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POPULATION AGING AND THE MACROECONOMY: EXPLORATIONS IN THE USE OF IMMIGRATION AS AN INSTRUMENT OF CONTROL*

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ABSTRACT

Simulation methods are employed to explore the effects of immigration as a control instrument to offset the economic and demographic consequences of low fertility rates and aging population distribution. A neoclassical economic growth model is coupled with a demographic projection model. The combined model is calibrated and used in a series of experiments. The experiments are designed to generate the time paths of a hypothetical but realistic economic-demographic system under alternative assumptions about immigration policy. The government seeks to optimize policy results in the model, according to a specified criterion function. The model is calibrated with Canadian data but some experiments are carried out using initial populations and fertility rates of other countries.

JEL Classifications: E170, J110, J180

1. INTRODUCTION

The background to this paper is the widespread phenomenon of fertility rates below the level required for natural replacement. The total fertility rate in Canada was 1.5 live births per woman in 2002, compared with a replacement rate of approximately 2.1. Similar or more extreme situations hold in many countries of Europe and elsewhere. Of the thirty countries with membership in the OECD at the beginning of the century, all but two had TFRs under 2.1 (the exceptions were Turkey

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and Mexico) and thirteen had TFRs below 1.5. The low rates of recent decades and the higher rates of earlier ones have produced situations in which the outlook is for large increases in the proportions of older population, slowing rates of population and labour force growth, and general concerns about the economic burdens of pensions and health care for the elderly. We explore the possibilities and implications of using immigration as a policy instrument in this context.

The principal focus of the paper is the level of immigration that would be required to achieve certain goals that the government of a country might deem desirable. Without passing judgement on whether in fact the goals are desirable the list might include keeping the population from falling below some initial level, maintaining the rate of growth of the population or labour force, moderating the shift in age distribution toward an older population and maintaining the rate of growth of the real national income per capita. We assume a large supply of potential immigrants and a government that can control the number entering each year.

The appeal of immigration as a national policy instrument in this situation is that it is in fact controllable and has immediate impact. Two principal drivers of economic growth are population growth and technical progress. An increase in fertility would raise the rate of population growth but would have little direct effect on the labour force for some two decades, during which time it would add more young dependents to the increasing stock of old ones. Moreover the links between fertility and possible policy instruments – financial inducements, let us say – are at best weak and uncertain. A faster rate of technical progress would serve as an effective offset to a declining labour force/population ratio but the rate of technical progress is not easily controlled. Inducing or facilitating higher labour force participation rates (if that could be achieved) would increase national output, but only for a while; once the rates had reached their maximum attainable levels that source of growth would no longer be available. A higher rate of saving would cause the stock of capital to rise more quickly, and hence raise productive capacity, but that too is not so easily brought about in a market economy. That leaves immigration as the most controllable and fast acting instrument:

letting 100,000 people into the country increases the population immediately by 100,000 and the labour force by some large fraction thereof.

Controllable and fast acting as it may be there are important considerations to be noted with regard to the use of immigration as a policy instrument. First there are limits to the rate at which immigrants can be absorbed into the population without creating severe social problems. The rate cannot simply be increased without penalty to any level to achieve a given demographic or economic objective. Secondly, immigrants are consumers as well as producers. Much popular discussion of immigration policy from an economic point of view seems to ignore this. It seems rather to focus on immigrants as additions to the labour force and a source of growth of the national product, ignoring the fact that the immigrants have a consumer claim on that product. Thirdly, while immigrants may be younger on average than the population at large they subsequently age and eventually grow old. The long-term effects of sustained immigration on the population age distribution may thus be quite different from the shorter-term effects.

There is a substantial theoretical literature on the effects of immigration on the population. Much of it has been concerned with the incorporation of immigration into the stable population model and the effects on equilibrium size and age distribution. The contributors include (among others) Tabah and Cataldi (1963), Coale (1972), Pollard (1973), Espenshade, Bouvier and Arthur (1982), Cerone (1987), Arthur and Espenshade, (1988), Mitra (1983, 1990), Feichtinger and Steinman (1992), and Schmertman (1992). The implications for policy have sometimes been implicit, sometimes explicit. Keyfitz (1971) provided a theoretical treatment of emigration as a means of relieving population pressure in developing regions of the world but his results are general and applicable to immigration as well. Blanchet (1989) was concerned explicitly with immigration as a means of offsetting the effects of low fertility rates and demonstrated in particular the undesirable consequences of a "stop and go" policy. Wu and Li (2003) focussed on immigration as a device for altering the dependency ratio in the population. They demonstrated that the immigration rate might have to be very high and concentrated at the young end of the adult age range to have a major effect. While some studies have been concerned only with steady state results some have simulated time paths and investigated dynamic properties. These include the simulations by Blanchet (1989) for France and by Feichtinger and Steinmann (1992) for Germany. Beyond the studies we have mentioned there have been many other empirical studies and projections for particular countries.

The contribution of the present paper is that it explores the feasibility and economic as well as demographic consequences of using immigration over a long period of time in pursuit of particular objectives relating to concerns about population aging. The tool that we use is a linked economic-demographic model. The model is theoretical but calibrated by assigning to it realistic parameter values. Realistic initial conditions are specified and the model is allowed to run in simulated time for ten decades under alternative assumptions, including assumptions about alternative immigration rates and policy objectives. The approach is generally similar to the one used by us in a series of earlier studies of the economic-demographic effects of fertility and migration (Denton and Spencer, 1973, 1974, 1975, 1983, 1984, 1988).

2. THE MODEL

The combined model consists then of a population projection model joined with a macroeconomic growth model. The equations are shown in the accompanying list, with definitions of symbols.

The Population

The population is moved forward in time year by year from an initial state by the application of fertility and mortality rates and the introduction of immigrants at each age, given a specified immigration total and age distribution. All calculations are by single years of age.

The time path of the total fertility rate (F) is specified and (for ease of calculation in simulations) the age-specific rates (f) vary in proportion to the total rate (equations 1a, 1b). Live births (B) are calculated by the application of fertility rates to population over the childbearing range (discrete ages 15 to 49), with averaging of rates and population over consecutive years to allow for aging during the 12-month interval.

Total immigration in each year (M) is set as a fraction (h) of the population and then allocated by age and sex (equation 4) according to a given set of distribution parameters (g). Immigration is interpreted as either gross immigration, with emigration set to zero, or as net immigration, under the assumption that the age and sex distributions of immigrants and emigrants are the same.

The population is calculated at age 0 as the number of births adjusted for mortality, plus infant immigrants (equation 5). For ages beyond 0 it is calculated by moving the existing population forward one year in age and one year in time, adjusting for mortality, and adding in immigrants (equation 6).

The Macroeconomy

The macroeconomy is represented by a neoclassical growth model adapted to link with the population model by incorporating single-age and sex distributions of the labour force and employment. Except for immigration (of workers and consumers) it is a closed system: there is no international trade or investment. It is also recursive, both internally and with respect to the population model: the population model feeds the macroeconomy through its connection with the labour force but there is no feedback from the economy to the population. We have chosen to keep the representation of both the economy and the population, and the linkage between the two, as simple as possible in order to focus attention on the basic quantitative effects of admitting large numbers of immigrants. We have thus chosen not to incorporate more uncertain or speculative aspects of behaviour, including possible differences between immigrants and nonimmigrants – differences in saving rates, labour force participation rates, and human capital for example. (The fiscal implications of immigration in the U. S. context have been investigated in a number of studies, using models with the more detailed structure required for that purpose. See Lee and Miller, 1998, MaCurdy, Nechyba and Bhattacharya, 1998, Storesletten, 2000, and other references cited in those studies.)

The labour force (L) is generated by applying participation rates to the population of each age and sex and summing the results (equation 7). Employment is obtained by modifying the labour force calculation to allow for unemployment, based on fixed unemployment rates, also specified separately by age and sex (equation 8). Employment is then fed into an aggregate production function (equation 9), along with the stock of physical capital (K), and the national income or product is thus generated. The production function is Cobb-Douglas in form, with constant returns to scale. Changes in the function are allowed for by incorporating a time-subscripted shift parameter (α), representing technical progress. (Technical progress is treated as neutral in the model rather than being associated with either labour or capital.)

The capital stock at the beginning of each year is generated by a perpetual inventory process (equation 10): the previous year's stock is depleted by depreciation (at an annual rate δ) and augmented by investment (I). Investment is determined (equation 11) by the level of saving (S), which in turn is determined as a constant proportion (γ) of the national output (equation 12). The model is thus complete. Output, investment, saving and the capital stock are all defined as real (price deflated). The economy, like the population, moves forward one year at a time from its initial state for as many years as required for a given simulation.

3. SOME PROPERTIES OF THE MODEL

The model has an infinitely long memory on both the demographic and economic sides. On the demographic side the population size and age distribution reflect the past history of fertility, mortality and immigration rates. If the rates are frozen at any given time t the population will move toward a path of steady state growth, decline or stationarity, depending on the levels at which the rates are set and their interactions. The resulting path will then represent either dynamic or stationary equilibrium. In the dynamic case the population will grow without bound or move toward extinction; in the stationary case it will attain a fixed size and stay there. In either case the population age distribution will move toward a stable state. Strictly speaking the time required for convergence to that state is infinite; convergence to a close approximation may take many decades, or even centuries. The practical importance for present purposes of thinking within a long-term framework is not the nature of some hypothetical ultimate equilibrium state. Rather it is the fact that the effects of an immigration policy set to deal with what are perceived as present or imminent problems may have unanticipated and undesirable effects in the longer term as the population moves toward that state. That may be true in particular if immigration levels are set to mitigate the nearer-term consequences of population aging and a perceived shortage of labour.

The long-memory aspect of the economic side of the model stems from the long-term influence of the population on the labour force and employment, hence on output, and hence again on saving, investment, and the growth of the capital stock, which in turn feeds back on output. Even if the population and its age distribution were magically to stop changing tomorrow the capital stock would still be a function of past investment levels and the economy would move only slowly toward an equilibrium state. The consequences of current immigration policy may thus live on in the economy well beyond the period for which they were intended to have a beneficial effect.

There are some well known theoretical properties of a neoclassical growth model of the kind we are using (Ferguson, 1969, Burmeister and Dobell, 1970). To explore the equilibrium properties assume the population is in steady state growth (or decline) with $\dot{N}$ its rate of growth (possibly negative), where we are using a dot over a variable to stand for a proportionate growth rate. The age distribution of the population will be constant, and with fixed labour force and unemployment rates the labour force and employment will grow also at the rate $\dot{N}$. The resulting steady state time path will then be characterized by a fixed capital/output ratio (k = K/Q), a ratio of capital to employed labour (e = K/E) that is growing at a constant rate, and a level of output per capita (q = Q/N) that is growing also at a constant rate:

$$k = \gamma[\dot{\alpha}(1-\beta)^{-1} + \delta + \dot{L}]^{-1}$$

$$\dot{e} = \dot{\alpha} / (1-\beta)$$

$$\dot{q} = \dot{\alpha} / (1-\beta)$$

Output per capita and the capital/labour ratio thus increase at the same rate in dynamic equilibrium.

The effect of immigration on per capita output is an important consideration for present purposes. Suppose that at time t the employed labour force is a fraction λ of the population. The production function (equation 9) can then be rewritten as

$$Q_t = \alpha_t K_t^{\beta} (\lambda_t N_t)^{1-\beta}$$

and output per capita as

$$q_t = \alpha_t K_t^{\beta} \lambda_t^{1-\beta} N_t^{-\beta}$$

where the subscript attached to λ reflects the fact that the employment/population ratio can change with time. It can change because the population is aging and a larger proportion is moving into the retirement age range. It can change also because the average age of adult immigrants is lower than the average age of the adult population at large, and hence tends to reduce the ratio. In a nonequilibrium situation immigration may tend to raise output per capita on the one hand by raising λ but reduce it on the other by adding to the size of the population. The net result of these two effects is investigated in the simulations reported below. Our impression is that popular discussion of immigration policy tends to focus more on the first effect than on the second – on immigration as a means of increasing output and income by increasing the size of the work force, that is. (Since λ is bounded its rate of growth in equilibrium must be zero so that the steady state growth rate of q is unaffected by it.)

4. CALIBRATION

The model is calibrated using Canadian data, except where otherwise noted. Aside from the fact of our familiarity with Canadian data, Canada represents the set of low-fertility developed countries rather well, in one sense. If the 28 OECD countries with total fertility rates less than 2.1 at the beginning of the century are ranked according to those rates, Canada is in the middle – one of the two countries straddling the median. It also has a recent history of relatively high immigration rates and a considerable degree of importance attaching to government immigration policy. We have used both Canadian demographic data and Canadian economic data in setting parameter values and initial conditions for the simulations.

On the demographic side, age-specific fertility rates (and hence the total rate) are set at the levels of 2001. The male/female ratio at birth is the average over the period 1999-2003. Mortality rates are based on the Statistics Canada life tables for 1996, projected by us to 2001. The proportionate age and sex distributions of immigrants are averages for Canada over the period 1999-2003. The initial age-sex distribution of the population is the proportionate distribution from the 2001 Canadian census. The total population is indexed at 100.0 at the start of a simulation (t = 0). Immigration is treated as a proportion of the population, with standard value 0.5 percent per annum, a level not far from the Canadian proportion for net immigration in recent years. (Net immigration to Canada averaged 0.58 percent in the five years 1999-2003, gross immigration 0.74 percent.) For the first two simulations reported below the immigration rate is set at zero but for all others 0.5 is used as the initial rate.

Turning to the economic side of the model, the labour force participation rates are 1999-2003 averages, based on estimates from the Canadian Labour Force Survey. The age-sex unemployment rates are annual averages over the same period, based also on Labour Force Survey data. National saving is set at 20 percent of the gross domestic product (the γ parameter in equation 12), based roughly on the average proportion calculated from the national income and expenditure accounts over the period 1992-2001. Given the initial level of GDP (Q in the model) the initial levels of saving and gross investment are determined by equations 11 and 12.

The capital stock in any year is determined by its initial level, its rate of depreciation, and the prior sequence of annual investments. We set the stock at time t = 0 by assuming an initial capital/output ratio of 3.0 and applying that to the initial output level. The 3.0 ratio provides a convenient starting point and is close to the ratio we have calculated in the economic growth model that forms part of the MEDS system for long-run economic-demographic projections (Denton, Feaver, and Spencer, 1994). The MEDS K/Q ratio for 2001 is 2.6, with K calculated by the perpetual inventory method applied separately (with different depreciation rates) to the residential construction, nonresidential construction, and machinery and equipment components of the stock. The average depreciation rate for the stock as a whole is calculated by us at about 4.0 percent per annum, and that is the value at which we have set δ in the model. With δ = 0.04 and k = 3.0 the net rate of investment is (I-δK)/Q = 0.08, compared with the gross rate γ = 0.20. (The gross rate is constant; the net rate changes through time. Both rates are constant in equilibrium.) The value of β is set at 0.3, which is the value used in MEDS. It is based on the average shares of Canadian GDP going to capital and to labour, the latter share including an estimated fraction of unincorporated business income as a return to labour, as well as wages and salaries. (β and $1-\beta$ can be interpreted as the theoretical income shares of capital and labour under perfect competition and although perfect competition is not assumed for the model the procedure provides a convenient way of setting a value for β.)

The rate of growth of α is also taken from MEDS. We set the rate at 0.4 percent per annum, which is the calculated Canadian average rate for the quarter-century 1976-2001. We think of it as a rate of neutral technical progress but it may be viewed equivalently as a production-function-based rate of increase in total factor productivity.

5. A FIRST SET OF SIMULATIONS

We begin with three simulations designed to bring out the separate effects of the initial state on the time paths of the population and economy and the effects of technical progress and immigration. The model is allowed to run for a century and the values of twelve variables are reported for each decade in Tables 1 to 3.

The demographic and labour force variables are the total population (N), the average annual percentage rates of change of the population and labour force during the decade (%Δ N, %Δ L), the labour force as a percentage of the population (%(L/N)), and three percent-of-total distribution variables: population 65 and over (%(N^a / N)), population under 20 (%(N^y / N)) and the two combined (%(N^{ay} / N)). The economic variables other than the labour force are output per capita and its percentage growth rate (Q/N, %Δ (Q/N)), the ratio of capital to employed labour (K/E) and the capital/output ratio, both its actual value (K/Q) and its equilibrium value (eq(K/Q)). The equilibrium capital/output ratio shown in the tables for each decade is what K/Q would be if the population were to continue to grow indefinitely at the rate of that decade but the age distribution were to remain fixed. A comparison of K/Q and eq(K/Q) is an indicator of how far the actual economy is from an equilibrium state. All point-in-time variables relate to the end of a decade; rates of growth are annual averages during the decade.

The total fertility rate is assumed to remain at its initial level of 1.5 in the top panel of each table. In the bottom panel it is assumed to rise by equal annual increments to 2.1 by the end of the first decade and to remain at that level thereafter. Zero technical progress and zero immigration are assumed in Table 1. Table 2 introduces technical progress at the standard rate of 0.4 percent per annum but retains the no-immigration assumption. Table 3 introduces immigration at the standard annual rate of 0.5 percent of the population, along with the 0.4 percent rate of technical progress. The three tables provide simulations that can be compared among themselves and with which the ones to follow can be compared. We consider each of the three in turn.

<u>No Technical Progress, No Immigration (Table 1)</u>

The effects on the population of setting immigration to zero with a total fertility rate of 1.5 are clear and expected. There is a very small increase in population in the first decade and then continuous decline. By the middle of the century the population is about 82 percent of its original size; by the end it is only 47 percent. The over-65 percentage doubles within three decades and rises somewhat further thereafter; the under-20 percentage falls. The net effect is an increase in the combined proportion of "dependent" population. On the economic side the ratio of labour force to population falls from 52 to 44 percent by mid-century and is then roughly constant for the remaining decades. In spite of the decrease in the labour force proportion, output per capita rises. The capital/output ratio more than doubles by the end of the century as the system moves toward a long-run dynamic equilibrium state while it shrinks in size. The capital/employment ratio doubles within five decades and almost triples within ten. Such is the outlook with a TFR of 1.5.

The situation is different in the lower panel of Table 1, where the TFR is allowed to rise to 2.1. The population no longer drops below its initial level but stays close to that level throughout the century. The over-65 proportion rises in the first three decades but then falls as the age distribution moves toward a steady state. The under-20 proportion is relatively constant in the range 23 to 25 percent of the total population. The combined "dependency" proportion increases more than in the 1.5 TFR case but then falls a little. By the end of the century the combined proportion is not much different from what it was with the TFR at 1.5; only its young/old composition has changed appreciably.

The ratio of labour force to population is not greatly affected by the higher fertility rate. It is somewhat lower in the early decades and somewhat higher in the later ones, but overall the differences are modest. The capital output ratio does not rise as much, and neither does the capital/employment ratio. Output per capita is consistently lower in the 2.1 TFR case, reflecting the greater effect on population size than on the productive capacity of the economy.

Technical Progress, No Immigration (Table 2)

Introducing technical progress affects the economy but has no effect on the demographic side of the model. The labour force size and proportion remain the same but the production function shifts upward at a constant rate, output per capita rises consistently in every decade and the capital/output and capital/employment ratios also rise consistently. While the directions of effect are the same as before, output per capita and the capital/employment ratio now rise more rapidly, the capital/output ratio less rapidly. With or without technical progress the effect of raising fertility is to reduce somewhat the productive capacity of the economy relative to the size of the population in any given decade.

Technical Progress and Constant Immigration (Table 3)

The 0.4 percent rate of technical progress is retained and annual immigration at 0.5 percent of the population per annum is now introduced as well. With the TFR at 1.5 that rate of immigration is sufficient to keep the population growing for the first four decades of the century, but at a diminishing rate. The population then starts to decline. By the end of the century it is still some 7 percent larger than at the beginning, but on a downward path. The over-65 proportion does not increase quite as much but still almost doubles by mid-century. The labour force starts to decline in the third decade and declines in every decade from there on, although the rates of decline are appreciably slower than in the no-immigration scenario of Table 2. The fact that the labour force is a somewhat greater proportion of the population when there is immigration is not sufficient to offset the effect of more rapid population growth on the denominator of the output per capita ratio: Q/N is lower with immigration than without it, although the differences are small.

Raising the TFR to 2.1 causes the population to increase in every decade and to more than double by the end of the century. The over-65 proportion is reduced appreciably and declines in the labour force are turned into increases once the larger numbers of newborn children come of working age. But again the effects on the labour force do not result in higher per capita output; the effect on the size of the population is still the quantitatively more important one.

6. TARGETED IMMIGRATION POLICY

We explore now the use of immigration to achieve a specific policy goal, in particular the stabilization of population size, the population growth rate, the labour force growth rate or the proportion of the population 65 and over. Results obtained from simulations relating to these policy goals are reported in Tables 4 and 5. (We pass no judgement on whether the goals are in fact desirable. We view them simply as possible choices by a policy maker.)

The policy maker is assumed now to focus on the matter of stabilizing the four variables, considered one at a time. By stabilization we mean setting the immigration rate in each decade so that the target variable does not fall below its initial level, or in the case of the 65+ proportion does not rise above that level. (The population and age proportion targets are the end-of-decade values. One of these variables may deviate from its target value in some year within a decade but the policy is deemed successful as long as the variable is back at its target value by the end. Similarly the population or labour force growth rate may fall below target value in a year as long as the average rate for the decade meets the target criterion.) The chosen immigration rate is constant within a decade but may vary from one decade to the next. What is of interest in examining Tables 4 and 5 is how high the rates must be for a given stabilization policy to be successful, and what are the ancillary effects on other variables. The ancillary effects can be seen from the tables but are assumed to be ignored by the policy maker. (Results based on the optimization of a criterion function that takes account of more than a single target variable are provided later.)

Consider Table 4, where the TFR is set at 1.5 throughout the simulation period, and in particular consider the results of targeting the population size, as shown in the top panel of the table. The first variable reported is the minimum immigration rate (M/N) required to keep the population at or above 100.0, its initial level. No immigration is required for two decades. A rate of 0.24 percent is necessary in the third decade and rates ranging from 0.59 to 0.70 in the subsequent ones. The effects on variables other than the targeted one are small. The 65+ proportion is increased a little in the first four decades and decreased a little in the later ones, compared with the simulations of Table 3 where the immigration rate is constant at 0.5 percent. Generally similar statements apply to the labour force/population ratio and the level of output per capita. A policy of maintaining the population size might well appear feasible to the hypothetical policy maker. In the long run it would require only that immigration be increased from the initial 0.5 percent rate to about 0.6 percent.

A policy of maintaining the rate of growth of the population would require a much higher immigration rate, beginning with the first decade. By the fourth decade the rate would have to be in the neighbourhood of 1.1 percent per annum, more than double its initial level. A similar result holds for the rate of growth of the labour force as a target variable although now the rate would have to rise to 1.2 percent per annum. Preventing the rate of growth from going below its initial level would not, be it noted, achieve a higher level of output per capita, in spite of the greater labour force proportion among immigrants; the level would in fact be somewhat lower in consequence of the associated increase in population size. Raising the immigration rate to as much as 1.1 or 1.2 percent might be considered undesirable. It might be thought too difficult to absorb immigrants at a rate of 11 or 12 percent per decade.

The immigration requirements are much more extreme for a policy of keeping constant the fraction of the population in old age. Maintaining the 65+ proportion at its initial level of 12.7 percent would call for an annual immigration rate of about 2.3 percent in the first decade and rates in the range 2.6 to 3.5 percent in all subsequent ones. (The population would increase more than five-fold by the middle of the century and thirty-fold by the end.) Presumably such rates would be considered out of the question from a policy point of view.

An increase in fertility to a TFR level of 2.1 (Table 5) would greatly alter the situation. No immigration at all would be required to stabilize the population size, and the immigration rates required to stabilize the growth rates of the population and labour force would be significantly lower. For the population growth rate an annual immigration rate of 0.4 to 0.7 percent in each decade would suffice, with rates in the later decades of the century only a little above the initial 0.5 level. For the labour force growth rate the immigration rate in the first decade would have to be as high as it was in Table 4, and in the second decade it would have to be only slightly lower. Beyond that though it would be substantially reduced, falling to about 0.6 or 0.7 by the second half of the century. The rates required to stabilize the 65+ proportion would be reduced also, but not to any level likely to be considered acceptable. They would still be in excess of 2 percent in all but three decades, and never less than 1.6 percent in any.

7. POLICY SIMULATIONS WITH ALTERNATIVE INITIAL DEMOGRAPHIC STATES

We investigate now the effects of changing the initial age distribution and total fertility rate on the rate of immigration required for stabilization. To do this we use the distributions and TFRs in the 28 OECD countries with TFRs below 2.1 at the beginning of the century. Summary information about those countries is provided in Table 6. The countries are ordered from lowest to highest TFR in the table, with values ranging from 1.17 (Czech Republic, Korea) to 2.03 (United States). Proportions of population under 20, 65+, and for the two groups combined are shown. The under-20 proportions range from 19.2 percent (Italy) to 30.7 percent (Iceland), the 65+ proportions from 7.3 (Korea) to 18.3 (Italy). The combined percentages range from 35.8 (Korea) to 42.3 (Iceland). Canada, the country whose data we have used for calibrating the model in the earlier simulations, ranks 14th out of 28 in the TFR ordering, 19th in the under-20 ordering, and 9th in the 65+ ordering.

Two target variables for stabilization are considered: population size (Table 7) and the rate of growth of the population (Table 8). We emphasize that the simulation results reported should not be regarded as realistic calculations for the 28 countries themselves. We simply use the data for those countries to provide a reasonable range of initial demographic states and below-replacement TFRs. The mortality rates used are the same as before, based on Canadian rates. The age-specific fertility rates are also the same, except that they are adjusted proportionally to the individual country TFR levels.

Considering first Table 7, none of the seven countries with TFRs of 1.75 or greater require any immigration in the first three decades to keep their populations at or above the initial levels and three of those countries require no immigration at all through to the end of the century. Immigration assumes much more significance as we move down the TFR rankings, as it must of course. By the end of the century the ordering of required immigration rates is almost monotonic, as one would expect, ranging from about 0.9 percent of the population for the lowest TFR countries to zero for the highest ones. The maximum rate required for any country in any decade is just short of 1.1 percent.

Higher rates are necessary when the target is the population growth rate (Table 8). Our criterion for stabilization in this case is the same as in Tables 4 and 5. The initial growth rate is assumed to be 0.82 percent per annum for every country, which of course is not a country's actual rate. We hold this rate constant across countries as a target and allow only the initial age distribution and TFR to vary. On that basis all countries require some immigration from the first decade on and the rates generally rise thereafter for several decades. By the 10th decade the pattern has become quite stable: the effects of initial age distributions have largely worn away and the immigration rate is strictly nondecreasing in TFR over the 28 countries, ranging from about 1.4 percent at the low TFR end to 0.6 at the high end. The highest rate of all for any country in any decade is just under 1.5 percent per annum. If rates greater than one percent were considered too high, 16 of the 28 countries would be unable to stabilize their population growth rates in every decade of the century. If rates of 0.8 percent or more were considered too high, 23 of the 28 would be unable to meet the stabilization target in every decade.

8. POLICY SIMULATIONS WITH A YOUNGER IMMIGRANT AGE DISTRIBUTION

The results of a policy of bringing in immigrants to offset the effects of population aging is sensitive to the immigrant age distribution. In the next set of experiments we alter that distribution by concentrating immigrants in the young adult range where the labour force content is much higher. (There is the question of whether such discrimination would be feasible or acceptable but that is not a concern here. We simply want to explore the effects.) For any given total we require all immigrants to be 20 to 34 years of age. (The proportionate distribution within that range is the same as in the other experiments.) As in Tables 4 and 5 we calculate the immigration rate necessary to stabilize the size or growth rate of the population, the growth rate of the labour force or the 65+ population proportion. The results are displayed in Tables 9 and 10. The TFR is constant at 1.5 in Table 9, rises to 2.1 in Table 10. The effects of changing the composition of immigration can then be seen by comparing Table 9 with Table 4 and Table 10 with Table 5.

Comparing Tables 9 and 4, the overall immigration rate required under the restriction is lower in every decade for policies targeting the population size, growth rate of the population or labour force growth rate. The differences are larger in some decades than in others but they exist in all decades for those policy targets. For a policy targeting the 65+ proportion the required rate is lower in eight of the decades, and much lower in some. In decade 5 the age-restricted and unrestricted rates are the same, and in decade 9 the restricted rate is actually much higher. The effects of the restriction are thus uneven across the century and in some cases would require large fluctuations in the immigration rate from one decade to the next. Even in decades in which the restricted rate is lower it is still much greater than 1 percent in all but two and greater than 2 percent in five.

The comparative situation is generally similar when the TFR is allowed to rise to 2.1, as in Table 10. Comparing Table 10 with Table 5, the required immigration rates are consistently zero in both cases when population size is the target and nonzero but lower when the target is either one of the two growth rates. The immigration rate is lower in eight decades when the target is the 65+ proportion, and in fact zero in two. Aside from the latter two though the rate is still well above 1 percent in seven decades. As in the TFR = 1.5 simulation, the sequence of required immigration rates is erratic and subject to large decade-to-decade fluctuations.

9. OPTIMIZATION WITH A COMPOSITE CRITERION FUNCTION

The policy simulations to this point have assumed in each case a single target variable. We now explore the consequences of using a composite policy criterion function, one that incorporates more than a single target variable. The choice of function is rather arbitrary, as is the choice of weights assigned to the different targets. Specifying such a function though gets us a little closer to a representation of the set of issues that might be considered important in practical policy-making.

The situation that we posit is the following. We envisage a “social planner” who, at the start of decade T, is charged with the responsibility of choosing an immigration rate so as to maximize a criterion function H_T defined over decades T, T+1, ..., T+A-1, where A is the length of the planning period. A time discount factor is specified, giving greater or lesser weights to current and future decades within the period. There are three target variables that enter as arguments of the function: the immigration rate itself, the 65+ population proportion, and the rate of growth of output per capita. A positive weight is assigned to output per capita and a negative weight to each of the other two variables. The annual immigration rate is the optimization instrument but it also enters the criterion function with a negative weight because of concern about the increasing difficulty of absorbing large numbers of immigrants as the rate rises.

The planner chooses an optimum immigration rate so as to obtain $\hat{H}_T$, the maximum value of H_T . The same rate is set for all years within a decade and all decades within the planning period. The initial plan is conceived at the start of decade T. At the start of decade T+1 the planner reviews the situation and reoptimizes by choosing a new immigration rate so as to obtain $\hat{H}_{T+1}$, and similarly at the start of each subsequent decade. The rate of immigration calculated as optimum in any given plan is thus actually implemented only for the first decade of the planning period. It is replaced ten years later by a newly calculated optimum rate.

Turning to the details, the calculation at the beginning of any decade T starts with the function

$$h_T = w_1\dot{q}_T + w_2(a_T - a_0)^+ + w_3((m_T - m_0)^+)^2$$

where the notation and correspondence with earlier notation are as follows:

$\dot{q}_T = (q_T - q_{T-1}) / q_{T-1}$ (rate of growth of per capita output)

$a_T = (N^a / N)_T$ (65+ proportion at end of decade)

$m_T = (M / N)_T$ (annual immigration rate)

$(a_T - a_0)^+ =$ actual value if positive, zero otherwise

$(m_T - m_0)^+ =$ actual value if positive, zero otherwise

w_1, w_2, w_3 are fixed weights ($w_1 > 0, w_2 < 0, w_3 < 0$)

It is assumed that there is no benefit attaching to a 65+ proportion equal to or lower than a_0 and no penalty attaching to an immigration rate equal to or lower than m_0. The values of a_0 and m_0 are the standard initial values for the simulations in Tables 3, 4, 5, 9 and 10 ($a_0 = 12.7$ percent, $m_0 = 0.5$ percent). The squaring of the (positive) difference between m_T and m_0 implies an increasing marginal penalty for higher immigration rates. Given the single-decade function h the multi-decade criterion function H is then defined for decades 1, 2, etc. by

$$H_1 = \sum_{T=1}^{A} d_{T-1} h_T \ , \ H_2 = \sum_{T=2}^{A+1} d_{T-2} h_T \text{ , etc.}$$

where d_T is obtained by truncating the geometrically declining series of discount factors $1, \rho, \rho^2, \ldots$, so that $d_T = \rho^T$ for T = 0, 1, ..., A, and zero otherwise. The proportionality of the discount factors is thus maintained for the sequence of decades within the planning period. (The optimal choice of m is invariant to a uniform scale transformation of the discount factors, or of the weights in the h function; only the relative sizes matter.)

Results based on the foregoing optimization process are shown in Table 11 for a selection of alternative weighting patterns and discount factors, with a five-decade planning period (A = 5).

The initial weights are set so as to make equivalent in their effects a 10 percent increase in output per capita over a decade ($\dot{q}$), a decrease of 6 percentage points in the 65+ proportion (a) over a decade and a decrease from 1.0 to 0.5 percent in the annual immigration rate (m). The initial weights are identified by the symbols w_1^*, w_2^* and w_3^*; w_1 is fixed at w_1^* in the simulations so only the changes in w_2 and w_3 are noted in the table. Calculations for two alternative values of ρ are reported: $\rho = 0.2$, implying little concern about decades beyond the initial one (and virtually no concern beyond two decades), and $\rho = 0.8$, implying significant (but declining) concern about subsequent decades within the planning period. The variables for which values are shown in the table are the optimal immigration rate and the resulting 65+ proportion and level of output per capita. (For consistency with the earlier tables the symbols %(M / N), %(N^a / N) and Q / N are used in Table 11, rather than $m, a,$ and q .)

The optimal immigration rates are only slightly higher than the initial 0.5 percent rate when the standard weighting pattern is used with ρ set at 0.2, and hence the 65+ proportion and output per capita levels are altered hardly at all from their Table 3 values (where the rate is 0.5 percent in every decade). With ρ raised to 0.8 the immigration rate is increased a bit more, but is never higher than 0.6 percent per annum. Reducing the marginal penalty for higher immigration by cutting w_3 by half ($w_3 = 0.5w_3^*$) causes some increase in the immigration rate but the rate is always less than 0.7 percent, even with $\rho = 0.8$. Reducing w_3 even more, to $0.25w_3^*$, causes further increase, and increasing w_2 by half (a greater penalty for a higher 65+ proportion) causes further increase still. Even with the weights most favourable to raising the immigration rate though it never exceeds 1 percent. The overall effect on output per capita is very small, whatever the weights and discount factor. There is some reduction of the 65+ proportion with those weights: by decade 6 it is 3.1 percentage points lower in the final panel of Table 11 compared with the first panel, and 3.5 percentage points lower compared with Table 3 (21.5 percent of the population compared with 25.0). The criterion function we have used was chosen somewhat arbitrarily but the results based on it are consistent with the view that the scope for using immigration to offset population aging is quite limited when policy choices must take account of potential adjustment difficulties at high annual rates.

10. SUMMARY

With the total fertility rate maintained at 1.5 children per woman and no immigration the rate of growth of our standard model population turns negative within two decades and the population itself falls below its initial level within three. The rate of labour force growth also turns negative. The proportion of the population 65 and over rises (doubling within three decades), the proportion under 20 declines and the combination of the two increases. However national output (or income) per capita continues to grow throughout the hundred years of simulation, even without technical progress but much more rapidly with it. The capital/output and capital/labour ratios rise as the economy and the population move toward a steady state path of decline. If output per capita is taken as a crude measure of welfare the decline in population is not accompanied by a decline in that regard, given the assumptions and structure of the model. Allowing the TFR to rise over ten years to the natural replacement level puts the population on a path toward stationarity, ultimately stabilizing its size close to the initial level. The older population proportion still increases (though not as much) and the dependency ratio rises too, as before. With or without technical progress, output per capita is somewhat lower in each decade than it would have been had there been no increase in fertility as the effect on population size outweighs the effect on the productive capacity of the economy.

Introducing immigration at a fixed annual rate of 0.5 percent of the population keeps the population from declining over the century of simulation when the TFR is set at a constant level of 1.5 and causes it to grow when fertility is allowed to rise. Immigration at that rate has a rather limited effect on demographic structure though, as represented by the percentage shares of the young and old. As with the increase in fertility its effect on population size outweighs its effect on productive capacity and per capita output is therefore somewhat lower than in the comparable no-immigration case. However the fact that per capita output is lower is not the important point; the differences are generally small. What is important is that if immigration is thought of as a means of increasing the economy's productive capacity (as it obviously does) that result does not carry over when output is related to the increased population size. The increase in aggregate output does not increase the welfare level, if output per capita can be interpreted in that way.

A policy of using immigration to prevent a long-run decline in population size appears feasible, based on our model simulations (and studies by others). With a TFR of 0.5 it requires no immigration for two decades and an annual immigration rate never greater than 0.7 percent of the population thereafter. With the TFR rising to the natural replacement level no immigration is required in any decade of the century. To maintain the initial rates of growth of population and labour force in every decade when the TFR is 1.5 requires annual immigration rates of up to 1.3 percent, and those might well be deemed too high. If the TFR rises to 2.1 the rates are much lower though, and might be acceptable. (The required long-run immigration rate varies almost monotonically with the total fertility rate when the TFRs of different countries are used in the simulations.)

A policy of using immigration to keep the older share of the population from rising requires very high rates – in excess of 3 percent per year (roughly 30 percent per decade) even with the TFR rising to 2.1. The population would have to increase 20 or 30 fold in a hundred years to accommodate immigration rates high enough to achieve the policy goal in this case, or 35 to 40 percent per decade. Such a policy would almost certainly be regarded as infeasible. Constraining immigrants to be in the range 20 to 34 years of age reduces the required immigration rates but does not alter the general conclusion of infeasibility. The age constraint raises the labour force content of immigration sufficiently to increase output per capita in the earlier decades of the century (relative to a no-immigration situation) but lowers it in subsequent decades. Overall the effects on output per capita are rather small.

A policy based on a criterion function that takes account simultaneously of the effects on output per capita, the 65-and-over proportion and difficulties of absorbing large numbers of immigrants requires (in our simulations) annual rates never greater than 1 percent of the population, and in many cases much lower rates. It leaves output per capita little changed and has some modest effect on the older population share.

The model that we have used and the simulations based on it lead to the conclusion then that while immigration may be helpful in controlling population size it is of only minor value as an instrument for long-run control of the age distribution (this is consistent with earlier studies – Blanchet, 1989, Wu and Li, 2003, and others) and is of virtually no value in controlling per capita national output or income. This conclusion applies to the overall effects of immigration of course, and does not preclude the effective use of a selective policy to deal with particular skill shortages or other situations of a specific and shorter-run character.

11. FINAL REMARKS

We have employed a quite basic model, one in which the behavioural characteristics of immigrants are assumed to be the same as those of the general population. Possible differences in productivity relating to the educational level or human capital of immigrants are thus ignored, differences in fertility, mortality and labour force participation rates, differences in saving rates, and so on. The existence and implications of such differences are more speculative and harder to allow for in a convincing way in long-run simulations but they may have some bearing on the impact of immigration. In employing a basic neoclassical model of the economy we have assumed also a fixed rate of saving and exogenous technical progress. Assuming otherwise would no doubt affect the results of simulations in some degree. It is difficult to imagine that the broad conclusions about the effectiveness of the immigration instrument would be much altered. However experiments with other assumptions and model specifications might be worthwhile and interesting, given the practical importance attaching to immigration policy in many countries. Our results could then be interpreted as providing a baseline with which other model results could be compared to see whether considerations we have ignored may in fact matter.

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ECONOMIC-DEMOGRAPHIC GROWTH MODEL

POPULATION

(1a) $f_{xt} = a_x F_t$ (x = 15, ...,49); (1b) $f_{xt} = 0$ (x < 15; x > 49)

(2) $B_{st} = \phi \sum_{x=15}^{50} (0.5(f_{x-1,t-1} + f_{xt}))(0.5(N_{2,x-1,t-1} + N_{2xt}))$ (s = 1,2)

(3) $M_t = h_t N_{t-1}$

(4) $M_{sxt} = g_{sx} M_t$ (s = 1,2; x = 0, ...,x*)

(5) $N_{s0t} = (1 - d_{s0}) B_{st} + M_{s0t}$ (s = 1,2)

(6) $N_{sxt} = (1 - d_{sx}) N_{s,x-1,t-1} + M_{sxt}$ (s = 1,2; x=1, ...,x*)

MACROECONOMY

(7) $L_t = \sum_{s=1}^{2} \sum_{x=15}^{x^*} p_{sx} N_{sxt}$

(8) $E_t = \sum_{s=1}^{2} \sum_{x=15}^{x^*} (1 - u_{sx}) p_{sx} N_{sxt}$

(9) $Q_t = \alpha_t K_t^{\beta} E_t^{1-\beta}$

(10) $K_t = (1 - \delta) K_{t-1} + I_{t-1}$

(11) $I_t = S_t$

(12) $S_t = \gamma Q_t$

GREEK SYMBOLS

α - state of technical progress
β - elasticity parameter in production function
γ - rate of saving
δ - rate of depreciation of capital stock
φ - proportion of births of given sex

LATIN SYMBOLS

a - ratio of age-specific fertility rate to total fertility rate
B - births
d - death rate
E - employment
F - total fertility rate
f - age-specific fertility rate
g - proportion of immigrants in given age-sex category
h - immigration rate (immigration/population ratio)
I - investment
K - capital stock
L - labour force
M - immigration
N - population
p - labour force participation rate
Q - output
S - saving
s - sex (s = 1 for male, 2 for female)
t - time (year)
u - unemployment rate
x - age
x* - maximum age in population

Table 1: Time Paths of Selected Variables with No Immigration and No Technical Progress

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
						-- TFR constant at 1.5 --					
N	100.0	101.7	101.0	97.2	90.1	81.7	73.6	66.0	59.0	52.8	47.3
%ΔN	0.32	0.17	-0.06	-0.39	-0.76	-0.97	-1.04	-1.09	-1.12	-1.11	-1.10
%(L/N)	52.3	51.9	48.4	45.7	45.2	44.4	43.8	44.2	44.1	43.9	44.1
%ΔL	0.44	0.08	-0.75	-0.96	-0.87	-1.15	-1.16	-1.01	-1.14	-1.14	-1.06
%(N^a/N)	12.8	15.4	20.6	26.1	27.5	28.2	29.6	29.2	28.9	29.4	29.2
%(N^y/N)	25.3	21.4	19.3	18.4	17.4	17.2	17.3	17.0	17.1	17.2	17.1
%(N^{ay}/N)	38.1	36.8	39.9	44.6	44.9	45.4	46.8	46.2	46.0	46.6	46.3
Q/N	100.0	105.5	104.9	104.0	106.4	108.0	109.3	111.9	113.4	114.4	115.7
%Δ(Q/N)	0.80	0.54	-0.06	-0.09	0.23	0.15	0.12	0.23	0.14	0.09	0.12
K/E	4.91	6.02	7.40	8.71	9.73	10.85	11.79	12.40	13.07	13.61	13.96
K/Q	3.00	3.52	4.06	4.55	4.92	5.31	5.62	5.83	6.04	6.22	6.33
eq(K/Q)	4.49	5.47	6.58	6.25	6.61	7.17	6.77	6.78	7.11	6.86	6.84
						-- TFR rises to 2.1 by end of decade 1 --					
N	100.0	103.6	106.8	106.7	104.7	102.6	100.8	100.2	100.5	101.0	101.4
%ΔN	0.32	0.36	0.30	-0.01	-0.19	-0.21	-0.18	-0.06	0.04	0.05	0.04
%(L/N)	52.3	50.9	46.0	44.0	44.3	44.1	45.2	46.2	45.5	45.7	46.0
%ΔL	0.44	0.08	-0.70	-0.46	-0.13	-0.24	0.08	0.15	-0.10	0.08	0.09
%(N^a/N)	12.8	15.1	19.5	23.8	23.6	22.5	21.6	19.7	20.1	20.4	19.9
%(N^y/N)	25.3	22.9	23.6	23.9	23.4	24.8	25.3	25.1	25.5	25.5	25.2
%(N^{ay}/N)	38.1	38.0	43.1	47.7	47.1	47.3	46.9	44.7	45.6	45.9	45.1
Q/N	100.0	103.5	99.6	98.4	100.8	102.0	104.9	107.2	106.5	106.9	107.5
%Δ(Q/N)	0.80	0.35	-0.39	-0.11	0.24	0.12	0.28	0.21	-0.06	0.04	0.06
K/E	4.91	6.02	7.37	8.32	8.82	9.29	9.39	9.42	9.63	9.64	9.65
K/Q	3.00	3.52	4.05	4.41	4.59	4.76	4.80	4.81	4.88	4.89	4.89
eq(K/Q)	4.49	5.47	6.23	5.17	5.27	5.18	4.71	5.03	5.06	4.82	4.99

Note: Point-in-time variables are reported at the end of a decade; rates of change are averages during the decade.

Table 2: Time Paths of Selected Variables with No Immigration and Technical Progress of 0.4 Percent per Year

Variable	Initial value (t=0)	Subsequent values Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
					-- TFR constant at 1.5 --						
N	100.0	101.7	101.0	97.2	90.1	81.7	73.6	66.0	59.0	52.8	47.3
%ΔN	0.32	0.17	-0.06	-0.39	-0.76	-0.97	-1.04	-1.09	-1.12	-1.11	-1.10
%(L/N)	52.3	51.9	48.4	45.7	45.2	44.4	43.8	44.2	44.1	43.9	44.1
%ΔL	0.44	0.08	-0.75	-0.96	-0.87	-1.15	-1.16	-1.01	-1.14	-1.14	-1.06
%(N^a/N)	12.8	15.4	20.6	26.1	27.5	28.2	29.6	29.2	28.9	29.4	29.2
%(N^y/N)	25.3	21.4	19.3	18.4	17.4	17.2	17.3	17.0	17.1	17.2	17.1
%(N^{ay}/N)	38.1	36.8	39.9	44.6	44.9	45.4	46.8	46.2	46.0	46.6	46.3
Q/N	100.0	110.2	114.9	119.7	128.8	137.6	146.9	158.5	169.5	180.5	192.8
%Δ(Q/N)	1.20	0.98	0.42	0.41	0.74	0.67	0.65	0.77	0.68	0.63	0.66
K/E	4.91	6.10	7.68	9.32	10.80	12.53	14.20	15.60	17.21	18.79	20.22
K/Q	3.00	3.39	3.83	4.22	4.49	4.79	5.02	5.15	5.30	5.42	5.48
eq(K/Q)	3.98	4.73	5.54	5.30	5.56	5.95	5.67	5.68	5.91	5.74	5.72
					-- TFR rises to 2.1 by end of decade 1 --						
N	100.0	103.6	106.8	106.7	104.7	102.6	100.8	100.2	100.5	101.0	101.4
%ΔN	0.32	0.36	0.30	-0.01	-0.19	-0.21	-0.18	-0.06	0.04	0.05	0.04
%(L/N)	52.3	50.9	46.0	44.0	44.3	44.1	45.2	46.2	45.5	45.7	46.0
%ΔL	0.44	0.08	-0.70	-0.46	-0.13	-0.24	0.08	0.15	-0.10	0.08	0.09
%(N^a/N)	12.8	15.1	19.5	23.8	23.6	22.5	21.6	19.7	20.1	20.4	19.9
%(N^y/N)	25.3	22.9	23.6	23.9	23.4	24.8	25.3	25.1	25.5	25.5	25.2
%(N^{ay}/N)	38.1	38.0	43.1	47.7	47.1	47.3	46.9	44.7	45.6	45.9	45.1
Q/N	100.0	108.1	109.0	113.3	122.1	130.3	141.3	152.4	160.0	169.8	180.6
%Δ(Q/N)	1.20	0.78	0.09	0.38	0.75	0.65	0.82	0.76	0.49	0.60	0.62
K/E	4.91	6.10	7.64	8.91	9.81	10.78	11.40	12.00	12.91	13.61	14.37
K/Q	3.00	3.39	3.82	4.08	4.20	4.31	4.31	4.29	4.34	4.33	4.32
eq(K/Q)	3.98	4.73	5.29	4.51	4.58	4.52	4.15	4.40	4.42	4.24	4.37

Note: See note to Table 1.

Table 3: Time Paths of Selected Variables with a Constant Annual Immigration Rate of 0.5 Percent and Technical Progress of 0.4 Percent per Year

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
						-- TFR constant at 1.5 --					
N	100.0	107.3	113.3	116.6	117.0	115.8	114.2	112.3	110.3	108.4	106.6
%ΔN	0.82	0.71	0.54	0.29	0.03	-0.10	-0.14	-0.17	-0.18	-0.17	-0.17
%(L/N)	52.4	52.2	49.4	47.5	47.2	46.6	46.3	46.6	46.5	46.4	46.5
%ΔL	1.00	0.68	0.00	-0.10	-0.04	-0.23	-0.20	-0.11	-0.20	-0.18	-0.15
%(N^a/N)	12.7	14.7	18.8	22.8	23.6	24.1	25.0	24.6	24.5	24.7	24.6
%(N^y/N)	25.3	21.9	20.3	19.6	18.9	18.8	18.9	18.7	18.8	18.8	18.8
%(N^{ay}/N)	38.0	36.6	39.0	42.4	42.4	42.9	43.8	43.3	43.3	43.5	43.4
Q/N	100.0	109.3	114.0	119.4	127.9	136.0	144.7	155.0	164.9	175.1	186.2
%Δ(Q/N)	1.09	0.89	0.43	0.46	0.69	0.62	0.62	0.69	0.62	0.60	0.61
K/E	4.88	5.78	6.95	8.08	9.09	10.20	11.23	12.13	13.13	14.10	15.04
K/Q	3.00	3.27	3.57	3.82	3.98	4.15	4.26	4.32	4.39	4.43	4.46
eq(K/Q)	3.58	4.10	4.51	4.34	4.50	4.63	4.50	4.52	4.59	4.53	4.53
						-- TFR rises to 2.1 by end of decade 1 --					
N	100.0	109.4	119.9	128.3	135.9	144.3	153.5	164.6	177.6	191.7	206.9
%ΔN	0.82	0.91	0.92	0.68	0.58	0.60	0.62	0.70	0.76	0.77	0.76
%(L/N)	52.4	51.2	47.0	45.7	46.0	45.8	46.6	47.3	46.8	47.0	47.1
%ΔL	1.00	0.68	0.07	0.38	0.64	0.56	0.81	0.83	0.68	0.79	0.79
%(N^a/N)	12.7	14.4	17.7	20.7	20.3	19.5	18.8	17.5	17.8	18.0	17.7
%(N^y/N)	25.3	23.4	24.6	24.9	24.6	25.8	26.1	25.9	26.2	26.2	26.1
%(N^{ay}/N)	38.0	37.8	42.3	45.7	45.0	45.3	45.0	43.5	44.1	44.2	43.8
Q/N	100.0	107.2	108.2	112.9	120.8	128.1	137.7	147.4	155.1	164.3	174.3
%Δ(Q/N)	1.09	0.70	0.10	0.42	0.68	0.59	0.73	0.68	0.51	0.58	0.59
K/E	4.88	5.78	6.91	7.73	8.33	8.96	9.40	9.88	10.54	11.11	11.73
K/Q	3.00	3.27	3.56	3.70	3.74	3.79	3.76	3.74	3.76	3.75	3.74
eq(K/Q)	3.58	4.09	4.33	3.82	3.89	3.83	3.65	3.78	3.78	3.70	3.76

Note: See note to Table 1.

Table 4: Time Paths of Selected Variables with Immigration Rates (%(M/N)) Set So as to Satisfy Alternative Stabilization Policies: TFR Constant at 1.5

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
						-- target variable: N --					
%(M/N)	0.50	0.00	0.00	0.24	0.63	0.70	0.64	0.59	0.59	0.59	0.60
N	100.0	101.7	101.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
%ΔN	0.82	0.17	-0.06	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%(L/N)	52.4	51.9	48.5	46.0	46.4	46.7	46.9	47.2	46.9	46.8	46.9
%ΔL	1.00	0.09	-0.74	-0.63	0.08	0.07	0.04	0.05	-0.05	-0.03	0.02
%(N^a/N)	12.7	15.3	20.5	25.5	25.2	24.1	23.9	23.5	23.7	24.0	23.9
%(N^{ay}/N)	38.0	36.8	39.8	44.2	43.7	43.0	43.2	42.6	42.7	43.1	42.9
Q/N	100.0	110.3	115.0	119.6	128.2	137.2	146.3	156.1	165.2	174.8	185.6
						-- target variable: %ΔN --					
%(M/N)	0.50	0.60	0.75	0.94	1.11	1.15	1.12	1.12	1.11	1.11	1.11
N	100.0	108.5	117.7	127.7	138.5	150.2	163.0	176.8	191.8	208.0	225.7
%ΔN	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
%(L/N)	52.4	52.3	49.8	48.4	48.7	48.6	48.6	48.8	48.7	48.7	48.7
%ΔL	1.00	0.80	0.32	0.54	0.87	0.81	0.82	0.86	0.80	0.81	0.83
%(N^a/N)	12.7	14.6	18.2	21.2	20.9	20.5	20.7	20.4	20.4	20.6	20.5
%(N^{ay}/N)	38.0	36.5	38.8	41.6	40.9	40.8	41.2	40.8	40.8	41.0	40.9
Q/N	100.0	109.1	113.6	118.7	126.7	134.4	142.5	151.4	160.3	169.7	179.8
						-- target variable: %ΔL --					
%(M/N)	0.50	0.77	1.27	1.22	1.16	1.30	1.25	1.20	1.25	1.24	1.22
N	100.0	110.5	126.9	143.1	157.7	175.5	194.6	214.2	236.8	262.0	289.1
%ΔN	0.82	1.00	1.40	1.20	0.98	1.08	1.04	0.96	1.01	1.01	0.99
%(L/N)	52.4	52.4	50.3	49.4	49.5	49.1	48.9	49.1	49.1	49.0	49.1
%ΔL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
%(N^a/N)	12.7	14.4	17.1	19.5	19.4	19.6	20.1	19.8	19.7	19.9	19.9
%(N^{ay}/N)	38.0	36.5	38.4	40.6	39.9	40.2	40.8	40.4	40.4	40.6	40.5
Q/N	100.0	108.7	112.6	118.1	126.2	133.2	141.0	150.2	159.0	168.3	178.5
						-- target variable: %(N^a/N) --					
%(M/N)	0.50	2.27	3.48	3.13	2.57	3.44	3.31	2.82	3.14	3.29	3.02
N	100.0	129.2	189.2	267.9	357.4	519.9	749.5	1027.7	1451.7	2085.8	2918.0
%ΔN	0.82	2.60	3.89	3.54	2.93	3.82	3.73	3.21	3.52	3.69	3.42
%(L/N)	52.4	53.2	52.8	53.0	53.0	52.8	52.9	53.0	52.9	52.9	52.9
%ΔL	1.00	2.75	3.81	3.59	2.92	3.78	3.74	3.22	3.50	3.69	3.43
%(N^a/N)	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
%(N^{ay}/N)	38.0	36.0	36.5	36.7	36.1	36.4	36.6	36.3	36.3	36.5	36.4
Q/N	100.0	105.8	107.3	112.4	119.7	124.2	130.5	139.4	147.0	154.6	164.4

Note: Point-in-time variables are reported at the end of a decade; rates of change are averages during the decade. The annual immigration rate required for stabilization is defined as the minimum rate (percent of population) necessary to keep a variable from falling below its initial level or rising above it in the case of %N^a/N.

Table 5: Time Paths of Selected Variables with Immigration Rates (%(M/N)) Set So as to Satisfy Alternative Stabilization Policies: TFR Rises to 2.1 by the End of Decade 1

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
-- target variable: N --											
%(M/N)	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	100.0	103.7	107.0	106.9	104.9	102.8	101.0	100.4	100.8	101.2	101.6
%ΔN	0.82	0.37	0.31	0.00	-0.19	-0.20	-0.18	-0.06	0.04	0.05	0.04
%(L/N)	52.4	50.9	46.1	44.0	44.2	44.1	45.2	46.1	45.5	45.7	46.0
%ΔL	1.00	0.09	-0.69	-0.46	-0.14	-0.24	0.08	0.14	-0.10	0.09	0.09
%(N^a/N)	12.7	15.0	19.4	23.7	23.7	22.5	21.6	19.7	20.1	20.4	19.9
%(N^{ay}/N)	38.0	38.0	43.1	47.6	47.1	47.3	46.9	44.7	45.6	45.9	45.1
Q/N	100.0	108.2	109.2	113.4	122.1	130.3	141.4	152.5	160.2	170.0	180.8
-- target variable: %ΔN --											
%(M/N)	0.50	0.42	0.42	0.64	0.71	0.66	0.63	0.55	0.52	0.53	0.54
N	100.0	108.5	117.7	127.7	138.5	150.2	163.0	176.8	191.8	208.1	225.7
%ΔN	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
%(L/N)	52.4	51.2	46.9	45.7	46.2	46.3	47.1	47.4	46.9	47.0	47.1
%ΔL	1.00	0.58	-0.06	0.56	0.94	0.83	0.99	0.89	0.71	0.83	0.84
%(N^a/N)	12.7	14.5	18.0	20.7	19.8	18.6	18.0	17.1	17.7	17.9	17.6
%(N^{ay}/N)	38.0	37.8	42.4	45.7	44.7	44.7	44.3	43.2	43.9	44.1	43.8
Q/N	100.0	107.3	108.4	112.7	120.6	127.9	137.2	146.4	154.1	163.4	173.4
-- target variable: %ΔL --											
%(M/N)	0.50	0.77	1.19	0.87	0.72	0.82	0.64	0.61	0.74	0.66	0.64
N	100.0	112.6	133.4	150.4	165.6	184.6	202.2	221.2	245.9	271.5	298.9
%ΔN	0.82	1.20	1.71	1.21	0.97	1.09	0.92	0.90	1.07	1.00	0.97
%(L/N)	52.4	51.4	47.9	46.9	47.1	46.7	47.1	47.6	47.3	47.3	47.5
%ΔL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
%(N^a/N)	12.7	14.1	16.3	18.4	18.2	17.9	17.9	17.0	17.1	17.3	17.1
%(N^{ay}/N)	38.0	37.7	41.6	44.3	43.5	44.1	44.4	43.1	43.5	43.8	43.4
Q/N	100.0	106.6	107.1	112.0	119.9	126.3	135.3	145.0	152.7	162.0	172.2
-- target variable: %(N^a/N) --											
%(M/N)	0.50	2.01	2.96	2.57	1.75	2.47	2.28	1.65	2.19	2.27	1.87
N	100.0	128.4	185.5	257.1	328.1	451.0	610.0	771.9	1030.9	1393.2	1804.8
%ΔN	0.82	2.53	3.75	3.32	2.47	3.23	3.07	2.38	2.94	3.06	2.62
%(L/N)	52.4	52.0	50.0	50.1	50.0	49.7	49.9	49.9	49.8	49.8	49.9
%ΔL	1.00	2.46	3.34	3.34	2.45	3.18	3.09	2.39	2.93	3.05	2.64
%(N^a/N)	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
%(N^{ay}/N)	38.0	37.3	39.9	40.8	40.3	40.6	41.0	40.6	40.6	40.9	40.8
Q/N	100.0	104.2	103.2	107.5	114.9	119.7	126.5	135.9	143.1	150.6	160.7

Note: See note to Table 4.

Table 6: Total Fertility Rates and Selected Age Characteristics, OECD Countries with TFRs<2.1

	Country	TFR	$\%(N^a/N)$	$\%(N^y/N)$	$\%(N^{ay}/N)$
1	Czech Republic	1.17	13.9	22.6	36.5
2	Korea	1.17	7.3	28.6	35.8
3	Slovak Republic	1.19	11.5	27.1	38.6
4	Poland	1.24	12.4	27.0	39.5
5	Greece	1.25	17.8	21.0	38.8
6	Spain	1.25	17.3	20.6	37.9
7	Italy	1.26	18.3	19.2	37.4
8	Hungary	1.30	14.7	23.0	37.7
9	Germany	1.31	16.9	21.0	37.9
10	Japan	1.33 [b]	17.7	20.4	38.0
11	Austria	1.40	15.5	22.5	38.0
12	Switzerland	1.40	15.2	23.0	38.2
13	Portugal	1.47	16.3	23.6	39.9
14	Canada	1.50	12.8	25.6	38.4
15	Belgium	1.62	16.9	23.3	40.3
16	Luxembourg	1.63	14.4	24.5	38.8
17	United Kingdom	1.64	15.6	25.0	40.6
18	Sweden	1.65	17.1	24.2	41.3
19	Denmark	1.72	14.8	23.9	38.7
20	Finland	1.72	15.1	24.4	39.5
21	Netherlands	1.73	13.7	24.4	38.0
22	Australia	1.75 [a]	12.5	27.6	40.1
23	Norway	1.75	15.0	26.0	41.0
24	France	1.89	16.1	25.2	41.3
25	New Zealand	1.90	11.5	29.1	40.6
26	Iceland	1.93	11.6	30.7	42.3
27	Ireland	1.97	11.3	29.8	41.1
28	United States	2.03 [b]	12.4	28.3	40.7

Note: The total fertility rates are taken from *OECD Health Data 2004* and are for the year 2002 unless otherwise noted: [a], data are for 2000, [b], data are for 2001. The age distributions are calculated from data taken from the *International Data Base* of the U.S. Census Bureau.

Table 7: Immigration Rates (%(M/N)) Required to Stabilize the Population (N) Based on Total Fertility Rates and Age Distributions of OECD Countries with TFRs<2.1

Country		Annual immigration rate required for stabilization (%)									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
1	Czech Republic	0.01	0.39	0.68	0.85	0.91	0.97	0.98	0.92	0.89	0.91
2	Korea	0.00	0.00	0.00	0.78	1.05	1.08	1.00	0.92	0.89	0.89
3	Slovak Republic	0.00	0.00	0.41	0.76	0.89	0.97	0.99	0.92	0.87	0.88
4	Poland	0.00	0.00	0.48	0.74	0.83	0.88	0.93	0.88	0.82	0.84
5	Greece	0.18	0.50	0.65	0.74	0.87	0.92	0.88	0.83	0.82	0.84
6	Spain	0.12	0.45	0.59	0.73	0.92	0.97	0.89	0.80	0.82	0.84
7	Italy	0.29	0.58	0.68	0.80	0.93	0.93	0.83	0.80	0.82	0.83
8	Hungary	0.00	0.30	0.58	0.73	0.79	0.83	0.84	0.79	0.78	0.79
9	Germany	0.26	0.50	0.67	0.80	0.87	0.83	0.77	0.78	0.78	0.78
10	Japan	0.20	0.54	0.69	0.74	0.76	0.80	0.79	0.76	0.76	0.76
11	Austria	0.09	0.33	0.51	0.69	0.79	0.76	0.69	0.68	0.69	0.69
12	Switzerland	0.10	0.31	0.50	0.73	0.79	0.73	0.67	0.69	0.70	0.69
13	Portugal	0.00	0.17	0.40	0.51	0.66	0.71	0.67	0.62	0.62	0.63
14	Canada	0.00	0.00	0.26	0.63	0.70	0.64	0.59	0.59	0.59	0.60
15	Belgium	0.01	0.23	0.35	0.50	0.56	0.50	0.46	0.47	0.48	0.48
16	Luxembourg	0.00	0.02	0.29	0.52	0.59	0.50	0.43	0.46	0.48	0.47
17	United Kingdom	0.00	0.05	0.28	0.46	0.51	0.49	0.45	0.45	0.46	0.46
18	Sweden	0.10	0.17	0.34	0.47	0.44	0.45	0.45	0.46	0.45	0.45
19	Denmark	0.00	0.05	0.27	0.45	0.46	0.38	0.35	0.37	0.39	0.38
20	Finland	0.00	0.03	0.34	0.48	0.43	0.36	0.36	0.37	0.38	0.38
21	Netherlands	0.00	0.00	0.10	0.47	0.51	0.42	0.33	0.34	0.37	0.38
22	Australia	0.00	0.00	0.00	0.00	0.30	0.44	0.39	0.35	0.33	0.34
23	Norway	0.00	0.00	0.00	0.35	0.41	0.37	0.34	0.34	0.35	0.35
24	France	0.00	0.00	0.00	0.05	0.32	0.26	0.20	0.18	0.19	0.20
25	New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.25
26	Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	United States	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: The annual immigration rate required for stabilization is defined as the minimum rate (percent of population) necessary to keep the population from falling below its initial level.

Table 8: Immigration Rates (%(M/N)) Required to Stabilize the Population Growth Rate (%ΔN) Based on Total Fertility Rates and Age Distributions of OECD Countries with TFRs<2.1

Country		Annual immigration rate required for stabilization (%)									
		Decade									
		1	2	3	4	5	6	7	8	9	10
1	Czech Republic	0.78	1.07	1.26	1.35	1.38	1.44	1.46	1.42	1.41	1.41
2	Korea	0.40	0.73	1.02	1.30	1.45	1.48	1.46	1.43	1.41	1.40
3	Slovak Republic	0.58	0.84	1.10	1.28	1.36	1.42	1.46	1.42	1.39	1.39
4	Poland	0.61	0.84	1.11	1.25	1.31	1.36	1.41	1.37	1.34	1.35
5	Greece	0.94	1.16	1.22	1.25	1.34	1.39	1.37	1.34	1.34	1.34
6	Spain	0.88	1.11	1.17	1.24	1.37	1.42	1.38	1.33	1.33	1.34
7	Italy	1.05	1.22	1.25	1.30	1.38	1.39	1.34	1.32	1.33	1.34
8	Hungary	0.73	1.01	1.16	1.24	1.27	1.32	1.33	1.30	1.29	1.30
9	Germany	1.02	1.15	1.24	1.29	1.33	1.31	1.29	1.29	1.29	1.29
10	Japan	0.96	1.18	1.24	1.24	1.24	1.28	1.29	1.27	1.27	1.27
11	Austria	0.85	0.99	1.09	1.19	1.25	1.24	1.21	1.20	1.20	1.21
12	Switzerland	0.87	0.97	1.09	1.22	1.25	1.22	1.20	1.21	1.21	1.21
13	Portugal	0.68	0.92	0.99	1.04	1.14	1.19	1.18	1.14	1.14	1.14
14	Canada	0.62	0.75	0.94	1.12	1.16	1.13	1.11	1.12	1.11	1.11
15	Belgium	0.77	0.88	0.93	1.01	1.03	1.02	1.00	1.00	1.00	1.00
16	Luxembourg	0.65	0.80	0.87	1.02	1.06	1.01	0.98	0.99	1.00	0.99
17	United Kingdom	0.70	0.77	0.86	0.97	1.00	1.00	0.99	0.99	0.98	0.98
18	Sweden	0.85	0.83	0.92	0.97	0.95	0.97	0.98	0.98	0.97	0.97
19	Denmark	0.67	0.79	0.85	0.95	0.94	0.91	0.90	0.91	0.91	0.91
20	Finland	0.67	0.78	0.91	0.97	0.92	0.89	0.90	0.91	0.91	0.91
21	Netherlands	0.56	0.73	0.83	0.95	0.97	0.92	0.88	0.89	0.90	0.90
22	Australia	0.41	0.55	0.71	0.86	0.90	0.89	0.88	0.88	0.88	0.88
23	Norway	0.62	0.67	0.73	0.88	0.90	0.88	0.88	0.88	0.88	0.88
24	France	0.53	0.64	0.69	0.76	0.78	0.76	0.74	0.74	0.75	0.75
25	New Zealand	0.15	0.38	0.50	0.65	0.74	0.75	0.74	0.73	0.74	0.74
26	Iceland	0.17	0.30	0.47	0.64	0.69	0.70	0.71	0.71	0.71	0.71
27	Ireland	0.04	0.31	0.50	0.57	0.66	0.70	0.68	0.67	0.67	0.67
28	United States	0.25	0.36	0.52	0.64	0.66	0.62	0.60	0.60	0.61	0.61

Note: The annual immigration rate required for stabilization is defined as the minimum rate (percent of population) necessary to keep the population growth rate from falling below its initial level.

Table 9: Time Paths of Selected Variables with Immigration Rates (%(M/N)) Set So as to Satisfy Alternative Stabilization Policies: TFR Constant at 1.5, Immigrants Restricted to 20-34 Years of Age

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
					-- target variable: N --						
%(M/N)	0.50	0.00	0.00	0.22	0.56	0.60	0.55	0.50	0.51	0.55	0.58
N	100.0	101.7	101.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
%ΔN	0.82	0.17	-0.06	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%(L/N)	52.4	51.9	48.5	46.4	47.3	48.1	48.7	48.4	47.5	47.3	47.7
%ΔL	1.00	0.09	-0.74	-0.56	0.20	0.17	0.11	-0.05	-0.20	-0.03	0.09
%(N^a/N)	12.7	15.3	20.5	25.4	24.8	23.1	22.5	22.5	23.9	24.5	23.9
%(N^{ay}/N)	38.0	36.8	39.8	43.7	42.5	41.2	40.7	40.3	41.5	42.2	41.5
Q/N	100.0	110.3	115.0	120.2	130.2	140.7	151.1	160.2	167.7	177.3	189.0
					-- target variable: %ΔN --						
%(M/N)	0.50	0.55	0.64	0.83	0.97	0.98	0.99	1.00	1.01	1.01	1.01
N	100.0	108.5	117.7	127.7	138.5	150.2	163.0	176.8	191.8	208.0	225.7
%ΔN	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
%(L/N)	52.4	53.0	50.9	50.4	50.9	50.5	50.4	50.5	50.3	50.3	50.4
%ΔL	1.00	0.95	0.40	0.73	0.92	0.73	0.80	0.84	0.77	0.82	0.84
%(N^a/N)	12.7	14.4	17.6	19.9	19.1	19.5	20.0	19.7	19.9	20.1	19.9
%(N^{ay}/N)	38.0	35.5	37.4	39.0	37.4	37.9	38.3	37.8	38.1	38.3	38.0
Q/N	100.0	110.3	115.7	122.9	131.9	139.5	147.9	157.1	166.0	175.8	186.5
					-- target variable: %ΔL --						
%(M/N)	0.50	0.59	1.02	0.98	0.97	1.19	1.15	1.04	1.14	1.16	1.09
N	100.0	108.9	123.6	137.5	150.4	168.2	187.8	205.9	227.6	253.1	279.0
%ΔN	0.82	0.86	1.27	1.07	0.90	1.13	1.11	0.93	1.00	1.07	0.98
%(L/N)	52.4	53.1	51.7	51.4	51.9	51.3	50.7	51.1	51.1	50.8	50.9
%ΔL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
%(N^a/N)	12.7	14.3	16.8	18.5	17.7	18.3	19.5	19.0	18.7	19.3	19.3
%(N^{ay}/N)	38.0	35.4	36.4	38.0	36.3	36.5	38.0	37.4	36.9	37.6	37.7
Q/N	100.0	110.3	115.8	123.1	132.6	139.4	146.5	156.6	166.0	174.8	185.6
					-- target variable: %(N^a/N) --						
%(M/N)	0.50	1.60	2.27	1.54	1.35	3.44	2.41	0.64	2.70	4.03	0.79
N	100.0	122.3	162.8	199.1	234.1	347.4	473.0	517.4	697.1	1124.5	1281.0
%ΔN	0.82	2.04	2.90	2.03	1.63	4.02	3.13	0.90	3.03	4.90	1.31
%(L/N)	52.4	55.0	55.3	55.4	55.2	56.3	55.7	54.9	55.9	56.5	54.9
%ΔL	1.00	2.53	2.96	2.06	1.58	4.24	3.03	0.77	3.20	5.01	1.03
%(N^a/N)	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
%(N^{ay}/N)	38.0	33.2	32.7	33.3	31.8	30.3	32.8	33.3	29.6	31.0	34.7
Q/N	100.0	110.1	115.4	123.8	132.8	136.3	142.4	156.6	164.2	165.9	181.1

Note: See note to Table 4.

Table 10: Time Paths of Selected Variables with Immigration Rates (%(M/N)) Set So as to Satisfy Alternative Stabilization Policies: TFR Rises to 2.1 by End of Decade 1, Immigrants Restricted to 20-34 Years of Age

Variable	Initial value (t=0)	Subsequent values									
		Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6	Decade 7	Decade 8	Decade 9	Decade 10
						-- target variable: N --					
%(I/N)	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	100.0	103.7	107.0	106.9	104.9	102.8	101.0	100.4	100.8	101.2	101.6
%ΔN	0.82	0.37	0.31	0.00	-0.19	-0.20	-0.18	-0.06	0.04	0.05	0.04
%(L/N)	52.4	50.9	46.1	44.0	44.2	44.1	45.2	46.1	45.5	45.7	46.0
%ΔL	1.00	0.09	-0.69	-0.46	-0.14	-0.24	0.08	0.14	-0.10	0.09	0.09
%(N^a/N)	12.7	15.0	19.4	23.7	23.7	22.5	21.6	19.7	20.1	20.4	19.9
%(N^{ay}/N)	38.0	38.0	43.1	47.6	47.1	47.3	46.9	44.7	45.6	45.9	45.1
Q/N	100.0	108.2	109.2	113.4	122.1	130.3	141.4	152.5	160.2	170.0	180.8
						-- target variable: %ΔN --					
%(I/N)	0.50	0.37	0.34	0.56	0.59	0.55	0.53	0.47	0.46	0.48	0.48
N	100.0	108.5	117.7	127.7	138.5	150.3	163.0	176.8	191.9	208.1	225.8
%ΔN	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
%(L/N)	52.4	51.6	47.3	46.9	47.4	47.3	48.1	48.2	47.5	47.7	47.8
%ΔL	1.00	0.68	-0.05	0.72	0.93	0.79	0.99	0.83	0.69	0.85	0.84
%(N^a/N)	12.7	14.4	17.6	19.9	18.7	17.9	17.4	16.7	17.5	17.7	17.3
%(N^{ay}/N)	38.0	37.1	41.8	44.2	42.8	43.3	42.7	41.9	43.0	43.0	42.6
Q/N	100.0	108.1	109.3	115.2	123.3	130.6	140.2	149.0	156.4	166.0	176.2
						-- target variable: %ΔL --					
%(I/N)	0.50	0.58	0.95	0.68	0.58	0.77	0.61	0.48	0.67	0.63	0.51
N	100.0	111.2	130.6	146.2	159.8	180.1	199.6	216.4	240.6	268.3	293.3
%ΔN	0.82	1.07	1.62	1.13	0.90	1.20	1.03	0.81	1.07	1.10	0.89
%(L/N)	52.4	52.0	48.9	48.3	48.8	47.9	47.7	48.6	48.3	47.9	48.4
%ΔL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
%(N^a/N)	12.7	14.0	15.9	17.4	16.6	17.0	17.7	16.4	16.4	17.2	16.7
%(N^{ay}/N)	38.0	36.7	40.1	42.7	41.0	41.8	43.4	41.7	41.4	42.8	42.2
Q/N	100.0	108.0	109.5	115.4	124.4	129.7	137.3	148.4	156.4	164.2	175.8
						-- target variable: %(N^a/N) --					
%(I/N)	0.50	1.39	1.87	1.22	0.78	2.48	1.59	0.00	1.83	3.10	0.00
N	100.0	122.3	162.8	199.1	228.9	322.3	420.4	442.6	567.9	879.5	951.9
%ΔN	0.82	2.04	2.90	2.03	1.41	3.48	2.69	0.52	2.52	4.47	0.79
%(L/N)	52.4	53.4	51.4	51.5	51.2	51.9	51.0	50.8	51.8	51.8	50.2
%ΔL	1.00	2.24	2.52	2.04	1.35	3.62	2.52	0.47	2.74	4.46	0.49
%(N^a/N)	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.6	12.7	12.7	12.6
%(N^{ay}/N)	38.0	35.1	37.5	39.0	37.7	36.6	39.5	39.6	35.6	37.6	41.9
Q/N	100.0	107.7	108.9	115.8	124.4	128.1	133.4	147.5	155.7	156.0	170.0

Note: See note to Table 4.

Table 11: Time Paths of Selected Variables with Immigration Rates (%(M/N)) Set So as to Maximize a Composite Criterion Function (TFR constant at 1.5)

Variable	Initial value (t=0)	Subsequent values Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Decade 6
			-- $w_2 = w_2^*$, $w_3 = w_3^*$, $\rho = 0.2$ --				
%(M/N)	0.50	0.52	0.53	0.54	0.55	0.55	0.55
%(N^a/N)	12.7	14.7	18.7	22.6	23.3	23.8	24.6
Q/N	100.0	109.2	114.0	119.3	127.8	135.9	144.5
			-- $w_2 = w_2^*$, $w_3 = w_3^*$, $\rho = 0.8$ --				
%(M/N)	0.50	0.58	0.59	0.59	0.60	0.60	0.60
%(N^a/N)	12.7	14.6	18.5	22.3	22.9	23.5	24.2
Q/N	100.0	109.1	113.8	119.3	127.6	135.6	144.3
			-- $w_2 = w_2^*$, $w_3 = 0.5w_3^*$, $\rho = 0.2$ --				
%(M/N)	0.50	0.53	0.56	0.59	0.59	0.60	0.60
%(N^a/N)	12.7	14.7	18.6	22.4	23.0	23.5	24.2
Q/N	100.0	109.2	113.9	119.3	127.7	135.7	144.3
			-- $w_2 = w_2^*$, $w_3 = 0.5w_3^*$, $\rho = 0.8$ --				
%(M/N)	0.50	0.65	0.67	0.68	0.69	0.69	0.69
%(N^a/N)	12.7	14.5	18.2	21.8	22.4	22.9	23.5
Q/N	100.0	109.0	113.7	119.1	127.4	135.3	143.8
			-- $w_2 = w_2^*$, $w_3 = 0.25w_3^*$, $\rho = 0.2$ --				
%(M/N)	0.50	0.56	0.63	0.67	0.67	0.68	0.69
%(N^a/N)	12.7	14.6	18.5	22.1	22.5	22.9	23.6
Q/N	100.0	109.1	113.8	119.2	127.5	135.5	144.0
			-- $w_2 = w_2^*$, $w_3 = 0.25w_3^*$, $\rho = 0.8$ --				
%(M/N)	0.50	0.78	0.82	0.84	0.84	0.84	0.84
%(N^a/N)	12.7	14.4	17.8	21.0	21.4	21.9	22.5
Q/N	100.0	108.7	113.3	118.9	127.0	134.7	143.0
			-- $w_2 = 1.5w_2^*$, $w_3 = 0.25w_3^*$, $\rho = 0.2$ --				
%(M/N)	0.50	0.63	0.71	0.76	0.77	0.78	0.79
%(N^a/N)	12.7	14.5	18.2	21.6	22.0	22.3	22.9
Q/N	100.0	109.0	113.6	119.0	127.3	135.1	143.5
			-- $w_2 = 1.5w_2^*$, $w_3 = 0.25w_3^*$, $\rho = 0.8$ --				
%(M/N)	0.50	0.91	0.96	0.99	0.99	1.00	1.00
%(N^a/N)	12.7	14.2	17.4	20.3	20.5	21.0	21.5
Q/N	100.0	108.5	113.0	118.6	126.5	134.0	142.2