Canadians to shift resources from the production of consumer goods to the provision of health care for the elderly — a requirement that is not included in the simulations. Thus, the two excluded considerations essentially cancel off one another. Debt reduction can give governments just the room their budgets need to cope with rising health-care costs.

Nevertheless, the mechanisms that insulate living standards from the aging phenomenon are still incomplete. We are left with something like a 3 percent reduction in average living standards (since this is the average of the 2 percent estimate discussed in the preceding section and the 4 percent estimate discussed in this section, and since all of the simulations exclude the two effects that cancel off).

We close this section by indicating how one-time *level* effects on the standard of living can be converted to equivalent *rate of growth* effects. The following calculation might put the finding of a 3 percent one-time reduction into a productivity-growth-rate perspective. Growth in real per capita income of 2.1 percent per year for 30 years results in a rise in living standards by a factor of 1.865. Growth at one-tenth of one percentage point less (that is, by 2 percent per year) for the same period results in living standards that are higher by a factor of 1.811 — an outcome that is 3 percent lower than achieved with the higher growth rate. Thus, one way of summarizing the simulation results is to say that the aging population can be expected to reduce the annual growth rate in living standards by one-tenth of one percentage point. Many Canadians may regard this loss as fairly modest, especially considering that it will be even smaller if it is assumed that immigration rates will not be increased.

AGING AND INVESTMENT IN HUMAN CAPITAL

The economic analyses discussed in previous sections have one particularly limiting feature. They assume that labour productivity can be increased only if labour has more physical capital with which to work. But recent advances in growth theory have stressed the fact that individuals can and do invest in education and training, so that their productivity is higher even if they work with no additional amount of physical capital. If labour is expected to be the relatively scarce input as the population ages, we can expect that the return to investment in human capital will rise. Thus, by excluding this option for increasing labour productivity, the simulations have *overestimated* the threat to our living standards that is posed by aging. In this section I will attempt to explain how economists have tried to estimate the magnitude of this overestimate.

Unfortunately, the studies that focus on aging and human-capital investment are based on model economies that are more complicated than those discussed above. No study has applied the simplest version of the human-capital, endogenous-productivity growth-rate model (the textbook model) to the aging-population question. In the appendix, I show how this can be done; only the essence of the approach and the results are described here in the body of the paper.

The analysis is an extension of the many-overlapping-generations framework. Households continue to save for their retirement; the main difference is that they have two options for investing their savings — in physical capital and in human capital. There are two sectors of the economy: the goods-producing sector, which produces both consumption goods and physical capital, as before; and the education sector, which produces knowledge (human capital, which raises each individual's productivity). The education sector uses human capital more intensively in the production of knowledge than the manufacturing sector uses human capital in the production of goods. In the simplest version of the analysis, physical capital is not needed at all in the education sector, so it is employed only in the manufacturing sector. It is the fact that knowledge is a man-made input in the production process, in this extended analysis, that makes the nation's productivity *growth rate* dependent upon both demographic events and government policy.

The details concerning the structure and empirical calibration of this model economy are provided in the appendix. Since we continue to assume that government debt reduction will make room, in government budgets, for rising health-care expenditures, we limit the reported experiments to the following three:

> *An increase in the old-age dependency ratio*. Since individuals plan to spend more time in retirement, this development induces each person to save more and to re-evaluate how much of her time she spends in training. These responses at the individual level have a positive effect on the growth of living standards. However, there is a reduction in aggregate human capital, since more individuals are retired, and this has a negative effect. The simulations show that these competing influences almost exactly cancel off. The net effect on the growth rate of per capita consumption is positive, but is too small to be relevant.

> *An increase in life expectancy*. This development induces competing effects as well, but the specifics are different. The incentive for increased saving is more pronounced, so there is, on balance, a noticeable increase in the annual productivity growth rate — roughly an additional one-tenth of one percentage point in the annual growth rate, for an increase in life expectancy of four years.

> *A decrease in the population growth rate*. Just as favourable income-level effects accompany this dimension of aging in the models that abstract from human capital, favourable productivity *growth rate* effects accompany it when investment in human capital is highlighted. A drop of one percentage point in annual population growth yields an increase of about one-third of one percentage point in the annual productivity growth rate.

Do these results call for a modification of the conclusions reached in the previous sections? In one sense, no modification is required. There is additional support for the proposition that the falling-population-growth-rate dimension of an aging population is good news for *average* living standards. Nevertheless, there is still the concern that governments will have difficulty meeting the likely rising demand for income redistribution in a global setting. Since lower population growth hurts those who are dependent on government transfers — even though it raises the average income level rather dramatically — governments may want to override this dimension of the aging population by increasing immigration quotas. Thus, as argued in the previous section, it is prudent to identify, but not to count on, this good-news dimension of an aging population.

Nevertheless, there is one reason why a modified conclusion is called for. In this analysis of human capital, rising life expectancy can be expected to have a positive effect on a productivity growth rate that is small, yet large enough to compensate for the unfavourable one-time level effect of aging seen in previous sections. Overall, then, a rather benign view of aging is supported. If it is assumed that policy-makers will adjust immigration rates to keep population growth roughly constant, there are likely to be neither large negative nor large positive effects on growth in productivity or in average living standards. If it is assumed that population growth will fall, we can expect to see an increase in the growth rate of living standards.

Before concluding this section, it is worth considering how we might develop confidence regarding the finding that a focus on human capital investment does not affect the results dramatically. This is particularly worthwhile since there is disagreement on this finding in the literature. On the one hand, Devereux and Love's (1994) simulation results concerning tax changes are consistent with the small effects reported here for changes in the dependency ratio. On the other hand, Fougère and Mérette's (2000) simulations involve large effects accompanying both demographic and tax changes. A full evaluation of these alternative specifications of training and education is beyond the scope of this paper. Thus, I provide perspective in another way — by considering the following "back of the envelope" calculations (which are discussed in more detail in Scarth 2000, 259).

Consider shifting resources away from current consumption and into education. Assume that the rate of return on education is 10 percent; a shift of 1 percent of GDP would lower annual consumption by this much. What would be the payoff? This reallocation is equivalent to society annually buying an equity that pays a dividend of 10 percent. If the initial year's GDP value is unity, the present value of the first "equity purchase" is $(.01)(.10)(1/(r\text{-}n))$, where r and n denote the discount rate and the GDP growth rate respectively. Since this permanent shift of resources involves the equivalent of buying such an equity every year, the total benefit is $(0.1)(.10)(1/(r\text{-}n)^2)$. The present value of the cost is $(.01)(1/(r\text{-}n))$, so the net one-time percentage increase in living standards is $(.01)[(.10/(r\text{-}n))\text{-}1]$, which equals 0.04 if r=.04 and n=.02.

In Canada, public expenditure on education is about 5 percent of GDP, so an increase of one percentage point is a significant initiative. Roughly speaking, the reasoning in the above paragraph suggests that the net benefit is equivalent to a one-time increase in consumption of 4 percent. What increase in the annual growth rate brings the same one-time equivalent benefit? If the interest rate is 4 percent, the answer is an increase in n from 0.02 to 0.02078. I therefore conclude that a significant investment in education can be expected to generate an increase in the growth rate of the economy of about one-thirteenth of one percentage point. It would seem that scepticism is warranted whenever formal growth models show more than a modest growth-rate effect following from variations in the size of the education sector.

CONCLUSIONS

I have summarized several approaches used by economists to analyze how an aging population might affect the growth rate of per capita consumption. I have focused on basic versions of each approach so that non-specialists can better appreciate why there are competing effects. A second reason for highlighting the simulation results from several simple model economies is so that our comparison of the numerical results can be interpreted as a bold test of the robustness of some conclusions. It is noteworthy that from this approach a fairly general conclusion has emerged. It appears that the aging population will probably lead to rather modest changes in the growth rate of our living standards, and that the net effect could even be a favourable one.

APPENDIX

To highlight the role of training in the growth process, I follow Uzawa (1965) and Lucas (1988), and focus on a simple model economy with two sectors. I start with the simplified treatment in Barro and Sala-i-Martin (1995) and Turnovsky (1995), and extend it to overlapping generations by using Nielsen's (1994) extension of Blanchard's (1985) analysis of household savings behaviour. As long as household utility depends on private consumption and government-provided goods in a separable fashion, private consumption is proportional to broadly defined wealth (the sum of physical and human capital). The factor of proportionality is the sum of each individual's rate of impatience, *m*, and the (constant) probability of death, *p*. More than one newborn appears to replace each individual as she dies, so the overall population grows (at rate *z*).

One sector uses physical capital and labour to produce goods, and these goods can be either consumed by households or used by firms as additional capital in future periods. The second sector involves just labour; it is the education sector that produces human capital. Individuals are more productive in the goods sector when they have more human capital. The production processes are a Cobb-Douglas function in the goods sector (with capital's share equal to *a*) and a linear function in the training sector. Net of depreciation, the increase in human capital equals *B* times the amount of human capital, *H*, that is employed in that sector. Parameters *b*, *p* and *f* are the fraction of non-retired individuals who are employed in the manufacturing sector, the annual death probability faced by each individual and the retirement age. As a result, the fraction of the population that is working in the training sector is $(1\text{-}b)(1\text{-}e^{-pf})$.

Long-run equilibrium exists when the growth rate for all per capita variables is the same — that is, when per capita consumption, per capita output, per capita physical capital and per capita human capital all grow at one rate, *n*, which I use to denote the growth rate in living standards. The model is used to determine how a reduction in the retirement age, *f*, an increase in life expectancy (a fall in *p*) and a reduction in the population growth rate, *z*, affect the growth rate in living standards, *n*.

Parameter *B* indicates the gross yield on human capital, since it indicates how much "output" follows from employing one unit of "input" in the training sector. It is assumed that both physical and human capital wear out with the passage of time at the same depreciation rate, *d*. Thus, the net return on human capital is $r^*=B\text{-}d$. Equilibrium requires that the pre-tax return on physical capital, *r*, generate the same net return, $r^*=r(1\text{-}t)$, where *t* is the tax rate. With firms in the manufacturing sector hiring physical capital so that its marginal product is just equal to its rental cost, we have $(Y/K)=(r+d)/a$, where Y and K denote manufacturing output and physical capital.

The full-equilibrium version of the human capital accumulation identity is:

$$n+z+d=B(1-b)(1-e^{-pf}) \quad (1)$$

The physical capital accumulation identity, when combined with the resource constraint (that output equals the sum of private consumption, C, government programs and investment in physical capital), the government budget constraint (that government spending equals tY), and the (Y/K) expression given above, implies:

$$z+x+n-d(1-t)(1-a)/a=r^*/a \quad (2)$$

where $x=C/K$. Finally, as derived in Nielsen (1994), the full-equilibrium version of the consumption function is

$$n=r^*-m-[(p+z)(p+m)]/x+q(Y/K)/x \quad (3)$$

where

$$q=[p(p+m)(1-a)(1-t)(1-e^{-r^*f})]/[r^*(e^{pf}-1)] \quad (4)$$

The total differential of these four equations, along with the definitions of r, r^* and the expression for (Y/K) given in the previous paragraph, are used to determine the changes in n, x, r, r^*, b, q and Y/K that result when changes in life expectancy $(1/p)$, the population growth rate (z) and the retirement age (f) are specified.

The model ensures that the discussion of these issues is internally consistent. While it is deliberately simplified, the model can be used to illustrate the quantitative effects of these developments. For this purpose, representative parameter values that are suitable if each period is interpreted as one year have been selected. The initial values for private consumption, government spending and investment in physical capital (as proportions of measured [manufactured goods] output) are assumed to be 0.55, 0.27 and 0.18. Physical capital's share of output in the manufacturing sector is 0.33; capital's depreciation rate is 0.04; the net-of-tax yield on capital is 6 percent; and the initial growth rate of the population and per capita living standards is 0.02 (n=z=0.02). All other parameter values are determined by the equations of the model. The numerical results are reported in the body of the paper.

NOTE

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