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## Appendix 3.1 : Demographic Change and the Global Economy: Data and Modeling Strategy

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### ► To cite this version:

Nicoletta Batini, Warwick Mckibbin, Nicola Spatafora, Mehmet Tosun, Michel Juillard, et al.. Appendix 3.1 : Demographic Change and the Global Economy: Data and Modeling Strategy. [Research Report] International Monetary Fund. 2004, pp.169 - 175. hal-03458783

**HAL Id: hal-03458783**

**<https://sciencespo.hal.science/hal-03458783v1>**

Submitted on 30 Nov 2021

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particular attention; announcing a prospective rise in the retirement age would not only ease pension burdens, but would also increase potential labor supply. Designing reforms that are resilient to uncertainties about the future is clearly a very difficult task. However, one way that uncertainties about life expectancy could be dealt with in pension systems would be to link increases in the retirement age to gains in life expectancy or to link pension benefits to life expectancy (as in Sweden). Lastly, aging may have important implications for financial markets if the elderly run down their assets in retirement, and regulators will need to ensure that financial systems are sufficiently resilient to cope with such possible changes (see the September 2004 *Global Financial Stability Report*).

The policy response to demographic change in developing countries has received less attention, but is very important, particularly as these countries will become an increasingly significant source of global growth in the period ahead. The main priorities for developing countries are to put in place a policy framework that ensures that the potential benefits from the demographic dividend are maximized, while setting the groundwork for eventual population aging. Pension and health care systems will need to be strengthened to ensure that they provide a safety net for the elderly that is both adequate and fiscally sustainable. In doing this, it will be important that governments learn from the current situation in many advanced countries, and do not commit themselves to provide benefits that will be difficult to finance.

The movement of goods, capital, and labor between countries will be an integral part of the global adjustment to the differential rates of population aging. Choices will need to be made about how these channels are allowed to operate, with policymakers having to balance the economic, political, and social implications of each. The more the adjustment is shared between the various channels, however, the less will be the burden on each, and this may help reduce the risks that could accompany large capital flows. At the international level, increased cooperation

will be needed to manage these cross-country flows and to ensure that the associated risks are minimized to the extent possible. In this regard, progress toward freer trade—including through the successful completion of the ongoing Doha Round—and the strengthening of the global financial architecture will be important.

Finally, some of the policies to tackle the impact of demographic change will inevitably involve difficult tradeoffs, will take time to agree and implement, and will need to be phased in to allow people sufficient time to adjust their behavior. This is most clearly true of pension reforms—which affect the welfare of the elderly and threaten benefits that people believe they are entitled to—but also of health care. Therefore, while the full impact of demographic change will not be felt in most countries for a number of years, the process of planning a response should not be delayed. This is particularly true for advanced countries, where reforms to pension and health care systems will become increasingly difficult to implement as populations age. Policymakers therefore need to take advantage of the current strong global economic rebound to advance the reform agenda before the window of opportunity begins to close.

### Appendix 3.1. Demographic Change and the Global Economy: Data and Modeling Strategy

*The main authors of this appendix are Nicoletta Batini, the INGENUE Team, Warwick McKibbin, Nicola Spatafora, and Mehmet Tosun.*

This appendix provides further details on the data and the modeling strategy used in the chapter to analyze the global economic impact of demographic change.

#### Econometric Analysis

The econometric work analyzes a broad panel of 115 advanced and developing countries, representing all major geographic regions, over the

**Table 3.2. Selected Summary Statistics, 1960–2000<sup>1</sup>**  
(Percent unless otherwise noted)

Variable	All Sample Countries
Economic variables	
Output growth per capita	1.7 (6.3)
Saving/GDP	16.9 (15.0)
Investment/GDP	21.8 (8.4)
Current account/GDP	-4.1 (10.4)
Budget balance/GDP	-3.4 (7.0)
Demographic variables	
Working-age population/total population	57.4 (6.3)
Elderly population/total population	5.7 (3.8)
Change in (working-age population/total population) <sup>2</sup>	0.11 (0.32)
Change in (elderly population/total population) <sup>2</sup>	0.05 (0.11)

Sources: World Bank, *World Development Indicators*; United Nations, *World Population Prospects: 2002 Revision*; and IMF staff calculations.

<sup>1</sup>Values are means at an annual frequency, with panel standard deviations provided in parentheses next to each value.

<sup>2</sup>Percentage points.

period 1960–2000.<sup>37</sup> For all variables, and for each country, the data are averaged over each decade. The analysis focuses on the impact of demographic change on each of the following measures of macroeconomic performance: growth of GDP per capita; saving/GDP; investment/GDP; current account balance/GDP; and central government budget balance/GDP.

Demographic change is measured using the following variables:

- ratio of working-age population to total population, and ratio of elderly population to total population, when analyzing any measure of macroeconomic performance except growth of GDP per capita;<sup>38</sup> and
- change in the ratio of working-age population to total population, and change in the ratio of

elderly population to total population, when analyzing growth of GDP per capita.

Summary statistics for the key variables used in the analysis are shown in Table 3.2. To examine the importance of demographic change as a determinant of economic performance, the following equation was estimated:

$$Y_{it} = \alpha_i + \beta \cdot Demo_{it} + \gamma \cdot Z_{it} + \varepsilon_{it} \quad (1)$$

where  $Y$  is the specific macroeconomic variable of interest;  $Demo$  are the relevant measures of demographic change;  $Z$  is a set of control variables; and the subscripts  $i$  and  $t$  denote the country and the time period, respectively. This equation is estimated using the panel fixed-effects estimator. More specifically:

- in the *growth* regression, the controls include initial income; secondary school enrollment ratios; investment/GDP; budget balance/GDP; inflation rate; external trade/GDP; and country risk (as measured by the ICRG);
  - in the regressions for *saving/GDP*, *investment/GDP*, and *current account/GDP*, the controls include initial income; budget balance/GDP; net foreign assets/GDP; M2/GDP; the standard deviation of a terms of trade index; external trade/GDP; and an oil-producer dummy; and
  - in the *budget balance* regression, the controls include initial income; the standard deviation of the terms of trade; and external trade/GDP.
- To control for possible endogeneity problems, all demographic variables, as well as several other controls, are instrumented using their lagged values (for all decades except the first, the lagged

<sup>37</sup>These countries are Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Barbados, Belarus, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Congo, Dem. Rep. of, Congo, Rep. of, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Gabon, The Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Iran, I.R. of, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Kyrgyz Republic, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico, Moldova, Morocco, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Rwanda, Senegal, Sierra Leone, Singapore, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Rep., Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Yemen, Zambia, and Zimbabwe.

<sup>38</sup>The working-age population is defined as the age group 15–64 inclusive; the elderly population is defined as the age group 65 years of age and older. When analyzing the determinants of the current account, demographic variables for each country are expressed as deviations from the world average.

**Table 3.3. Main Characteristics of the Multiple-Generations Models**

Characteristic	INGENUE	Tosun	MSG3
Number of countries/blocks <sup>1</sup>	6	2	4
Intertemporal optimization/ overlapping generations	Yes	Yes	Yes
Expectations	Rational	Rational	Rational and rule of thumb
Sectors	1	1	3
Age cohorts	4 young, 15 adult (including elderly)	0 young, 1 adult, 1 elderly	1 young, 1 adult (including elderly)
Period lengths (years)	5	30	1
Life ends at	Fixed at 60–94 years	Fixed at 60 years	Fixed with probability “ <i>p</i> ”
Rigidities	No	No	Yes
Capital mobility	Yes	Yes	Yes
Labor mobility	No	Yes	No
Intergenerational transfers	Adults to young Adults to elderly	Adults to elderly	Adults to young
Public sector	Yes (simple public pension scheme)	Yes (articulated with public pension scheme)	Yes (articulated without public pension scheme)

<sup>1</sup>INGENUE regions include (1) Western Europe; (2) North America: Australia, Canada, New Zealand, and the United States; (3) Japan; (4) developing rapidly aging countries; (5) developing moderately aging countries; and (6) developing slowly aging countries. Tosun’s model’s regions include an advanced and a developing country bloc. MSG3 regions include (1) the United States; (2) Japan; (3) other OECD economies; and (4) rest of the world.

value is defined as the value in the preceding decade; for the first decade, the lagged value is defined as the value in the first year).<sup>39</sup>

### Macroeconomic Models

This section describes in more detail the three multiple generations models (MGM) used in this chapter.<sup>40</sup> Table 3.3 summarizes and contrasts the key features of each model.

#### *The INGENUE Model*

The INGENUE model (INGENUE Team, 2001) is a multiregion world model in the spirit of those developed by Obstfeld and Rogoff

(1996) in which the structure of each regional economy is similar to that of other applied OLG general equilibrium models such as Auerbach and Kotlikoff (1987) or Cazes and others (1992, 1994), except that labor supply is exogenous.<sup>41</sup>

The world is divided into six regions, including three advanced areas (Europe, North America, and Japan) and three developing country zones ranked according to their stage in the demographic transition (a “rapidly aging,” a “moderately aging,” and a “slowly aging” zone) (Table 3.4). Each region of the world comprises three categories of economic agents: households, firms, and the public sector. These are described below.

<sup>39</sup>Specifically, secondary school enrollment ratios; investment/GDP; budget balance/GDP; inflation rate; external trade/GDP; and country risk.

<sup>40</sup>Multiple generations models were first proposed by Samuelson (1958) and Diamond (1965). In their purest overlapping-generations (OLG) form, these innovate upon the Ramsey infinitely-lived representative-consumer hypothesis by introducing at each point in time individuals of different generations. Work by Blanchard (1985), Buiter (1988), Weil (1989), and more recently Faruqee (2000a, 2000b, 2003) suggested simplified alternatives to pure OLG models. Multicountry extensions in the OLG tradition include Buiter (1981), Cutler and others (1990), Attanasio and Violante (2000), INGENUE Team (2001), Börsch-Supan, Ludwig, and Winter (2003), and Fehr, Jokisch, and Kotlikoff (2003), among others. Faruqee, Laxton, and Symanski (1997), and Bryant and McKibbin (2004) all proposed multicountry extensions in the Blanchard-Buiter-Weil multiple-generations-model tradition.

<sup>41</sup>A new, more sophisticated version of the INGENUE model with 10 regions, imperfect financial markets, 2 sectors, autonomous population projections based upon UN coefficient methods, stochastic life expectancy, and bequest motives is currently under construction.

**Table 3.4. INGENUE Model: Countries Composing Each Demographic Zone**

Name of Region	Countries in Region
Western Europe	European Union, Switzerland, Norway, and Iceland
North America and Oceania	United States, Canada, Australia, and New Zealand
Japan	Japan
Developing: rapidly aging	Armenia, Bahrain, Belarus, Bosnia-Herzegovina, Bulgaria, China, Czech Republic, Cyprus, Estonia, Georgia, Hong Kong SAR, Hungary, Korea, Dem. People's Rep., Korea, Rep. of., Latvia, Lithuania, Macao, Moldova, Poland, Qatar, Romania, Russian Federation, Singapore, Slovak Republic, Thailand, Ukraine, United Arab Emirates, and Uruguay.
Developing: moderately aging	Albania, Argentina, Azerbaijan, Bahamas, Brazil, Brunei, Caribbean zone, Chile, Colombia, Dominica, Guyana, India, Indonesia, Israel, Jamaica, Kuwait, Lebanon, Malaysia, Mexico, Panama, Peru, Sri Lanka, Suriname, Trinidad and Tobago, Turkey, and Vietnam.
Developing: slowly aging	Afghanistan, Africa, Bangladesh, Bhutan, Bolivia, Cambodia, Costa Rica, Ecuador, El Salvador, Fiji, Guatemala, Haiti, Honduras, Iran, Islamic Rep. of., Iraq, Jordan, Kazakhstan, Kyrgyz Republic, Lao PDR, Melanesia, Micronesia, Mongolia, Myanmar, Nepal, Nicaragua, Oman, Pakistan, Papua New Guinea, Paraguay, Philippines, Polynesia, Samoa, Saudi Arabia, Syrian Arab Republic, Tajikistan, Turkmenistan, Eastern Timor, Uzbekistan, Vanuatu, Venezuela, West Bank and Gaza, and Yemen, Rep. of.

### Households

In each region the household sector consists of 15 overlapping five-year-long cohorts of adults aged 20–94, and four cohorts of “young” who are dependent on their parents: individuals become adults when they turn 20, and remain in the labor force until legal, mandatory retirement age, which differs according to the region. Death occurs with certainty between ages 60 and 94, but is modeled in a way that mimics realistic probabilistic assumptions for the various world regions.

Households are assumed to supply labor, inelastically and locally, during the first periods of their adult life (youth and maturity) and then to retire. In addition, young adults bear the costs of educating children, modeled as a “tax” on the parent’s consumption, proportional to the number of births. Households maximize life-cycle utility, with perfect foresight: when working, they save and invest in shares of the capital stock of production firms that are sold on a unified world capital market to finance their consumption during retirement—when they dissave. There is no bequest motive so at the end of each household’s life each household’s cumulated saving is zero.

### Firms

The model assumes that identical firms located in various regions of the world are per-

fectly competitive, are equipped with a Cobb-Douglas constant-return technology using two factors (capital and labor), and produce a single good that may be used for consumption and investment. In the model this good is used as a numeraire and is freely traded at no cost on a world market. The assumption of a single good traded at no cost in world markets implies that regional real exchange rates are constant and always equal to one. In the model, capital is also perfectly mobile and the world financial market is perfect so that, in the long run, regional interest rates are equalized. Although the production technology is assumed to be identical across regions, the model is simulated assuming a wide initial gap in the level of total factor productivity between regions, which in turn is driven by an exogenous growth and convergence process. A mechanism of exogenous international diffusion of technological progress is specified, whereby the various regions of the world slowly converge to the level of total factor productivity in the North American economy—the world’s technological leader—so that in the very long run all regions grow at the same rate.

### Public Sector

The public sector is reduced to a pay-as-you-go public pension scheme. It is financed by a pay-

roll tax on all labor incomes and pays pensions to retired households. The replacement rate on the after tax wage is fixed, and the payroll tax is endogenous in order to enforce a balanced-budget rule. The adopted calibration allows the model to reproduce realistic regional intergenerational transfers.

### Equilibrium

The general equilibrium of the world economy is solved by equating, in each region, the optimal labor demand emanating from domestic firms to the exogenous local labor supply, and the sum of regional supplies of saving with the sum of regional demand for investment. These equilibrium conditions respectively yield the six regional real wage rates and the world real interest rate, which in turn determine regional GDP, aggregate consumption, and saving, as well as their distribution over living cohorts in the various regions. In any given period, the difference between the flows of domestic saving and domestic investment in any of the six regions gives the inflow or outflow of the capital for the region, while the ratio of the stock of accumulated wealth of resident households to the stock of accumulated productive capital in a particular region, defined as the ownership ratio, measures its net external position—that is, net foreign assets or net external debt.

### Calibration

Fertility rates and households' life expectancy in the model are set to mimic demographic projections from the UN's medium-fertility scenario up to 2050. The evolution of regional populations beyond that date is obtained by setting reproduction rates so that populations become stationary after 2100. Parameter values governing households' and firms' behavior together with assumptions on exogenous growth rates, the degree of international technological convergence, and contribution and replacement rates for pension schemes in the various regions of the world are based on historical data in order to match as closely as possible the observed dynamic of key economic variables,

notably current account balances and interest rates.

### *MSG3 Model*

The MSG3 model is a three-sector—energy, nonenergy, and capital-producing—version of the G-Cubed model developed by McKibbin and Wilcoxon (1998) building on the earlier MSG2 model developed by McKibbin and Sachs (1989) and the Jorgenson and Wilcoxon (1990) model. The model divides the world into four regions: the United States, Japan, the rest of the OECD, and the rest of the world (in essence, the world's developing bloc). It combines the modern intertemporal optimization approach to modeling economic behavior (as found in Blanchard and Fischer, 1989; and Obstfeld and Rogoff, 1996) with short-run rule-of-thumb behavior. In doing this it brings together features of real business cycle models—with a fully articulated analysis of forward-looking producers and consumers—and modern macroeconomic models—describing the effects of demand downturns in the face of wage (and price) stickiness. The main features of the model are as follows.

- *Demographics.* The model includes demographic considerations, such that economic agents in the model possess finite life spans and their income varies as they age. Specifically, drawing heavily on Faruquee (2000a, 2000b), who extended the Blanchard (1985) model of finitely lived agents to include aging considerations, in the MSG3 economic agents progress from being financially dependent children to being adults who are financially responsible for their own children. Death occurs with a fixed probability.
- *Explicit optimization.* The model is based on explicit intertemporal optimization by agents (consumers and firms) in each economy. Thus, time and dynamics are of fundamental importance in the MSG3 model, making its core theoretical structure like that of real business cycle models.
- *Rule-of-thumb agents.* To track the inertial dynamics of some key macroeconomic vari-

ables, the behavior of agents is modified to allow for short-run deviations from optimal behavior, owing either to myopia or to restrictions on the ability of households and firms to borrow at the risk-free bond rate on government debt.

- *Cash-in-advance constraints.* Holdings of financial assets including money are explicitly modeled. In particular, money is introduced into the model through a restriction that households require money to purchase goods.
- *Nominal rigidities.* The model allows for short-run nominal wage rigidity (by different degrees in different countries) and therefore allows for protracted periods of unemployment depending on the labor market institutions in each country.
- *Two types of capital.* The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital that can flow immediately where expected returns are highest. This distinction leads to a difference between the quantity of physical capital that is available at any time to produce goods and services and the valuation of that capital as a result of decisions about the geographical allocation of financial capital.
- *Estimation/calibration.* Key parameters in the model—such as the elasticities of substitution in production and consumption decisions—are estimated, enhancing the model’s ability to reproduce the dynamics of historical data.

As a result, the model exhibits a rich dynamic behavior, driven on the one hand by asset accumulation and, on the other hand, by wage adjustment to a neoclassical steady state. Details of the model can be found on the Internet at [www.gcubed.com](http://www.gcubed.com).

### ***Tosun’s Two-Region OLG Model with International Labor Mobility***

This two-period two-country model builds on the standard closed-economy overlapping generations framework developed by Diamond (1965). The model features either capital or labor mobility in line with work by Galor (1986,

1992) and Crettez, Michel, and Vidal (1996, 1998). In the version used here the two countries represent the advanced and developing regions of the world, each with a population that is composed of two age groups (workers and the retired). The population characteristics of each country are calibrated to actual UN projections for advanced and developing blocs of the world so that the advanced countries age more quickly than the developing countries. The model incorporates the interaction of household behavior, firm behavior, political process, and international labor flows. These are described in more detail below.

#### Households

Individuals live for two (30-year-long) periods and seek to maximize the utility that they derive from consumption over their lifetime. To pay for consumption, households supply labor according to a distribution of abilities that is replicated in each new generation. Effective labor is the product of human capital that is accumulated from the interaction of the ability level of the individual and government spending per young on a productivity-enhancing public good such as education. Both labor and capital income are taxed to finance the provision of public goods.

#### Firms

Each country produces a single good using a Cobb-Douglas technology. Competitive factor markets require that the real wage and the real interest rate are equalized to the marginal product of labor and capital, respectively.

#### Political process

The government provides two public goods: a productivity-enhancing good (education) and social security. It is assumed that there is a predetermined “earmarked” level of social security spending. Thus the social security tax is simply determined by the government budget constraint where social security spending per worker is fixed. However, spending on the productivity-enhancing public good is determined through a political process for which a median-voter frame-

work with voter heterogeneity is used. Voter heterogeneity is introduced by assuming a distribution of genetic ability levels for the working generation. The ability level of the individual will, in turn, determine the value that the individual receives from the public good.

The preferred tax rate is increasing with the ability level of the individual and with income per worker and it is decreasing with the social security tax rate. Since retirees do not derive any benefit from this public good, they incur a cost without enjoying any benefits. Therefore, their preferred tax rate will always be zero, regardless of their ability. With an increase in the dependency ratio, retired people will need fewer working voters to form a majority. Since these working voters are at the lower end of the ability distribution, they prefer lower taxes than higher-ability people because their return from the productivity-enhancing public good is lower. Therefore, the median voter becomes a person with lower ability and the preferred tax rate of the median voter falls. The migration of workers increases the number of working voters, the upshot of which is a higher preferred tax rate of the median voter, and thus a larger provision of productivity-enhancing good. In turn, this supports labor income and growth relative to a scenario of aging where no migration takes place.

### Equilibrium

In the absence of international capital mobility, capital market equilibrium requires that saving in each period equals accumulated capital in the following period. Two alternatives are also contemplated to close the dynamic model. Either capital is fully mobile internationally (so that rates of return are equalized between the two countries) or labor is perfectly mobile between the two countries (so that net-of-tax real wages are equalized across countries, given that the model uses source-based income taxation for both countries).

In the case of perfect labor mobility, it is assumed that only people of working age move between regions. Additionally, migration is assumed to have no effect on the ability distribution in both

regions. This means that migration of labor affects the size rather than the composition of the working-age generation in the two regions.

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