IMF *Staff Papers*
Vol. 37, No. 3 (September 1990)

Macroeconomic Effects of Projected Population Aging in Industrial Countries

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The effects of population aging are examined with a theoretical model and simulations of MULTIMOD. An older population will consume more of aggregate disposable income, require higher government expenditure, and decrease labor supply. These effects should raise real interest rates and lower capital stock and output. Effects on current balances will depend on the relative speed and extent of aging. Simulations of projected demographic changes suggest that by 2025, real interest rates would be increased in all countries, and net foreign assets would be increased in the United States and decreased in the Federal Republic of Germany and Japan. [JEL 224, 421, 840]

IF CURRENT projections prove to be correct, the populations of most industrial countries will experience significant aging in the first few decades of the next century. Birthrates have already declined markedly from their high levels of the early postwar period, and are projected to decline further. Even though projections that far ahead are obviously subject to considerable uncertainty, a prospective increase in the average age of the population is to a large extent inevitable as the postwar "baby boom" generation moves through the age structure. Aging of the popu-

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The authors are grateful to A. Lans Bovenberg, William Branson, Ernesto Hernández-Catá, Andrew Dean, Robert Hagemann, Richard Hemming, Robert Holzmann, Yusuke Horiguchi, and Mark Lutz for comments, and to Warwick McKibbin, Torsten Persson, and Lars Svensson for useful discussion.

lation can be expected to bring about major changes in the economy, associated with an increase in the number of dependents relative to those that are employed (the dependency ratio), and in some countries with very low birthrates, projected declines in the population. An especially large element of uncertainty attaches to birthrate projections and to changes in population due to migration, but in any case, dependency ratios will almost certainly rise in the next three decades; a substantial rise in birthrates would, if anything, increase dependency ratios over this time period.

With the aging of the population, it is plausible to expect a decline in saving rates to the extent that "life-cycle" motives for saving operate—that is, individuals save for retirement during the years in which they are employed and dissave subsequently.[1] In addition, the demand for social services will change toward providing more medical services and pension benefits and away from spending on education. Finally, the presence of fewer individuals of working age will be associated with lower levels of employment and hence of output, other things being equal, than would otherwise be the case. What happens to per capita output will depend on the resulting capital stock per worker, as well as on the proportion of the population in the labor force.

The macroeconomic effects of these changes, which can be expected to be substantial, are the subject of this paper. Changes in saving propensities, government spending, and labor supply have implications for relative prices, real interest rates, and real exchange rates; these variables in turn feed back onto decisions to spend and produce. The paper is an attempt to gauge the global macroeconomic consequences of generalized aging of the population in industrial countries.

To understand these consequences requires a macroeconomic model. A multicountry context is also important because some of the effects—for example, on real exchange rates and on current account balances—depend crucially on the extent of aging in one country *relative* to that in other countries. In this paper, we use simulations of the International Monetary Fund's multiregion econometric model (MULTIMOD) in order to gauge the effects of the demographic developments described above.

[1] Saving may in fact be "hump-shaped"; that is, saving may be negative in the early years of adulthood, positive in the middle years, and negative again after retirement. Intergenerational transfers complicate the analysis of saving behavior, which should be modeled at the household level. Parents finance consumption for their children when young and may save for their college education. Moreover, the aged may also save in order to make bequests to their children (or to charity).

Aging of the population affects macroeconomic variables in the model through three channels.[2] First, aggregate consumption relative to income is increased by a rise in the dependency ratio. Second, higher dependency ratios lower the labor force, which is associated with a decline in potential output. Third, an older population requires larger government expenditures on medical services and on pension benefits; however, these may be partially offset by a decline in education expenditures.

To date, a macroeconomic framework has not been used to capture the general equilibrium, multicountry effects of demographic projections. There are a number of relevant studies of various features of the issue, however. Heller and others (1986) considered the effect of aging on social expenditures in seven major industrial countries (the so-called Group of Seven), and we will use their estimates below as input to our simulations. Heller (1989) examined the impact of aging on private saving, using several estimated consumption models; he also discussed implications for government budgets. The Organization for Economic Cooperation and Development (OECD) has produced several studies of saving behavior, including effects of demographic factors (Dean and others (1989) and Herd (1989)), and has examined implications of aging for public finances (Hagemann and Nicoletti (1989)). In addition, Auerbach and others (1989) studied the dynamics of the effects of aging on the economies of four industrial countries using a general equilibrium, overlapping-generations model; however, that model considered each country in isolation rather than as part of a closed world system. Ritzen and van Dalen (1989) considered the optimal fiscal policy in the transition to an older population, using a single-country theoretical model. Lee and Lapkoff (1988) looked at intergenerational transfer issues in an overlapping-generations context, but did not treat multicountry issues. Horne, Kremers, and Masson (1989) examined the long-run relationship between dependency ratios and net foreign asset positions for the United States, Japan, and the Federal Republic of Germany.

It is important to make clear at the outset the limitations of our study.[3] We do not examine issues related to intergenerational transfers—namely, questions of equity—since this would require a more detailed model. Furthermore, policy questions—for instance, how should increases in government spending be financed, or whether incentives for private saving should be put in place today—are not treated here.

[2] Another channel, through the rate of population growth, is ignored here; the population is taken to be exogenous in our simulations discussed below.

[3] Some of the issues mentioned in what follows are discussed in Bös and Weizsäcker (1989).

We have not attempted to incorporate projections for aging in developing countries. Finally, we do not take into account effects of the age structure on labor force participation due to endogenous participation or retirement decisions,[4] or to changes in the growth rate of the population.[5]

The plan of the paper is as follows. Section I discusses the OECD's demographic projections and presents the projections of expenditures on government services given in Heller and others (1986). Section II details the model of private consumption that is embodied in MULTIMOD and compares its estimate of the effect of demographic factors to those found in other studies. Section III presents simulations of the effects of aging using MULTIMOD; the results are compared to the long-run effects that can be derived from a simple theoretical model that is the prototype for MULTIMOD. (Derivations are detailed in the Appendix.) Finally, Section IV provides some concluding remarks.

I. Demographic Trends and Projections

In most industrial countries, the decade and a half following the end of World War II saw very high birthrates, which have since moderated. The early postwar generation—often termed the baby boom generation—is now 30–45 years old; as a result, a large fraction of the population is currently employed. However, when the baby boom generation retires in the years 2010–25, there will likely be large declines in the number employed relative to those that depend on them—or on their own savings.

A measure of the age structure of the population is the dependency ratio, which can be calculated in various ways. Table 1 gives historical data and projections for three measures—the ratios of the young and of the old to those of working age (assumed to be between 15 and 64), as well as their combined ratio.[6] The youth dependency ratio declined

[4] However, Table 8 below assesses the sensitivity of our results to these factors.

[5] Some theoretical effects of permanent changes in population growth are analyzed in the Appendix; other things being equal, a lower population growth rate would imply lower real interest rates.

[6] These projections of dependency ratios are substantially the same as those given in the *World Economic Outlook* (International Monetary Fund (1989)), with a few revisions. In particular, Japan's dependency ratio is projected here to be several percentage points higher in the 2010–20 period. However, the simulations discussed below extend the analysis in the *World Economic Outlook* by taking into account induced labor force and government spending changes. In International Monetary Fund (1990), some tax policy issues related to aging are also considered.

markedly from 1965 to 1985; that ratio is projected to decline further in some countries (the United States, France), but generally to remain constant through 2025, at least if birthrates do not change substantially. In contrast, the elderly dependency ratio—roughly constant since 1965—is projected to rise in all countries by 2025. However, the extent of the rise varies greatly across countries.

A summary statistic of the importance of the age structure is the overall dependency ratio, given in the bottom panel of Table 1. This ratio captures the labor force implications of the fraction of the population

Table 1. *Selected Demographic Variables, 1965–2025*

(In percent)

Country	1965	1975	1985	Projections 1995	2005	2015	2025
			Population under 15/population 15–64				
United States	51	39	33	34	29	29	30
Japan	38	36	32	25	28	28	27
Germany, Fed. Rep. of	35	34	22	23	22	19	23
France	41	38	32	31	28	26	28
Italy	—	—	—	25	25	22	24
United Kingdom	36	37	29	31	31	31	31
Canada	57	41	32	30	27	25	28
			Population 65 and over/population 15–64				
United States	16	16	18	19	18	21	29
Japan	9	12	15	19	26	33	32
Germany, Fed. Rep. of	18	23	21	24	29	31	37
France	19	22	20	22	24	27	33
Italy	—	—	—	22	25	28	32
United Kingdom	19	22	23	23	22	24	28
Canada	13	13	15	18	19	25	34
			Overall dependency ratio				
United States	67	55	51	52	47	50	59
Japan	48	48	47	44	54	61	59
Germany, Fed. Rep. of	54	56	43	47	51	51	60
France	61	60	52	53	52	53	61
Italy[a]	52	54	45	47	50	50	55
United Kingdom	55	59	52	54	53	55	59
Canada	70	54	48	48	46	50	61

Sources: Organization for Economic Cooperation and Development, *Labour Force Statistics, 1964–84, 1967–87;* and OECD Secretariat, Directorate for Social Affairs, Manpower, and Education, Demographic Databank projections.

[a] Fund staff estimates for 1965–85.

that is either too young or too old to work.[7] Whether the increase in the overall dependency ratio occurs because of an increase in the young or the old has implications for other variables, for instance medical care and education, as discussed below. It may also matter for the economy's saving propensity; however, consumption equation estimates reported in Section II below use the overall ratio, since there was no significant difference between the effects of youth and elderly dependency ratios.

With the year 1995 as a base (as is done in the simulations in Section III), changes in the overall dependency ratio to 2025 vary greatly across countries, though dependency ratios end up at similar levels in 2025. Increases of 13–15 percentage points are projected for Japan and the Federal Republic of Germany; moreover, a large part of the increase occurs by 2015 (especially in Japan). In contrast, the ratio for the United States increases by 7 percentage points by 2025, and is actually projected to be lower in 2015 than in 1995; the ratio for the United Kingdom increases by 5 percentage points. Canada is projected to have a large increase, but only in the 2015–25 period. France and Italy have increases on the order of 8 percentage points by 2025, with the changes occurring fairly gradually. Thus, both the extent of aging and the speed with which it occurs differ substantially among the major industrial countries. Projections for the smaller industrial countries (Hagemann and Nicoletti (1989)) also indicate significant increases in dependency ratios.

Heller and others (1986) projected the change of social expenditures by governments on the basis of demographic projections similar to those in Table 1. They included in their study expenditures on education, medical care, pensions, unemployment compensation, and income maintenance for the poor, at both the general and local government levels.

We focus in this paper on three components of government spending that are closely related to demographic developments: medical expenses, education expenses, and pension benefit payments. We do not attempt to disaggregate *revenues*, however—for instance, by separating social security contributions from other taxes. Whether social security programs are funded or unfunded and the resulting implications for the economy are beyond the scope of this paper. Instead, we simulate the model with a tax-rate reaction function that tends to resist movements

[7] Of course, in many countries secondary education extends beyond age 15, and in addition many students proceed to university before entering the labor force. Also, retirement age may not correspond to age 65; early retirement is possible; conversely, in most professions retirement at 65 is not compulsory. A more precise measure of dependency would adjust the denominator (the working-age population) by the participation rate, to obtain those actually in the labor force (see Hagemann and Nicoletti (1989)).

away from an exogenous government debt to gross national product (GNP) ratio. This rule prevents a snowballing accumulation of debt leading to eventual government default. Deficits do occur for a number of years as a result of demographic changes, but they are eventually eliminated.

Table 2 summarizes the projections in Heller and others (1986) for government spending on medical care, education, and pensions. The effects of demographic changes are calculated as the difference between the GNP share of spending on each category projected for 2000–25, and its value in 1980 (a more recent year of historical data was not available in their study). The increases in government expenditure on medical care (as a percent of gross domestic product (GDP)) are large but not enormous. Moreover, except in Germany and Japan, they are mostly offset by declines in projected education expenditures. In contrast, pension benefits (which are treated in the model as negative taxes) increase by between 5 percent and 10 percent of GDP for Germany, Italy, and Japan. By 2025, government spending in all three areas taken together increases by up to 10 percentage points of GDP; however, these increases differ markedly across countries. They are largest in Japan, Germany, and Italy, and smallest in the United States and Canada, as would be expected given the demographic trends discussed above.

II. Estimated Consumption Equation

This section describes the estimated consumption equation and compares the effect it attributes to the dependency ratio to effects found in other studies. The starting point for the consumption equation is the intertemporal optimizing model of Blanchard (1985), as extended by Buiter (1988). This model makes consumption a function of financial and "human" wealth—that is, the expected value of lifetime earnings, discounted to the present. It is a useful tool for analyzing fiscal policy because it allows for an effect of the government stock of bonds on interest rates (provided the birthrate is nonzero); the model allows simple aggregation because of the assumption that the probability of death is the same for individuals of all ages. However, as noted by Blanchard (1985, p. 235), the model is not convenient for rigorously treating "saving for retirement" or for allowing for a path of labor income that abruptly drops to zero at a certain point. Moreover, it does not allow for constraints that individuals face on their borrowing. In our estimated model, we implement liquidity constraints in an error-correction framework, as in Davidson and others (1978) and Hendry and von Ungern-

Table 2. *Changes in Government Expenditures Due to Demographic Changes, 2000–25*

(In percent of GDP)

Country	Medical Expenditures			Education			Pension Expenditures			Combined Effects of (1)–(3)		
	2000	2010 (1)	2025	2000	2010 (2)	2025	2000	2010 (3)	2025	2000	2010 (4)	2025
United States	0.01	0.15	1.06	−0.92	−1.14	−1.29	−0.50	−0.60	0.60	−1.41	−1.59	0.37
Japan	0.67	1.25	1.63	−1.00	−0.50	−0.70	5.41	8.69	9.20	5.08	9.44	10.13
Germany, Fed. Rep. of	0.43	0.92	1.59	−0.63	−0.88	−0.81	3.80	5.30	7.20	3.60	5.34	7.98
France	0.34	0.40	0.80	−0.46	−0.54	−0.51	1.00	1.50	3.00	0.88	1.36	3.29
Italy	0.20	0.49	0.88	−0.80	−0.90	−1.00	2.50	4.60	8.60	1.90	4.19	8.48
United Kingdom	0.05	—	0.66	−1.00	−1.00	−1.10	0.85	1.42	2.56	−0.10	0.42	2.12
Canada	−0.06	0.18	1.45	−1.91	−2.15	−1.87	−0.40	−0.40	0.80	−2.37	−2.37	0.38

Source: Heller and others (1986, Table 14).

Note: Figures represent the difference between the share of spending projected for 2000–25 and its 1980 value (the latest year of historical data available from the Heller study). Medical expenditure figures were obtained directly from Peter Heller.

Sternberg (1981). We also add a dependency ratio to capture effects of differences in age structure on consumption and saving, admittedly in an ad hoc fashion. The data for human wealth used to estimate the consumption equation do not include adjustment for future demographic changes; rather, human wealth is the discounted value of future net disposable income from production, the latter variable extrapolated from historical data.

We implement the consumption model by allowing a lagged adjustment to the long-run wealth/consumption ratio. The specification, in logs, forces that ratio to be constant in the steady state. The dynamics are affected by the change in the log of disposable income and the level of the real interest rate. The latter variable serves two purposes: it captures intertemporal substitution, and it serves to pick up effects on the discounted present value of future income not captured in our measure of human wealth, which uses a constant discount rate. In addition, the path of consumption (and the long-run wealth/consumption ratio) is assumed to be influenced by the dependency ratio.

The equation was estimated using ordinary least squares with annual data from 1969 to 1987 pooled across the Group of Seven countries and the "smaller industrial country" block. The estimated equation, which is used in the simulations described below, is as follows:

$$\Delta \log C = \text{country constants} + \underset{(3.5)}{.113} \log (W_{-1}/C_{-1}) - \underset{(4.0)}{.473}\, RLR$$

$$+ \underset{(5.5)}{.408}\, \Delta \log YD + \underset{(1.5)}{.124}\, DEM3 + \underset{(2.2)}{.032}\, DEM3{*}DUM80$$

$$\bar{R}^2 = .641, \qquad \text{SER} = .026,$$

where the numbers in parentheses are t-statistics ($\bar{R}^2$ is the coefficient of determination corrected for degrees of freedom and SER is the standard error), and where C is the real consumption expenditure, W is real wealth, RLR is the real long-term interest rate (expected inflation is proxied for estimation purposes by a centered ten-year moving average of actual inflation), YD is real, after-tax net domestic product, $DEM3$ is the overall dependency ratio (the ratio of dependents to the working age population),[8] and $DUM80$ is a dummy variable equal to 1.0 after 1980. This variable was included because visual inspection of our population data indicated a break in that year, perhaps because of imperfect splicing of census data with earlier estimates. It is important to note that wealth includes the discounted present value of future (noninterest)

[8]Expressed as a decimal fraction, rather than in percent as in Table I.

disposable income, WH.[9] Total wealth W is the sum of WH and the real value of financial wealth, held in the form of domestic outside money M, government bonds B, and net claims on foreigners NFA (in U.S. dollars; ER is the exchange rate):

$$W = WH + (M + B + NFA/ER)/P.$$

The disposable income variable YD is constrained by the error-correction specification to have only transitory effects, because liquidity constraints are assumed to operate only in the short to medium term.

The estimated equation attributes a positive effect on consumption of an increase in the overall dependency ratio--significant at the 5 percent level when the product of the dependency ratio and the dummy variable is considered. Including the youth and elderly dependency ratios separately did not significantly increase the explanatory power of the equation; hence, they were constrained to have the same coefficient. The data also could not reject the constraint of a common coefficient on the overall dependency ratio across countries. Some further estimation was done, after the above equation was incorporated into the model, in order to examine the robustness of the results. Using instrumental variables to estimate the equation[10] yielded a somewhat larger and more significant effect of the dependency ratio, as well as a higher coefficient on YD and a lower one on RLR (in absolute terms).[11] Adding the inflation rate (as in Bovenberg and Evans (1990; this issue)) in place of the post-1980 dummy variable, however, decreased the value of the coefficient on the remaining dependency ratio. Also, differences in sample periods or countries included could make a nonnegligible difference to the results, and the sensitivity of our simulation results to this coefficient is discussed below. Nevertheless, there is some evidence from our results that increases in the dependency ratio may have been associated historically with increases in consumption relative to income and wealth, a conclusion that emerges more strongly from the quarterly estimation by Bovenberg and Evans (1990) using U.S. data of a specification similar to ours.[12]

From our equation, a 1 percentage point increase in the dependency ratio is estimated to cause an increase in consumption in the post-1980

[9] As defined, therefore, WH includes the discounted present value of income to both labor and capital.

[10] Instruments were the rate of money growth, the ratio of government spending to GDP, the lagged wealth/consumption ratio, the lagged change in disposable income, and the dependency ratio.

[11] Results from a similar specification are discussed in Masson, Symansky, and Meredith (1990).

[12] Their measure of wealth is household net worth, and they include separate population variables to capture dependents below age 20 and over age 65.

Table 3. *Long-Run Effects of an Increase in Elderly Dependency Ratio on Private Saving Rate in Various Models*

Model	Estimate
Modigliani	−0.88
Modigliani and Sterling	−0.51
Feldstein	−1.21
Horioka	−1.61
Memorandum item:	
MULTIMOD	−1.10

Source: Heller (1989).

period of 0.16 percent in the short run and 1.4 percent in the long run (equal to 0.124 plus 0.032, divided by 0.113). It is of interest to compare these results to those found in other studies. Heller (1989) surveyed saving equations that included estimated effects of dependency ratios. Though the definitions of variables differ, as do sample periods, a rough comparison can be made with the equation estimated for MULTIMOD, after converting it to a saving equation. The private saving rate (s) can be defined as C above, divided by private national income (Y), and subtracted from unity: $s = 1 - C/Y$. Therefore, MULTIMOD's equation implies that the saving rate responds to the dependency ratio in the long run (for a given real interest rate and wealth/income ratio) as follows:

$$\frac{ds}{dDEM3} = -\frac{d(C/Y)}{dDEM3} = -\frac{d \log C}{dDEM3} C/Y = \frac{(.124 + .032)}{.113} C/Y.$$

Table 3 gives estimates for MULTIMOD as well as four other models.[13] It can be seen that MULTIMOD is near the center of the range of available estimates. Each estimate shows a powerful effect on saving of an increase in the elderly as a proportion of the working-age population.[14] There thus appears to be considerable additional support for the hypothesis that the aging of the population projected for the next century is likely to increase consumption relative to income. However, it must be stressed that other studies (Aaron, Bosworth, and Burtless (1989), for instance, examining U.S. evidence), have failed to find a significant effect. The next section uses simulations of MULTIMOD to

[13] The estimate for MULTIMOD assumes a consumption income ratio (C/Y) of 0.8.

[14] These studies also estimate a separate effect of the proportion of the young in the population; in each case, this variable has the same sign but a smaller coefficient.

capture the implications of our estimated consumption equation for the effects of aging on macroeconomic variables, as well as effects through the other two channels mentioned above.

III. Simulation of the Effects of Population Aging

In order to study the macroeconomic effects of the demographic shifts discussed above, we use simulations of MULTIMOD, which is a macroeconometric model of the Group of Seven countries and the remaining industrial countries and of developing countries divided into capital exporters and capital importers (see Masson, Symansky, and Meredith (1990)). The simulations take place over a horizon from 1996 to 2025. The baseline simulation of the model is constructed by constraining growth rates of real variables to converge to current estimates of potential output growth, while private and government saving rates remain constant at their levels projected for 1995. With respect to the demographic variables, the dependency ratio and the labor force participation rate are assumed to remain constant in each country throughout the baseline. It should be emphasized that we are not attempting to construct an ex ante forecast for the Group of Seven countries through 2025—we are only attempting to quantify the macroeconomic effects of aging over that horizon.

Demographic effects are captured in MULTIMOD using the dependency ratio defined above. This variable appears in the model in two equations for each industrial country: in the consumption function, as described above, and in the production function, in which the total labor force is set equal to the working-age population times an exogenous participation rate. The working-age population is determined by the total population, which is exogenous, and the dependency ratio. The dependency ratio is also exogenous, but we simulate the model with an alternative path for this variable to quantify the effects of the projected aging of the population.

The alternative scenario we simulate with MULTIMOD allows the dependency ratio in each country to evolve along its projected path through 2025, rather than remaining constant as in the baseline scenario at its 1995 value. The labor force participation rate is, however, assumed to remain on its baseline path. As described more fully in Section I above, two different periods can be identified: in the first, through 2010, there is *differential* aging in the industrial countries, while the *average* dependency ratio remains roughly constant. In the second period, the populations in all industrial countries except Japan age steadily, and

dependency ratios rise substantially. In Japan the dependency ratio remains approximately at the same level above baseline.

Finally, we include a simulation of the projected changes in government expenditures related to aging and a simulation of the combined effects.

Effects of Aging on Consumption Expenditure

As discussed in the Appendix, a shift in the dependency ratio affects the economy through several channels. The first channel is through the effect on consumption expenditure; as the ratio of dependents to the working-age population increases, consumption increases (for given values of income and wealth).

Table 4 presents the results of a simulation of the effects of a shift in dependency ratios over the period 1996–2025,[15] operating only through the change in consumption behavior. In this simulation the labor force is held exogenous in each country, and no change is made to government expenditure. As shown in the table, the private saving rate in the United States is above its baseline level (which was assumed to be constant) throughout the simulation; it rises through 2015 (relative to the baseline, it is almost 3 percentage points higher then), and then drops back somewhat, as the dependency ratio first falls, and then rises. The rise in the saving rate is mirrored in the movement of domestic demand, which is below the baseline throughout the simulation, reaching its lowest level in 2005 before beginning to recover. The reduction in domestic demand is offset by an increase in demand for U.S. exports from abroad due both to lower saving rates abroad and to a real depreciation of the dollar. As a result, real GNP in the United States is above the baseline after 2005.

The increase in the saving rate initially leads to a modest increase in investment, but this effect is offset later on by an increase in the real interest rate resulting from higher aggregate demand. The government balance is largely unchanged, as a share of GNP, so the increase in private saving is manifested primarily in the current account, which improves by up to 3 percent of GNP over the simulation range. As a result, the net foreign asset position of the United States improves steadily, and is higher by more than 30 percent of GNP at the end of the simulation.

[15] Because the model requires that terminal conditions be imposed on expectations variables, and in order to minimize the effects of those terminal conditions, the simulation period was extended to 2040. After 2025, the changes in dependency ratios were assumed to be gradually reversed.

Table 4. *Demographic Shift: Consumption Effects*
(Deviations from baseline)

Country	2000	2005	2010	2015	2020	2025
United States			*(in percent)*			
Real GNP	−1.0	−0.2	1.1	1.9	2.2	2.1
Real domestic demand	−2.8	−3.8	−3.7	−3.0	−2.2	−1.5
Real interest rate	0.6	−0.2	−0.5	−0.0	0.9	2.0
Real effective exchange rate	−6.2	−11.6	−12.8	−11.3	−8.4	−4.9
GDP per worker	−0.9	−0.6	0.0	0.4	0.4	0.1
Capital stock per worker	−0.5	−0.7	−0.4	0.0	−0.0	−0.8
			(as a percent of GNP)			
Current account balance	0.8	2.0	2.8	3.0	2.8	2.6
General government financial balance	−0.4	0.0	0.2	0.1	−0.0	−0.1
Private saving	1.3	1.4	2.3	2.6	2.3	1.6
Gross private investment	0.1	0.3	0.4	0.2	−0.3	−0.9
Net foreign assets	1.9	7.9	16.7	25.0	31.0	34.5
Government debt	1.3	1.7	0.7	−0.3	−0.7	−0.6
Japan			*(in percent)*			
Real GNP	2.1	0.7	−0.9	−2.8	−4.6	−6.1
Real domestic demand	7.1	9.6	9.9	8.2	5.1	1.8
Real interest rate	−2.3	−0.3	1.0	2.4	3.4	3.7
Real effective exchange rate	14.2	27.5	33.8	33.1	26.1	17.1
GDP per worker	2.5	2.1	1.2	0.0	−1.2	−2.2
Capital stock per worker	1.8	2.6	2.2	0.7	−1.4	−3.7
			(as a percent of GNP)			
Current account balance	−2.1	−3.5	−4.3	−4.5	−4.4	−4.2
General government financial balance	0.5	0.4	0.3	0.0	−0.3	−0.5
Private saving	−2.9	−4.8	−5.9	−6.2	−5.8	−5.2
Gross private investment	−0.2	−1.0	−1.4	−1.7	−1.7	−1.5
Net foreign assets	−11.3	−23.9	−35.7	−45.8	−53.6	−58.5
Government debt	−1.7	−3.2	−3.3	−2.5	−0.7	1.6
Germany, Fed. Rep. of			*(in percent)*			
Real GNP	0.7	0.0	−1.0	−1.5	−1.2	−0.5
Real domestic demand	1.1	2.4	2.6	1.8	1.0	1.2
Real interest rate	−0.3	−0.2	0.0	0.6	1.5	2.4
Real effective exchange rate	0.2	1.3	1.9	1.8	0.9	0.9
GDP per worker	0.5	0.5	0.1	−0.2	−0.2	0.0
Capital stock per worker	0.2	0.5	0.6	0.4	−0.2	−1.2
			(as a percent of GNP)			
Current account balance	−0.1	−1.3	−2.3	−2.2	−1.7	−1.2
General government financial balance	0.2	0.0	−0.1	−0.2	−0.2	−0.1
Private saving	−0.3	−1.3	−2.1	−2.0	−1.8	−2.1
Gross private investment	0.0	0.0	0.1	−0.0	−0.3	−0.9
Net foreign assets	−2.3	−6.6	−13.0	−18.2	−20.8	−21.4
Government debt	−0.4	−0.8	−0.4	0.3	0.9	1.0

Table 4 (*concluded*).

Country	2000	2005	2010	2015	2020	2025
Other Industrial Countries			*(in percent)*			
Real GNP	−0.2	0.1	0.2	0.7	0.3	−0.3
Real domestic demand	−0.3	−0.4	−0.6	−0.2	−0.4	−1.1
Real interest rate	−0.1	−0.1	−0.0	0.3	1.4	2.4
Real effective exchange rate	−0.8	−1.7	−2.5	−2.8	−2.4	−2.1
GDP per worker	−0.1	−0.0	−0.2	0.3	0.0	−0.4
Capital stock per worker	−0.1	−0.0	0.0	0.2	−0.2	−1.4
			(as a percent of GNP)			
Current account balance	0.2	0.6	0.7	0.6	0.4	0.2
General government financial balance	0.1	0.0	0.0	−0.1	−0.4	−0.4
Private saving	0.1	0.5	0.7	0.6	0.4	−0.2
Gross private investment	0.0	0.0	0.0	0.0	−0.4	−0.8
Net foreign assets	1.1	3.1	5.3	6.5	6.6	5.8
Government debt	0.5	0.3	0.1	−0.6	−0.0	1.7

In Japan, the private saving rate falls steadily through 2015 as a result of the aging of the population, leading to substantial increases in domestic demand. Real output is initially higher than in the baseline as a result of the increase in demand, but the real interest rate rises above the baseline, tending to crowd out domestic demand. The real exchange rate appreciates by about 30 percent at its peak, and the current account is substantially lower, as a share of GNP, throughout the simulation. As a result, Japan's net foreign asset position deteriorates substantially, by almost 60 percent of GNP, by 2025.

In the Federal Republic of Germany saving is also lower and domestic demand higher as a result of the demographic shift. The results for the external sector are, however, quite different: the real exchange rate appreciates very little, though the current account ratio falls substantially, by about 20 percent of GNP. The extent of the demographic shift is smaller in Germany than in Japan, which accounts for some of the difference. Also, imports of manufactures are a much larger share of GNP in Germany, so that a given change in the real exchange rate can achieve a larger demand shift in Germany than in Japan.[16]

The effects of the demographic shift on all other industrial countries taken as a group are smaller in comparison. These countries include Canada, with demographic projections that resemble those for the

[16] If relative price elasticities were the same, a unit change in the real exchange rate would bring about a larger change in imports as a share of GNP in Germany than in Japan as a result. In fact, the price elasticity of imports of manufactures is also higher in Germany; see Masson, Symansky, and Meredith (1990).

United States, and European countries, with projections for aging that are closer to Germany's, but less severe. The saving rate, domestic demand, and real output for other industrial countries taken together are all roughly unchanged for most of the period, although by 2025 the real interest rate rises significantly and output declines.

In MULTIMOD, foreign and domestic assets are assumed to be perfect substitutes, so that real interest parity holds. Differences in real interest rates across countries therefore reflect expected future appreciation or depreciation of the real exchange rate, and the overall level of real interest rates reflects global saving and investment (or aggregate demand and supply). From 2015 onwards the demographic shift is toward more aging in all industrial countries, leading to global excess demand, and higher real interest rates in all countries. Before 2015, it is the composition of global demand that is shifting, leading to changes in real exchange rates, while the global real interest rate remains (approximately) unchanged.

Effects of Aging on Production

Demographic shifts also operate through a change in the labor force, which, assuming that the participation rate is constant, changes one-for-one with the decline in those aged 15–64. Aging of the population reduces the labor force and thereby reduces potential output, leading to excess demand for domestic output. As a result, real output would also be expected to fall, and the real exchange rate, to appreciate. The effect on real interest rates is ambiguous, since, on the one hand, a reduction in supply creates excess (global) demand for goods, which tends to raise the real interest rate, and, on the other hand, a fall in the labor force tends to lower the marginal product of capital and hence tends to lower the equilibrium real interest rate. In the long run, however, for a given saving rate a smaller labor force should lead to a proportionate contraction of the capital stock and output, leaving real interest rates unaffected.

Table 5 shows the results of a simulation in which the demographic shift affects only the total labor force in each country.[17] The results are consistent with the analysis given above—in both Germany and Japan real output falls steadily relative to the baseline, while the real exchange rate appreciates. In both countries the real interest rate is initially below the baseline, and then rises above it at the end of the simulation. In both

[17] That is, the direct effects on consumption discussed above are ignored. However, changes in output do induce changes in human wealth and, hence, in consumption.

Table 5. *Demographic Shift: Production Effects*
(Deviations from baseline)

Country	2000	2005	2010	2015	2020	2025
United States			*(in percent)*			
Real GNP	1.0	2.9	3.7	2.4	−0.2	−2.9
Real domestic demand	0.8	2.2	2.9	1.8	−0.2	−2.5
Real interest rate	−0.3	−0.7	−0.8	−0.3	0.3	0.9
Real effective exchange rate	−1.0	−2.6	−3.1	−2.7	−2.2	−1.3
GDP per worker	−1.0	−1.2	−0.4	0.6	1.5	1.9
Capital stock per worker	−1.6	−2.6	−1.6	0.9	3.4	4.9
			(as a percent of GNP)			
Current account balance	0.0	0.2	0.2	−0.0	−0.3	−0.5
General government financial balance	0.2	0.4	0.2	−0.2	−0.5	−0.6
Private saving	0.0	−0.9	−0.5	−0.1	0.0	−0.1
Gross private investment	0.0	0.1	0.2	0.2	0.1	0.0
Net foreign assets	−0.1	0.3	1.0	1.1	0.2	−1.4
Government debt	−0.3	−1.5	−2.3	−1.6	0.3	2.7
Japan			*(in percent)*			
Real GNP	−1.8	−3.7	−5.7	−6.8	−7.0	−6.7
Real domestic demand	−1.4	−2.6	−4.2	−5.5	−6.2	−6.3
Real interest rate	−1.1	−1.0	−0.3	0.3	0.9	1.2
Real effective exchange rate	1.5	3.9	5.9	6.0	5.1	4.1
GDP per worker	1.5	3.2	3.6	3.4	2.5	1.7
Capital stock per worker	3.1	6.4	7.9	7.5	5.7	3.3
			(as a percent of GNP)			
Current account balance	−0.1	−0.3	−0.3	0.1	0.6	1.0
General government financial balance	−0.2	−0.3	−0.4	−0.3	−0.2	−0.0
Private saving	0.7	0.7	0.7	0.7	0.6	0.4
Gross private investment	0.5	0.7	0.6	0.3	−0.2	−0.6
Net foreign assets	−0.1	−1.1	−1.8	−1.2	0.7	3.6
Government debt	0.6	1.6	2.8	3.5	3.5	3.0
Germany, Fed. Rep. of			*(in percent)*			
Real GNP	−1.0	−2.1	−2.4	−2.2	−2.9	−4.7
Real domestic demand	−1.2	−1.8	−2.2	−2.5	−3.4	−5.1
Real interest rate	−0.6	−0.7	−0.6	−0.2	0.3	1.2
Real effective exchange rate	0.1	0.8	0.8	0.2	0.6	1.9
GDP per worker	0.3	0.9	0.4	0.4	1.4	2.5
Capital stock per worker	1.0	2.5	2.2	2.1	3.7	5.5
			(as a percent of GNP)			
Current account balance	0.2	−0.0	−0.0	0.3	0.5	0.9
General government financial balance	−0.1	−0.2	−0.1	−0.1	−0.2	−0.4
Private saving	0.5	0.4	0.4	0.6	0.7	0.7
Gross private investment	0.2	0.3	0.3	0.2	−0.1	−0.6
Net foreign assets	1.1	1.7	1.9	1.9	1.8	3.6
Government debt	0.5	1.0	1.3	1.3	1.6	2.5

Table 5 (*concluded*).

Country	2000	2005	2010	2015	2020	2025
Other Industrial Countries			*(in percent)*			
Real GNP	−0.0	0.4	0.5	−0.4	−2.4	−3.7
Real domestic demand	−0.0	0.3	0.4	−0.4	−2.4	−3.7
Real interest rate	−0.5	−0.6	−0.7	−0.2	0.6	0.9
Real effective exchange rate	−0.1	−0.3	−0.6	−0.5	−0.6	−1.0
GDP per worker	−0.0	0.1	0.2	1.0	1.0	1.8
Capital stock per worker	0.1	0.3	0.7	2.3	3.2	3.9
			(as a percent of GNP)			
Current account balance	−0.0	0.1	0.0	−0.1	−0.2	−0.3
General government financial balance	0.0	0.1	0.1	−0.2	−0.5	−0.4
Private saving	0.1	0.2	0.2	0.2	0.2	−0.0
Gross private investment	0.1	0.2	0.2	0.1	−0.1	−0.1
Net foreign assets	−0.1	0.0	−0.0	−0.2	−0.6	−1.5
Government debt	0.1	−0.4	−0.9	−0.6	1.8	3.6

countries also, the capital stock per worker is higher throughout, though investment as a share of GNP is below the baseline.

In the United States until 2010, the demographic shift leads to a larger labor force (and therefore to higher output), a depreciation of the real exchange rate, and a lower real interest rate. After 2010 the dependency ratio begins to rise, and these effects are in large part reversed.

In the other industrial countries, there is no substantial effect until 2020, when real output drops off significantly and real interest rates rise. There is only a negligible effect on the current account position of these countries. In sum, for all countries the net foreign asset implications of aging are simulated to be considerably less important through their effects on production reported here than those operating through consumption.

Effects of Aging on Government Expenditures

An increase in the elderly dependency ratio would be expected to increase government expenditures on medical care, while a decline in the youth dependency ratio would lead to lower education expenditures. Furthermore, an increase in the number of retirees would increase payment of government pension benefits. Heller and others (1986) report projections for these components of government spending in individual Group of Seven countries for the years 2000, 2010, and 2025 (see Table

2 above); we interpolated these estimates to obtain annual series.[18] Education and health care are components of government expenditure on goods and services, and so they directly increase aggregate demand. Pension benefits take the form of a transfer, which we treat in MULTIMOD as if it were a negative, nondistortionary tax. We do not examine the impact of funding social security expenditures, including pensions, and taxation is assumed not to be linked to those benefits.

Table 6 reports the results of a simulation of these changes in government expenditure. In the United States, government expenditure is reduced throughout the simulation, relative to the baseline, leading to a reduction in domestic demand of only ¼ of 1 percent in 2025. The reduction in Japanese net exports is enough to lead to a slight reduction in output, despite the increase in government expenditure resulting from an increased dependency ratio in that country. In Germany real output rises slightly as a result of higher government expenditure; in other industrial countries output is lower. In sum, although government debt rises substantially in Germany and Japan, effects on output and net foreign assets are relatively modest.

Combined Effects

The combined effects of the demographic shifts are shown in Table 7 (including results for France, Italy, the United Kingdom, Canada, and the remaining smaller industrial countries). The interpretation of the results is straightforward, since they are approximately a simple sum of the results for the three partial simulations just discussed. What is of interest is the magnitudes—the simulation shows that demographic shifts can be expected to have very substantial effects on the global pattern of external balances over the next 35 years. In the United States the net foreign asset position improves by over 35 percent of GNP in 2025, compared, for instance, with an assumed net debtor position in 1995 of about 23 percent of GNP.[19] In Japan and Germany the net foreign asset positions in 2025 are lower by about 60 and 25 percent, respectively, as compared with assumed net creditor positions in 1995 of 26 and 38 percent of GNP. It is clear that the aging of the population in the

[18] We used a simple average of the increases in the Group of Seven countries for the aggregate of smaller industrial countries.

[19] An alternative comparison would be what the net foreign asset position would be in 2025 *without* the shift in dependency ratios. In our baseline projection, which extrapolates medium-term trends but which is not intended to be a forecast, the net asset share in 2025 is −39 percent for the United States, 37 percent for Japan, and 85 percent for Germany.

Table 6. *Demographic Shift: Government Expenditure Effects*
(Deviations from baseline)

Country	2000	2005	2010	2015	2020	2025
United States			*(in percent)*			
Real GNP	−0.0	0.5	0.2	0.3	0.2	0.2
Real domestic demand	−0.6	−0.0	−0.3	−0.1	−0.2	−0.2
Real interest rate	−0.3	−0.1	−0.0	0.1	0.1	0.1
Real effective exchange rate	−1.7	−1.3	−1.2	−1.0	−1.0	−1.1
GDP per worker	−0.1	0.3	0.0	0.1	0.0	0.0
Capital stock per worker	0.0	0.2	0.2	0.2	0.1	0.0
			(as a percent of GNP)			
Current account balance	0.3	0.3	0.3	0.3	0.3	0.3
General government financial balance	0.9	0.5	0.3	−0.2	−0.5	−0.6
Private saving	−0.4	−0.2	0.0	0.5	0.8	0.8
Gross private investment	0.2	0.0	0.0	−0.0	−0.0	−0.1
Net foreign assets	0.6	1.9	2.6	3.2	3.6	4.0
Government debt	−2.4	−4.7	−4.8	−3.3	−0.6	2.0
Japan			*(in percent)*			
Real GNP	0.0	−0.4	−0.3	−0.5	−0.4	−0.5
Real domestic demand	1.2	0.9	0.9	0.5	0.6	0.6
Real interest rate	−0.0	0.0	0.1	0.0	0.1	0.1
Real effective exchange rate	2.8	3.0	2.9	2.4	2.4	2.5
GDP per worker	0.2	−0.0	0.0	−0.1	−0.1	−0.1
Capital stock per worker	0.1	0.1	0.0	−0.1	−0.1	−0.2
			(as a percent of GNP)			
Current account balance	−0.5	−0.6	−0.5	−0.4	−0.5	−0.5
General government financial balance	−3.1	−3.0	−2.9	−1.8	−1.3	−1.1
Private saving	2.3	2.3	2.3	1.3	0.8	0.5
Gross private investment	−0.2	−0.1	−0.2	−0.1	−0.1	−0.1
Net foreign assets	−2.7	−4.1	−5.2	−5.5	−6.1	−6.5
Government debt	9.0	19.7	27.0	29.3	27.6	24.9
Germany, Fed. Rep. of			*(in percent)*			
Real GNP	−0.0	−0.4	−0.2	−0.3	−0.3	−0.4
Real domestic demand	0.9	0.4	0.4	0.5	0.4	0.5
Real interest rate	−0.1	−0.0	−0.0	0.1	0.1	0.1
Real effective exchange rate	0.7	0.6	0.3	0.5	0.5	0.5
GDP per worker	0.2	−0.1	0.1	0.1	0.0	0.0
Capital stock per worker	0.1	0.1	0.1	0.1	0.1	−0.0
			(as a percent of GNP)			
Current account balance	−0.6	−0.5	−0.5	−0.5	−0.6	−0.6
General government financial balance	−2.0	−1.5	−1.2	−1.2	−1.2	−1.2
Private saving	1.5	1.0	0.7	0.7	0.6	0.6
Gross private investment	0.0	0.0	0.1	0.0	0.0	0.0
Net foreign assets	−2.2	−3.5	−4.6	−5.6	−6.5	−7.3
Government debt	6.1	11.6	14.0	15.3	16.2	16.9

Table 6 (*concluded*).

Country	2000	2005	2010	2015	2020	2025
Other Industrial Countries			*(in percent)*			
Real GNP	0.0	0.3	−0.0	0.1	0.0	0.0
Real domestic demand	−0.1	0.1	−0.1	−0.0	−0.1	−0.1
Real interest rate	−0.2	−0.1	0.0	0.1	0.1	0.1
Real effective exchange rate	−0.2	−0.3	−0.2	−0.3	−0.3	−0.3
GDP per worker	−0.0	0.2	−0.0	0.1	0.0	−0.0
Capital stock per worker	0.0	0.2	0.1	0.1	0.0	−0.1
			(as a percent of GNP)			
Current account balance	0.1	0.1	0.1	0.1	0.1	0.1
General government financial balance	−0.4	−0.5	−0.6	−0.7	−0.9	−0.9
Private saving	0.5	0.6	0.6	0.8	0.9	0.9
Gross private investment	0.2	0.0	0.0	0.0	0.0	−0.1
Net foreign assets	0.3	0.6	0.8	0.9	1.0	1.0
Government debt	1.4	2.5	4.2	6.0	7.9	9.7

Table 7. *Demographic Shift: Combined Effects*
(Deviations from baseline)

Country	2000	2005	2010	2015	2020	2025
United States			*(in percent)*			
Real GNP	−0.1	3.2	4.9	4.7	2.5	−0.1
Real domestic demand	−2.7	−1.7	−1.0	−1.0	−2.2	−3.8
Real interest rate	0.1	−1.1	−1.4	−0.5	1.1	2.9
Real effective exchange rate	−9.1	−15.5	−16.6	−14.0	−9.9	−5.3
GDP per worker	−2.0	−1.4	−0.4	1.1	2.0	2.2
Capital stock per worker	−2.2	−3.1	−1.7	1.2	3.7	4.3
			(as a percent of GNP)			
Current account balance	1.1	2.5	3.1	3.0	2.8	2.7
General government financial balance	0.8	0.9	0.7	−0.3	−1.0	−1.3
Private saving	0.7	2.1	3.0	3.6	3.6	3.0
Gross private investment	0.3	0.5	0.6	0.3	−0.2	−1.0
Net foreign assets	2.7	10.4	19.9	27.9	33.1	36.2
Government debt	−1.5	−4.7	−6.5	−5.3	−1.3	3.5
Japan			*(in percent)*			
Real GNP	0.4	−3.1	−6.4	−9.5	−11.8	−13.2
Real domestic demand	6.8	7.2	5.8	2.4	−1.3	−4.7
Real interest rate	−3.3	−1.2	0.6	2.5	4.1	4.8
Real effective exchange rate	18.8	35.0	43.0	41.4	32.7	21.5
GDP per worker	4.4	5.1	4.8	3.2	1.2	−0.5
Capital stock per worker	5.1	9.1	10.2	8.3	4.3	−0.5

Table 7 (*continued*).

Country	2000	2005	2010	2015	2020	2025
			(as a percent of GNP)			
Current account balance	−2.5	−3.8	−4.4	−4.5	−4.4	−4.0
General government financial balance	−2.5	−2.6	−2.8	−2.1	−1.9	−1.6
Private saving	0.1	−1.7	−2.7	−3.8	−4.2	−4.3
Gross private investment	0.0	−0.5	−1.1	−1.5	−1.7	−1.8
Net foreign assets	−13.4	−26.7	−38.5	−48.0	−55.0	−59.0
Government debt	7.5	16.3	23.0	26.1	26.9	27.3
Germany, Fed. Rep. of			*(in percent)*			
Real GNP	−0.2	−2.3	−3.6	−4.0	−4.6	−5.8
Real domestic demand	0.8	1.0	0.8	−0.4	−2.1	−3.9
Real interest rate	−1.1	−1.0	−0.7	0.3	1.7	3.6
Real effective exchange rate	1.0	2.7	3.0	2.3	1.9	3.2
GDP per worker	1.0	1.3	0.5	0.1	1.2	2.6
Capital stock per worker	1.3	3.2	3.0	2.7	3.6	4.2
			(as a percent of GNP)			
Current account balance	−0.5	−1.8	−2.7	−2.5	−1.8	−0.9
General government financial balance	−1.9	−1.5	−1.5	−1.5	−1.6	−1.5
Private saving	1.7	0.1	−0.8	−0.7	−0.5	−0.9
Gross private investment	0.3	0.4	0.4	0.2	−0.3	−1.5
Net foreign assets	−3.3	−8.1	−15.0	−20.9	−24.0	−23.5
Government debt	6.1	11.4	14.6	16.6	18.1	19.0
France			*(in percent)*			
Real GNP	−0.4	1.1	1.5	1.0	−0.3	−1.6
Real domestic demand	−0.9	−0.1	−0.1	−0.9	−2.2	−3.7
Real interest rate	−0.3	−1.0	−1.0	0.0	1.5	3.0
Real effective exchange rate	−1.2	−4.1	−5.4	−5.5	−4.8	−3.3
GDP per worker	−0.8	−0.2	−0.3	0.7	1.6	2.1
Capital stock per worker	−0.7	−0.7	−0.1	1.9	3.4	3.2
			(as a percent of GNP)			
Current account balance	0.5	0.7	0.8	0.8	0.9	1.3
General government financial balance	−0.3	−0.2	−0.4	−0.8	−1.1	−1.2
Private saving	0.9	1.2	1.6	1.9	1.8	1.6
Gross private investment	0.0	0.4	0.5	0.2	−0.2	−0.9
Net foreign assets	2.1	4.3	6.5	8.5	9.8	11.8
Government debt	2.2	2.9	2.9	4.1	6.6	9.0
Italy			*(in percent)*			
Real GNP	0.8	−0.2	−2.0	−1.6	−4.4	−3.3
Real domestic demand	2.1	1.1	−1.4	−1.9	−6.0	−5.2
Real interest rate	−1.4	−0.1	−0.0	0.3	2.8	2.0
Real effective exchange rate	1.8	4.1	1.3	−2.3	−3.7	−7.6
GDP per worker	1.7	1.6	−0.9	0.3	−1.5	1.8
Capital stock per worker	1.8	3.0	1.3	1.8	0.5	0.7

Table 7 (*continued*).

Country	2000	2005	2010	2015	2020	2025
			(as a percent of GNP)			
Current account balance	−0.4	0.4	0.7	0.5	1.2	0.2
General government financial balance	−0.7	−1.2	−0.9	−1.7	−2.8	−2.5
Private saving	0.6	1.1	1.4	2.1	3.2	2.6
Gross private investment	0.3	−0.4	−0.1	−0.1	−0.7	−0.1
Net foreign assets	−0.6	0.1	1.9	2.7	5.6	7.4
Government debt	0.3	2.2	12.0	15.6	22.9	29.0
United Kingdom			*(in percent)*			
Real GNP	0.0	0.8	1.2	0.6	−1.4	−2.3
Real domestic demand	−0.8	−0.8	−1.1	−1.9	−4.3	−5.8
Real interest rate	−0.7	−0.9	−0.9	0.3	2.0	2.9
Real effective exchange rate	−2.0	−3.3	−4.9	−5.1	−5.9	−7.0
GDP per worker	−0.1	−0.4	−0.5	0.4	−0.1	1.0
Capital stock per worker	−0.1	−0.3	0.0	1.6	1.7	1.3
			(as a percent of GNP)			
Current account balance	0.4	1.1	1.0	0.9	0.3	−0.1
General government financial balance	0.0	−0.1	−0.3	−0.6	−1.1	−1.1
Private saving	0.7	1.4	1.8	1.8	1.4	0.7
Gross private investment	0.3	0.2	0.5	0.2	−0.0	−0.2
Net foreign assets	0.9	4.8	7.7	9.4	8.9	6.3
Government debt	0.2	0.2	1.0	2.7	6.1	9.5
Canada			*(in percent)*			
Real GNP	0.2	2.8	3.5	2.4	−0.2	−3.3
Real domestic demand	−1.1	1.2	1.7	1.0	−0.7	−2.9
Real interest rate	−0.5	−1.4	−1.5	−0.4	1.1	3.3
Real effective exchange rate	−5.5	−7.7	−7.1	−4.9	−1.8	2.4
GDP per worker	−0.3	−0.0	0.5	1.8	2.5	3.0
Capital stock per worker	−0.3	−0.5	1.1	3.7	5.5	5.8
			(as a percent of GNP)			
Current account balance	1.3	2.4	3.0	2.8	2.1	1.5
General government financial balance	1.6	1.3	0.8	−0.4	−1.3	−1.9
Private saving	0.0	1.3	2.2	2.5	1.8	0.4
Gross private investment	0.3	0.2	−0.0	−0.7	−1.6	−2.9
Net foreign assets	4.1	12.2	21.3	28.1	31.0	30.2
Government debt	−4.0	−9.2	−10.8	−8.0	−2.0	4.8
Smaller Industrial Countries			*(in percent)*			
Real GNP	−0.2	0.8	0.3	−0.7	−3.1	−5.3
Real domestic demand	−0.1	0.8	0.5	−0.3	−2.3	−4.2
Real interest rate	−0.8	−1.1	−0.7	0.3	1.9	3.3
Real effective exchange rate	−0.2	−1.0	−1.0	−1.3	−1.2	−1.1
GDP per worker	−0.2	0.6	0.4	1.1	1.4	1.7
Capital stock per worker	0.1	0.9	1.7	3.1	3.7	3.0

Table 7 (*concluded*).

Country	2000	2005	2010	2015	2020	2025
			(as a percent of GNP)			
Current account balance	−0.0	0.2	0.0	−0.3	−0.8	−1.1
General government financial balance	−0.5	−0.5	−0.8	−1.1	−1.5	−1.6
Private saving	0.7	1.0	1.1	0.8	0.3	−0.6
Gross private investment	0.3	0.3	0.3	0.0	−0.4	−1.1
Net foreign assets	1.1	1.6	1.2	−0.7	−3.4	−6.8
Government debt	2.1	3.3	5.0	7.4	10.8	14.5

industrial countries has the potential to generate large swings in foreign indebtedness over time, and that a simple extrapolation of present current account positions is likely to be well off the mark.

The projected aging of the population also has significant implications for real GNP. In the simulation, the contraction in the labor force in the industrial countries after 2015 reduces real GNP in 2025 by 13 percent in Japan, by 6 percent in Germany, and by a somewhat smaller amount in the other industrial countries outside the United States. However, it should be noted that output per worker is higher in several countries, as is the capital stock per worker. In the United States aggregate output is roughly unchanged in 2025, and it is in fact higher for most of the simulation, as a result of the increase in the working-age population in the early part of the next century.

Fiscal deficits do not evolve as dramatically as external positions in these simulations, in large part because of endogenous tax increases. The real cost to the world economy shows up in the effect on production through a smaller labor force and a lower capital stock. Government financial positions do nonetheless weaken toward the end of the simulation period, as tax revenues fall and pension expenditures increase substantially in all industrial countries. In particular, government debt rises significantly in Japan and Germany.

Given the magnitude of the effects on net creditor and debtor positions, it is of interest to see how sensitive they are to estimated parameters and projections of key exogenous variables. Two such experiments are reported in Table 8. The first reduces the coefficients on the dependency ratio (which were not very well determined statistically) by a factor of 2. The second supposes that aging of the population induces an increase in participation rates (for instance, because of delayed retirement or increased labor supply of those who must support aged relatives). In particular, participation rates are assumed to offset half of the effect on the labor force of the rise in dependency ratios.

Table 8. *Effect of Aging on Net Foreign Assets in 2025 Under Three Alternative Assumptions*

(Deviations from baseline as a percent of GNP)

Country	Standard Model[a]	Consumption Coefficient[b]	Participation Rate[c]
United States	36	23	36
Japan	−59	−34	−59
Germany, Fed. Rep. of	−24	−16	−23
France	12	4	13
Italy	7	3	7
United Kingdom	6	−2	9
Canada	30	25	25

[a]From Table 7.
[b]The consumption coefficient of *DEM3* is assumed to be halved.
[c]The participation rate is assumed to rise by one half of the proportionate decline in those aged 15–64.

The first change makes a substantial difference for net foreign asset positions, as can be seen in Table 8. The second assumption, in contrast, has only minor effects—as might be expected from the discussion of production effects above. Taken together, these simulations suggest that the numerical results discussed above should at best be considered rough orders of magnitude, and that they are especially sensitive to assumed effects of aging on saving rates.

IV. Concluding Remarks

The paper has isolated some of the implications of the aging of the population that is projected for the next three and a half decades. Using MULTIMOD to simulate the net effect of aging through three channels—reduced saving rates, a lower labor force, and higher government expenditure—suggests that macroeconomic effects may be substantial by 2025. Moreover, though some of the effects are common to all countries—higher real interest rates and lower output in the later years of our simulation period—some of the effects differ substantially because of differences in the extent and speed of aging across countries. As a result, there are substantial long-run changes in current account and net foreign asset positions, in a direction that reverses recent tendencies among the three largest industrial economies.

A number of policy issues arise in the context of population aging; they are not, however, the subject of this paper. Governments can influence capital formation by their expenditure and tax policies; a key

question is whether the capital stock will be adequate to support a higher consumption ratio and greater demands for government medical services in the future. Questions of intergenerational equity are at the heart of the debate over whether anticipated increases in government expenditure should be financed through government saving today, or through taxes on the working population in the next century (see Halter and Hemming (1987) and Aaron, Bosworth, and Burtless (1989)). Another important question relates to the prospects for capital accumulation and sustained growth in developing countries when industrial countries are saving less.

It is important to stress once again the limitations and uncertainties associated with our analysis. The prospect of substantial migration within Europe and North America makes any demographic projections 35 years into the future extremely tentative. Moreover, our model of household behavior is rudimentary, and the effects on consumption estimated over a historical period with a much younger population may not provide a good guide to the future. Other effects, which we have not considered, include an endogenous response of participation rates—for instance, because of a rise in two wage-earner households or an increase in the average retirement age—and effects of the age composition of the working population on productivity levels. We have also not analyzed the effects of a continued slowdown of population growth—which, in itself, might be expected to lower real interest rates and increase the capital stock per worker (see the Appendix). Clearly, more research into these various questions is in order.

APPENDIX

Steady-State Effects of Demographic Changes

In this Appendix we work out analytically the long-run effects of having an older population. In MULTIMOD the effects of aging operate through three channels. (1) The consumption equation has an estimated positive coefficient on the dependency ratio, which is consistent with greater consumption during one's retirement years relative to income and wealth. (2) Potential output depends on the labor force, which is reduced when a larger fraction of the population is retired. (3) An older population is associated with higher government spending (based on estimates in Heller and others (1986)). We also consider a decrease in the birthrate β, which for an unchanged mortality rate implies slower population growth, although these effects are not discussed in the text, given difficulties in simulating MULTIMOD with different population growth rates in different countries (implying the impossibility of ever reaching a steady state) and because

of uncertainty concerning birthrate projections. The macroeconomic effects that one would expect to result through these linkages can be described in a simplified version of MULTIMOD, as laid out below.

If we ignore monetary factors and, as a result, can express all variables in real terms, we can represent MULTIMOD for the global economy as follows:[20]

$$C = (\rho + \lambda + \alpha\Delta)(B + H) \tag{1}$$

$$\dot{H} = (r + \beta)H - (Y - \delta K - T) \tag{2}$$

$$\dot{B} = rB + G - T \tag{3}$$

$$Y = F(K, L) \tag{4}$$

$$F_1(K, L) = r + \delta \tag{5}$$

$$Y = C + G + \delta K + \dot{K}. \tag{6}$$

Consumption C is modeled as in Blanchard (1985) and Buiter (1988), with the addition of a multiplicative term in the dependency ratio; liquidity constraints are ignored here. It is assumed that the birthrate β is exogenous; population (and all stock and flow variables in steady state) grows at rate $n = \beta - \lambda$, where λ is the mortality rate (constant, and independent of age), and ρ is the rate of time preference for any given individual. Productivity growth is assumed to be zero. As a result, consumption is proportional to wealth, with the constant of proportionality depending positively on the dependency ratio Δ (equation (1)). The only forms of wealth are government bonds B and human capital H; that is, discounted future after-tax income (including net income to capital K) (equation (2)). The government budget constraint makes bonds grow with the deficit (equation (3)), and bonds pay a real rate of interest r. Output is given by a production function that depends on capital K and the labor force L (equation (4)), and conditions for profit maximization imply that the marginal product of capital (F_1) equals the real rate of interest plus the rate of depreciation (equation (5)).[21] Finally, output produced has to equal demand on the part of households and the government (equation (6)), plus replacement investment.

In a steady state with growth at rate $n = \beta - \lambda$, $\dot{H}$, $\dot{K}$, and $\dot{B}$ have to be equal to nH, nK, and nB, respectively. To consider steady-state effects, we therefore replace equations (2) and (3) with the following equations:

$$H = (Y - \delta K - T)/(r + \lambda) \tag{7}$$

$$B = (T - G)/(r - \beta + \lambda) \tag{8}$$

$$Y = C + G + (\beta - \lambda + \delta)K. \tag{9}$$

The effects of a greater proportion of the elderly show up in three exogenous variables: Δ, G, and L—the first two increase, and the third declines.[22] A decrease in birthrates produces a fall in β and therefore a fall in real growth n. We

[20] Implications for a single open economy are discussed below.

[21] Corporate taxes are ignored; taxes are assumed to be lump-sum levies on households.

[22] For a given population P and participation rate R, Δ and L are related as follows: $L = \Delta RP$. In order to understand the mechanisms at work, we separate the labor force effects of a change in Δ from its effect on consumption.

therefore differentiate the above system of equations (1), (7), (8), (4), (5), and (9) with respect to Δ, G, L, and β (noting that $dn = d\beta$). The results are as follows:

$$dC = (\rho + \lambda)(dB + dH) + \alpha d\Delta(B + H) \tag{10}$$

$$dH = (dY - \delta dK - dT)/(r + \lambda) - [(Y - \delta K - T)/(r + \lambda)^2]dr \tag{11}$$

$$dB = (dT - dG)/(r - \beta + \lambda) - [(T - G)/(r - \beta + \lambda)^2](dr - d\beta) \tag{12}$$

$$dY = F_1 dK + F_2 dL \tag{13}$$

$$F_{11} dK + F_{12} dL = dr \tag{14}$$

$$dY = dC + dG + (\beta - \lambda + \delta)dK + K d\beta. \tag{15}$$

Equations (10)-(15) give six equations in seven endogenous variables—dC, dH, dB, dT, dY, dr, and dK. The underdetermination results from government variables; we take the steady-state bond stock to be exogenous (as is the case in MULTIMOD for the bond/GNP ratio). Moreover, to simplify the analysis, we consider the case where the primary deficit $(G - T)$ is zero; so from equation (12) $dT = dG$ (and also $B = 0$). In this case, lower birthrates have no effect on the long-run equilibrium real interest rate, except through the steady-state rate of investment, in (15).

It is straightforward to reduce the system of equations to three equations in three endogenous variables, dC, dK, and dr:

$$\begin{bmatrix} 1 & -\theta(F_1 - \delta) & \theta H \\ 0 & F_{11} & -1 \\ -1 & F_1 - \mu & 0 \end{bmatrix} \begin{bmatrix} dC \\ dK \\ dr \end{bmatrix} = \begin{bmatrix} \alpha H & \theta F_2 & -\theta & 0 \\ 0 & -F_{12} & 0 & 0 \\ 0 & -F_2 & 1 & K \end{bmatrix} \begin{bmatrix} d\Delta \\ dL \\ dG \\ d\beta \end{bmatrix}, \tag{16}$$

or

$$Ady = Bdx,$$

where $\theta = (\rho + \lambda)/(r + \lambda)$ and $\mu = \beta - \lambda + \delta$. It can be shown that $\rho \leq r < \rho + \lambda$ (provided bonds B are positive, but less than some upper limit), so $0 < \theta < 1$.

Now the determinant of the matrix A is equal to

$$\det(A) = F_1(1 - \theta) + F_{11}\theta H - (\mu - \delta\theta). \tag{17}$$

The marginal product of capital is positive, $F_1 > 0$, and by diminishing marginal returns, $F_{11} < 0$; det (A) can therefore not be signed a priori. However, stability of the dynamic system (not analyzed here) requires that at a point of equilibrium, an increase in the real interest rate should increase saving net of investment. This can be shown to imply that det $(A) < 0$, as follows. The change in net savings dS is equal to

$$\begin{aligned} dS &= dY - dC - \mu dK \\ &= [(1 - \theta)F_1 + \delta\theta]dK + \theta H dr - \mu dK \\ &= (1 - \theta)F_1 dr/F_{11} + \theta H dr - (\mu - \delta\theta)dr/F_{11}. \end{aligned} \tag{18}$$

Multiplying by F_{11} (which is negative) shows from equation (17) that the condition that $dS/dr > 0$ is equivalent to det $(A) < 0$.

Calculating $A^{-1}B$ and simplifying gives the following comparative static results:

$$\begin{bmatrix} dC \\ dK \\ dr \end{bmatrix} = \frac{1}{\det(A)} \cdot \begin{bmatrix} \alpha H(F_1 - \mu) & D_1 & -\theta H F_{11} + n\theta & \theta K(F_1 - \delta - HF_{11}) \\ \alpha H & D_2 & (1-\theta) & K \\ \alpha H F_{11} & D_3 & F_{11}(1-\theta) & F_{11}K \end{bmatrix} \cdot \begin{bmatrix} d\Delta \\ dL \\ dG \\ d\beta \end{bmatrix}, \tag{19}$$

where

$$D_1 = \theta H[F_{11}F_2 - (F_1 - \mu)F_{12}] - n\theta F_2$$
$$D_2 = -(1-\theta)F_2 - \theta H F_{12}$$
$$D_3 = -(1-\theta)F_{11}F_2 + F_1 F_{12}(1-\theta) - F_{12}(\mu - \delta\theta).$$

Noting that $F_{12} > 0$, $F_{11} < 0$, $F_1 - \mu = r - n > 0$, and $\mu - \delta\theta > 0$, and recalling that $\det(A) < 0$, the signs of the comparative statics results are as follows:

	$d\Delta$	dL	dG	$d\beta$
dC	−	+	−	−
dK	−	+	−	−
dr	+	0[23]	+	+

Let us consider in turn the changes in the exogenous variables. An increase in private consumption due to aging ($d\Delta > 0$) paradoxically *decreases* steady-state consumption. The reason is that it raises the real interest rate and lowers the capital stock, leading to lower output. Though there is short-run stimulus to consumption and to output demand, in the long-run steady state, aggregate supply effects dominate: an economy that saves less has a lower capital stock.[24] The effect of increased government spending $dG > 0$ is similar; it drains resources away from capital formation. A decrease in the labor force due to an increase in retirees ($dL < 0$) tends to *lower* aggregate consumption, capital, and output, but has no effects on per capita variables or the real interest rate, given the somewhat artificial assumption that the aggregate consumption/wealth ratio is unaffected and if one makes the further assumption that government spending per capita is unchanged. Such a change in L just corresponds to a scale change in the econ-

[23] Assuming that G changes proportionately.
[24] Provided it is below the golden-rule capital stock.

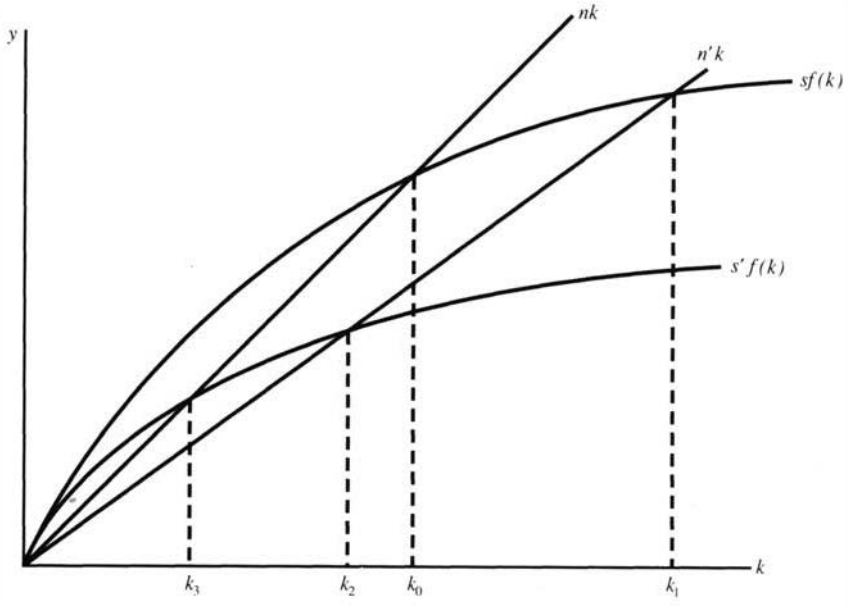
omy. A decline in population growth ($d\beta < 0$) should increase capital intensity and consumption and decrease the real interest rate.

Some intuition about long-run effects can be obtained with the help of a simple diagram, taken from the neoclassical growth literature (Figure 1). All variables have been put in per capita terms; that is, divided by the labor force. A constant returns to scale production function (and the assumption that G grows with LF, discussed above) allows us to do this. In equilibrium, saving must equal investment. For the equilibrium to be a steady state, investment must be sufficient to maintain a constant capital/labor ratio k; that is, the capital stock must grow at the growth rate of the labor force n. Hence, saving per capita ($sf(k)$, where s is the saving rate) must equal investment per capita (nk).

Now a change in the level of the labor force would just scale up or down all macroeconomic flow and stock variables, but have no effect on such variables as capital intensity (plotted on the horizontal axis) or saving per capita (the curve $sf(k)$). The level of the real interest rate can be inferred from the value of the capital/labor ratio k; from the production function and the equilibrium condition that the marginal product of capital is equal to the real interest rate plus the depreciation rate, a higher value of k is associated with a lower real interest rate.

A permanent change in the age structure toward an older population, leaving population growth unaffected, would shift down the saving schedule because the aggregate saving rate would be lower. This would occur because the government would spend more in order to provide increased services and because the elderly

Figure 1. *Steady-State Equilibrium with Different Saving Rates and Population Growth Rates*



save less. Lower saving for a given population growth would shift the $sf(k)$ curve down to $s'f(k)$ and lead it to intersect with investment at a lower capital labor ratio, k_3. In other words, capital intensity would be lower, and the real interest rate higher, with an older population.

A permanent decline in the population's growth rate, keeping age structure unchanged,[25] would have the opposite effect. It would shift down the investment line to $n'k$; with slower population growth, the economy can devote a lower proportion of its output to investment and yet maintain its standard of living. As a result, with unchanged saving behavior capital intensity rises to k_1, and the real interest rate falls. The net effect of slower population growth and an older population depends on the extent of the demographic changes and the size of effects on saving: k can either rise or fall.

In the case of an open economy facing the above demographic shifts, the results would be modified in several important ways. Suppose, first, that the country is small and that it alone experiences the demographic shifts. In the long run the home country's interest rate will equal the exogenous world rate. Therefore, instead of raising interest rates and lowering the capital stock, population aging will lead to a rundown of net claims on foreigners. Another channel will involve changes in the terms of trade. Increases in consumption demand and decreases in supply (through a shrinkage of the labor force) will each lead to an appreciation of the home country currency in real terms, which will also have the effect of pushing the current account position into deficit and leading to a decline in net foreign assets. Thus, in a small open economy model, crowding out of excess demand for the home good will occur through net exports and not through declines in investment and the capital stock, as in the closed economy model.

To the extent that the economy is large, there will be a combination of effects on real interest rates and on the foreign balance. Moreover, if the demographic shifts occur in a large number of countries, then the closed economy results will be approximated at the global level. If the shifts are of different magnitudes, however, the countries with the more pronounced aging will experience a decline in net exports, and a real appreciation, as described above.

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[25] In practice, the two phenomena are interrelated: unless mortality rates change, permanently lower birthrates will yield an older population as well as slower population growth.

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