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Orazio Attanasio
Andrea Bonfatti
Sagiri Kitao
Guglielmo Weber

Inter-American Development Bank
Department of Research and Chief Economist

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Orazio Attanasio*
Andrea Bonfatti**
Sagiri Kitao***
Guglielmo Weber****

* University College London, Centre for Economic Policy Research, Institute for Fiscal Studies and National Bureau of Economic Research
** University of Padua
*** Hunter College and Graduate Center, City University of New York
**** University of Padua, Centre for Economic Policy Research and Institute for Fiscal Studies

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Abstract

This paper studies the effect of demographic transitions on the economy of Latin America and the Caribbean (LAC). The paper builds a model of multi-regions of the world and derives the path of macroeconomic variables including aggregate output, capital, labor and the saving rate as economies face a rapid shift in demographics. The timing and the extent of the demographic transition differ across regions. The model is simulated under both closed economy and open economy assumptions to quantify the roles played by factor mobility across regions in shaping capital accumulation and equilibrium factor prices.

JEL classifications: E21, F21, F41, J11
Keywords: Capital flows, Demographic trends, Latin America and the Caribbean (LAC)

1 Introduction

Demographic trends in the last century have dramatically changed the size and composition of the world's population. Developed and mature economies have experienced dramatic reductions in fertility rates and increases in longevity. These trends have led to a considerable aging of the populations of developed countries and increases in old age dependency ratios. Aging demographics have implied that many public pension systems, based on Pay-As-You-Go (PAYG) schemes, have in many developed countries become unsustainable at pre-existing levels of benefits and contributions. As a consequence, there has been a tendency to move towards funded systems often based on defined contribution schemes. Several papers have pointed out that large changes in the age structure of the population are likely to imply large changes in factor prices. A large cohort preceded and followed by a small one will experience relatively low wages when on the job market and relatively low returns in later life. The same mechanisms that make a PAYG system unsustainable imply (in a world with funded pensions) movements in rates of return that will negatively affect the welfare of the large cohort. These effects are mediated by existing pension and social security arrangements, as well as the presence of government debt. These issues are discussed in studies including Attanasio, Kitao and Weber (2014), henceforth AKW, Attanasio, Kitao and Violante (2006 and 2007), Boersch-Supan, Ludwig and Winter (2006) and Krueger and Ludwig (2007).

Middle income countries have started on demographic transitions and trends that resemble those of developed countries, but with a delay of several decades. Fertility rates have declined rapidly in those countries, and longevity has increased. As these trends are much more recent, old age dependency ratios are still substantially below those currently observed in developed countries.

Among middle income countries, the demographic trends in China and Latin America and Caribbean (LAC) are particularly interesting and noticeable. On the one hand China, which is the country with the largest population in the world, has for many years successfully implemented a one-child policy that has decreased fertility rates to a very low level and has changed dramatically the predicted absolute and relative size of China. On the other hand, LAC is a region where fertility rates have decreased dramatically and very rapidly.

Low income/developing countries still have relatively high fertility rates and lag behind in mortality improvement. They are therefore the youngest countries in the world and will remain so for the coming decades. Those relatively high fertility rates further imply that they are projected to become by far the world's most populous group of countries.

All these changes have implied large shifts in the relative composition of the world's population and its age structure in several regions. These changes are expected to continue or become even more dramatic over the coming decades. As discussed below, this has important implications for factor prices and for the financing of old age public systems throughout the world.

The effects of demographic transition might nonetheless be compounded (or attenuated) by different degrees of development and different levels of productivity. In the presence of mobile factors of production, the presence of unsynchronized trends affords important opportunities to attenuate the adverse effects on some generations mentioned in the previous paragraph.

Large and unsynchronized demographic changes create incentives for the mobility of factors of production. These can occur in a number of ways, such as capital flows, migration and outsourcing. However, factor mobility is not without problems. Migration can imply large social problems connected with the integration of potentially large numbers of migrants with different cultures. At the same time, these large inflows can cause changes in the real wages of sectors of society and, as a consequence, generate political resistance.

Capital mobility might also be problematic: financial and political institutions need to be sufficiently well developed to guarantee that the return to capital invested in certain regions goes back to the regions where savings originated. These tensions increase the pressure on financial markets. Political risks can also be important in this respect.

Given these large demographic changes it is important to quantify the potential impacts of different projections. As the size of the effects will depend on the nature of government policies, it is important to quantify different scenarios. Other major forces that can affect the size of impacts are productivity (of both capital and labor), longevity and fertility rates.

In this paper, we consider a stylized model of the world to quantify the possible effects of demographic trends. We will also consider capital flows across regions of the world. We will exclude from our analysis migration and labor mobility. Given these simplifications and our other assumptions, our results need to be taken with some caution. However, the simulations we present constitute a useful benchmark for quantifying the importance of the demographic and macroeconomic trends we observe.

Based on heterogeneous demographic trends, we consider five regions of the world:

1. High Income: United States, Europe, Japan, Canada, Australia, New Zealand.

2. Latin America and the Caribbean (LAC).

3. Medium Income: India, Russia, South Africa, South Korea, Taiwan, Thailand, Turkey.

4. Low Income: Africa, rest of Asia and Oceania.

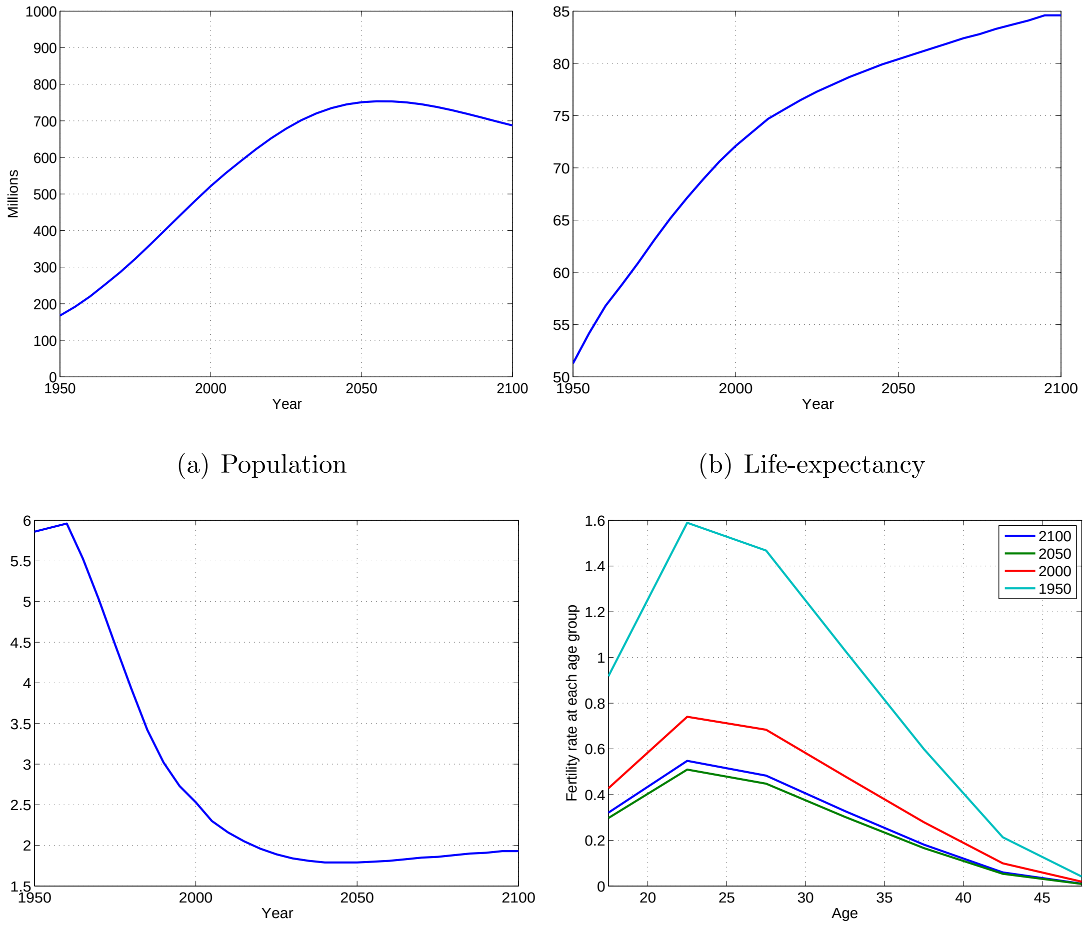
5. China.

In AKW, we had considered the medium income region of Latin America as a unified region. We think the present exercise is useful not only because of the policy focus on Latin America but also because, as we will see, LAC is different from other regions in many regards, as we discuss below. Although the focus of the paper will obviously be Latin America and the Caribbean, it should be clear that the results we present can only be properly understood if we consider them within the global context.

The rest of the paper is organized as follows. We first present some of the demographic trends we mentioned. We then sketch our five-region model. We calibrate the parameters of the model using a number of different data sources. We then present the simulations of the model and discuss them.

2 Demographic Trends

In this section, we present figures that show more details of the main demographic trends in LAC, which constitutes the focus of the analysis. We focus on four statistics: population size, life expectancy, total fertility rate and fertility rates by age. The sources are either actual data or projections from the United Nations (U.N.)



(a) Population

(b) Life-expectancy

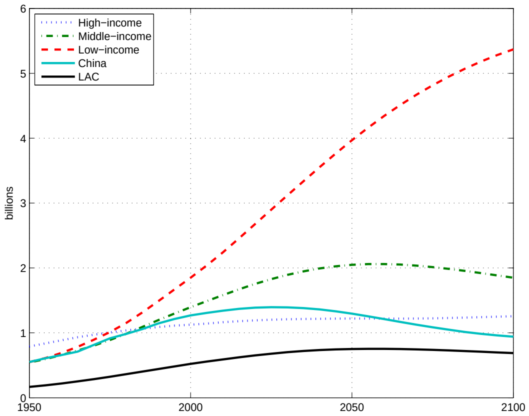
(c) Total fertility rate

(d) Fertility by age

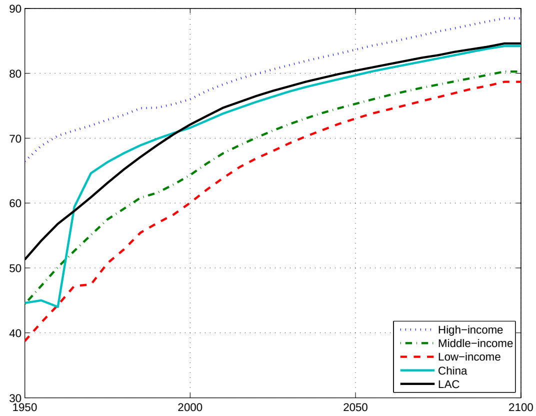
Figure 1: Demographic transition in LAC

World Population Prospects: The 2012 Revision. In Figure 1 we report the figures for LAC, while in Figure 2 we consider all other regions.

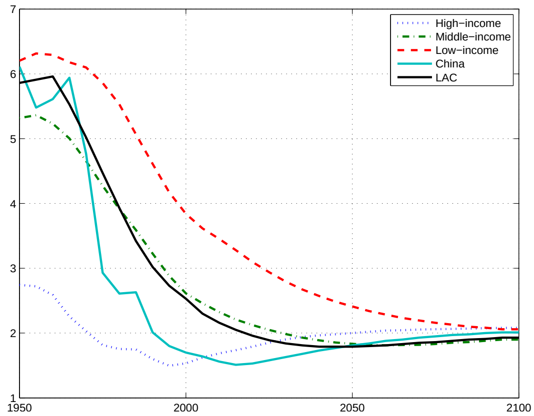
As shown in Figure 1(b), improvement in medical technology and health quality contributed to an increase in longevity and a rapid improvement in life expectancy, which increased from about 52 in 1950 to 72 in 2000. According to U.N. projections, life expectancy will continue to rise and reach almost 85 by the end of the century. At the same time, total fertility rates have declined rapidly from about 6 children per woman in 1950 to 2.5 in 2000. The U.N. projects fertility will fall below the replacement rate and stay below 2.0 for several decades beginning in the mid 2020s. A rise in longevity will have a positive effect on total population, as shown



(a) Population



(b) Life-expectancy



(c) Total fertility rate

Figure 2: Demographic transition of the world

in Figure 1(a), but low fertility rates will eventually dominate in the net effect and the population will start to decline after 2050.

As shown in Figure 2, other regions of the world share similar trends in life expectancy and fertility rates. The timing, however, of the demographic transition varies across regions. The High Income region already had a high life expectancy of 68 in 1950, and it has increased moderately since then. The Low and Middle Income regions and China started at a much lower life expectancy than High and Middle Income regions, but the difference has shrunk over the last several decades. The gap will continue to shrink, but the difference will persist even at the end of the century. All regions have experienced a decline in fertility rates since 1950, with the most dramatic drop observed in China due to its unique one-child policy. Fertility rates in the Low Income region are close to 4 in 2000 and are expected to remain above 2 throughout the century. As a result of unsynchronized demographic trends, the population distribution of the world is projected to change dramatically, as shown in Figure 2(a). When LAC's population starts to decline in the 2050s, the Low Income region will continue to grow, and its population will exceed 5 billion by 2100. China will start to see a decline in population earlier than LAC, and its population will fall below 1 billion by the end of the century.

3 The Model

The model we present in this section extends the one developed by AKW. The model is a general equilibrium, overlapping generations model of five interdependent economies. We exogenously limit migration flows and compare the situation where there are no capital flows (closed economy) and where there are capital flows (open economy).

Most of the assumptions we make are relatively standard or discussed in AKW. However, we do make some slightly different modelling choices that need to be discussed and motivated, which we do at the end of this section. The two issues we discuss are discount factor heterogeneity and assumptions about technical progress convergence.

3.1 Economic Environment

Preliminaries: The world economy is composed of five regions: i) High Income region H, ii) Middle Income region M, iii) Low Income region L, iv) China C and v) Latin America and the Caribbean LAC. The five regions differ in demographic structure, total factor productivity level, individual endowment profiles, subjective discount factor, and fiscal institutions. In what follows these differences are spelled out in more detail. There is no aggregate or region-specific uncertainty, but since we will model a deterministic transition across two steady states, equilibrium factor prices will be time-varying in a deterministic way. The only source of individual risk is related to the uncertain life span, which is region specific. We let t denote time, i individual's age, and r the five regions, with $r \in \{H, M, L, C, LAC\}$.

Technology: In each region r, a constant returns to scale, aggregate production function $F(Z_t^r, K_t^r, H_t^r)$ produces output of a final good Y_t^r which can be used interchangeably for consumption C_t^r and investment X_t^r. Among the arguments of the production function, Z_t^r denotes the total factor productivity level in region r at time t, H_t^r is the stock of human capital (i.e., the aggregate efficiency units of labor), and K_t^r is the aggregate stock of physical capital used in production in region r. Physical capital depreciates geometrically at rate δ each period. The level of technology in region r grows exogenously at rate λ_t^r between t and $t+1$, but in the long run all regions reach the same productivity level and grow at the same constant rate λ.

Demographics: Each region is populated by overlapping generations of ex ante identical "pairs of individuals" who may live for a maximum of $\overline{I}$ periods and their age is indexed by $i = 1, 2, ..., \bar{I}$. Pairs of individuals are dependent children for the first I^d periods of their life and then they become adults and form households. For a pair of individuals born in region r, denote by $s_{i,t}^r$ the probability of surviving until age i at time t, conditional on being alive at time $t-1$ (with age $i-1$). Hence, in region r, the unconditional probability of surviving i periods up to time t is simply

$$S_{i,t}^r = \prod_{j=1}^{i} s_{j,t+(j-i)}^r,$$

where $S_{1,t}^r = s_{1,t}^r \equiv 1$ for all t by definition. In each period t, pairs of age i in region r have an exogenously given fertility rate (i.e., a probability of giving birth to another pair of individuals) equal to $\phi_{i,t}^r$. During childhood, i.e., until age I^d, fertility is assumed to be zero. For what follows, it is useful to define $d_{i,t}^r$ as the total number of (pairs of) dependent children living in a(n) (adult) household of age i at time t, i.e.,

$$d_{i,t}^r = \begin{cases} 0 & \text{for } i \leq I^d \\ \sum_{k=i-I^d+1}^{i} \phi_{k,t-(i-k)}^r S_{i-k+1,t}^r & \text{for } i > I^d. \end{cases}$$

We denote by $\mu_{i,t}^r$ the size of the population of age i at time t in region r and by $\boldsymbol{\mu}_t^r$ the $\left(\overline{I} \times 1\right)$ vector of age groups. Thus, in each region the law of motion of the population between time t and $t+1$ is given by $\boldsymbol{\mu}_{t+1}^r = \Gamma_t^r \boldsymbol{\mu}_t^r$ where Γ_t^r is a time-varying $\left(\overline{I} \times \overline{I}\right)$ matrix composed of fertility rates and surviving probabilities for households of region r described by

$$\Gamma_t^r = \begin{bmatrix} \phi_{1,t}^r & \phi_{2,t}^r & \cdots & \cdots & \phi_{\bar{I},t}^r \\ s_{2,t+1}^r & 0 & \cdots & \cdots & 0 \\ 0 & s_{3,t+1}^r & 0 & \cdots & 0 \\ 0 & 0 & \ddots & \ddots & 0 \\ 0 & 0 & \cdots & s_{\bar{I},t+1}^r & 0 \end{bmatrix}.$$

The first row of this demographic transition matrix contains all the age-specific fertility rates, the elements $(i+1, i)$ contain the conditional surviving rates, whereas all the other elements are zeros. Lee (1974) shows that the largest eigenvalue of Γ_t^r is the growth rate of the population between time t and $t+1$, which we denote as γ_t^r (see also Ríos-Rull, 2001).

Since we are interested in the economically active population, we reshape the matrix Γ_t^r and the vector $\boldsymbol{\mu}_t^r$ down to size $I = \overline{I} - I^d$ and we normalize the first period of adulthood (and economically active) life to be period 1 of life for households. We also restrict the parameters of the two matrices Γ_t^r to converge across regions as t becomes large in order to generate a common long-run growth rate of the population γ.[1]

Household Preferences: Households of age i at time t in region r are composed of a pair of adults and a number $d_{i,t}^r$ of pairs of dependent children living with their parents. The adults in the household jointly make consumption allocation decisions for themselves and their dependent children so as to maximize expected lifetime utility. The only uncertainty faced by the consumer is that about longevity. The utility function over the life cycle is assumed to be intertemporally separable, and the future is discounted geometrically by a factor β^r. Note that the discount factor, unlike other parameters of the utility function, is region specific, an assumption that we discuss below.

The within-period felicity function is given by:

$$u^r(c_{i,t}^a, c_{i,t}^d) = \frac{\left(c_{i,t}^a\right)^{1-\theta}}{1-\theta} + d_{i,t}^r \omega\left(d_{i,t}^r\right) \frac{\left(c_{i,t}^d\right)^{1-\theta}}{1-\theta}, \tag{1}$$

where $c_{i,t}^a$ denotes consumption for the adults, $c_{i,t}^d$ consumption per dependent child,

[1] This restriction, similar to the one we impose for productivity growth, is necessary to achieve a long-run growth path where neither region is negligible in terms of output and population compared to the rest of the world.

and $\omega\left(d^r_{i,t}\right)$ is a positive function that weighs consumption of children in households' utility. The intertemporal elasticity of substitution for consumption is $1/\theta$.

This preference specification is convenient, because it permits expressing utility only as a function of the total consumption of the household $c_{i,t} = c^a_{i,t} + d^r_{i,t} c^d_{i,t}$. From the optimality condition of the household with respect to $c^d_{i,t}$ one obtains

$$c^d_{i,t} = c^a_{i,t} \omega\left(d^r_{i,t}\right)^{\frac{1}{\theta}}, \tag{2}$$

which optimally sets the consumption of children to a fraction of the consumption of parents proportional to their weight in the utility function. Using (2) into (1), together with the definition of the total consumption of the household $c_{i,t}$, one obtains

$$u^r(c_{i,t}) = \Omega^r_{i,t} \frac{c_{i,t}^{1-\theta}}{1-\theta}, \tag{3}$$

where $\Omega^r_{i,t} = \left[1 + \omega\left(d^r_{i,t}\right)^{\frac{1}{\theta}} d^r_{i,t}\right]^{\theta}$ and acts like an age- and time-dependent preference shifter. Finally, as mentioned above, the discount factor β^r, which weights future utility, is region specific. There is no explicit altruistic motive.

To summarize, the intertemporal preference ordering for households born (adult of age $i = 1$) at time t is given by

$$U^r = \sum_{i=1}^{I} (\beta^r)^{i-1} S^r_{i,t+i-1} \Omega^r_{i,t+i-1} \frac{c_{i,t+i-1}^{1-\theta}}{1-\theta}. \tag{4}$$

Household Endowments: Households derive no utility from leisure. They have a fixed time endowment, normalized to one unit, that they can devote either to productive activities in the labor market or to child care at home. We denote by $\mathbf{d}^r_{i,t}$ the $(I^d \times 1)$ vector of pairs of children's by age groups for a household of age i at time t. Labor supply for households of region r at age i at time t is given by

$$l^r_{i,t} = \begin{cases} \Lambda^r_t\left(\mathbf{d}^r_{i,t}\right) & \text{if } i < I^R \\ 0 & \text{otherwise,} \end{cases} \tag{5}$$

$\Lambda^r_t\left(\mathbf{d}^r_{i,t}\right)$ is an exogenous fraction of time that each household of age i in region r devotes to market work at time t. The function $\Lambda^r_t\left(\mathbf{d}^r_{i,t}\right)$ is decreasing in the number of dependent children and captures the time trend and a rise in labor force participation of women. At age I^R, households are subject to compulsory retirement from any working activity. Households of age i at time t in region r are endowed with $\varepsilon^r_{i,t}$ efficiency units of labor for each unit of time worked in the market. Finally, we assume that the initial asset holdings of each household is zero, i.e., $a_{1,t} = 0$ for any t in all regions.

Household Budget Constraint: Let $a^r_{i,t}$ be the net asset holding of individual i at time t in region r. We assume that there are annuity markets to cover the event of early death. Every household has the right to keep the share of assets of the deceased in the same cohort, thus we can write the budget constraint as:

$$\left(1 + \tau^r_{c,t}\right) c^r_{i,t} + s^r_{i+1,t+1} a^r_{i+1,t+1} = y^r_{i,t} + \left[1 + \left(1 - \tau^r_{a,t}\right) r_t\right] a^r_{i,t}. \tag{6}$$

We require households to die with non-negative wealth once they reach age I, but otherwise we impose no borrowing constraint during their life. Net income $y^r_{i,t}$ accruing to households of age i in region r at time t is defined as

$$y^r_{i,t} = \begin{cases} \left(1 - \tau^r_{w,t}\right) w^r_t \varepsilon^r_{i,t} l^r_{i,t} = \left(1 - \tau^r_{w,t}\right) \tilde{y}^r_{i,t} & \text{if } i < I^R, \\ \\ p^r_{i,t} & \text{if } i \geq I^R, \end{cases} \tag{7}$$

where w^r_t is the wage rate, $\varepsilon^r_{i,t}$ is the efficiency units of labor of an individual of age i, and $p^r_{i,t}$ is pension income. $\tilde{y}^r_{i,t}$ is the before-tax labor income. Households pay taxes $\tau^r_{c,t}$ on consumption, $\tau^r_{a,t}$ on capital income, and $\tau^r_{w,t}$ on labor income. Residents of region r pay capital income taxes in region r, independently of where capital was invested. Social security benefits are given by the formula

$$p^r_{i,t} = \kappa^r_t \frac{W^r_{i,t}}{I^R - 1},$$

where κ^r_t is the replacement ratio of average past earnings. Cumulative past gross earnings $W^r_{i,t}$ are defined recursively as

$$W^r_{i,t} = \begin{cases} \tilde{y}^r_{1,t} & \text{if } i = 1 \\ \\ \tilde{y}^r_{i,t} + W^r_{i-1,t-1} & \text{if } 1 < i < I^R \\ \\ W^r_{i-1,t-1} & \text{if } i \geq I^R. \end{cases} \tag{8}$$

Government Budget Constraint: In each region r, public expenditures and the social security program are administered by the government under a unique consolidated intertemporal budget constraint. The government can raise revenues through its fiscal instruments $\left(\tau_{c,t}^{r}, \tau_{a,t}^{r}, \tau_{w,t}^{r}\right)$ and can issue one-period risk-free debt B_t^r. Government borrowing and tax revenues finance a stream of expenditures G_t^r and the PAYG social security program described above. The consolidated government budget constraint reads as

$$\begin{aligned} & G_t^r + (1 + r_t) B_t^r + \sum_{i=I^R}^{I} p_{i,t}^r \mu_{i,t}^r = \\ & \tau_{w,t}^r w_t^r \sum_{i=1}^{I^R - 1} \mu_{i,t}^r \varepsilon_{i,t}^r \Lambda_{i,t}^r + \sum_{i=1}^{I} \mu_{i,t}^r \left(\tau_{a,t}^r r_t a_{i,t}^r + \tau_{c,t}^r c_{i,t}^r \right) + B_{t+1}^r . \end{aligned} \tag{9}$$

Commodities, Assets and Markets: There are three goods in the world economy: i) a final good which can be used either for consumption or investment, ii) the services of labor and iii) the services of capital. The price of the final good (homogeneous across the five regions) is used as the world numeraire. Labor is immobile, thus wages are determined independently in regional labor markets. Physical capital is perfectly mobile across the five regions, so there is one world market for capital. We denote as N_t^r the external wealth of region r, i.e., the stock of capital productive in other regions which is owned by households of region r, with the convention that a negative value denotes ownership of capital used for production in region r held by households of the rest of the world. The sum of positive and negative external wealth across regions is zero by definition, that is, $\sum_{r=1}^{5} N_t^r = 0$ at any time t. Finally, in every region there is a financial market for government debt. The markets where these goods and assets are traded are perfectly competitive. An intuitive no-arbitrage condition between assets and the absence of aggregate uncertainty implies that the return on all regional bonds is equal to the return on physical capital, as we have already implicitly assumed when we wrote the budget constraints of the government and households.

3.2 Equilibrium

Before stating the definition of equilibrium, it is useful to point out that, without further restrictions, the equilibrium path of the fiscal variables $\left\{G_t^r, \kappa_t^r, \tau_{w,t}^r, \tau_{a,t}^r, \tau_{c,t}^r, B_t^r\right\}_{t=1}^{\infty}$ is indeterminate, as there is only one budget constraint we can operate on. In what follows, we define an equilibrium for the case where the paths of all fiscal variables are given, except for $\left\{\tau_{w,t}^r\right\}_{t=1}^{\infty}$. This case corresponds to our baseline experiment.

It is straightforward to extend this definition to the case where the path of a different set of government policies is given exogenously. Finally, for brevity we omit the definition of the closed-economy equilibrium and state directly the equilibrium conditions for the open economy.

A *Competitive Equilibrium of the Five-Region Economy*, for a given sequence of region-specific demographic variables $\{\Gamma_t^r, \Lambda_t^r\}_{t=1}^{\infty}$, TFP levels $\{Z_t^r\}_{t=1}^{\infty}$, and fiscal variables $\left\{G_t^r, \kappa_t^r, \tau_{a,t}^r, \tau_{c,t}^r, B_t^r\right\}_{t=1}^{\infty}$, is a sequence of:
(i) households' choices $\left\{\left\{c_{i,t}^r, a_{i,t}^r\right\}_{i=1}^{I}\right\}_{t=1}^{\infty}$,
(ii) labor income tax rates $\left\{\tau_{w,t}^r\right\}_{t=1}^{\infty}$,
(iii) wage rates $\{w_t^r\}_{t=1}^{\infty}$,
(iv) aggregate variables $\{K_t^r, H_t^r, X_t^r, C_t^r\}_{t=1}^{\infty}$ in each region r,
(v) world interest rates $\{r_t\}_{t=1}^{\infty}$, and
(vi) external wealth of each region $\{N_t^r\}_{t=1}^{\infty}$ such that:

1. Households choose optimally consumption and wealth sequences $\left\{\left\{c_{i,t}^r, a_{i,t}^r\right\}_{i=1}^{I}\right\}_{t=1}^{\infty}$, maximizing the objective function in (4) subject to the budget constraint (6), the income process (7), and the time allocation constraint (5) .

2. Firms in each region maximize profits by setting the marginal product of each input equal to its price, i.e.,

$$w_t^r = F_H(Z_t^r, K_t^r, H_t^r), \tag{10}$$

$$r_t + \delta = F_K(Z_t^r, K_t^r, H_t^r). \tag{11}$$

3. The regional labor markets clear at wage w_t^r, and aggregate human capital in each region is given by

$$H_t^r = \sum_{i=1}^{I^R-1} \mu_{i,t}^r \varepsilon_{i,t}^r \Lambda_{i,t}^r. \tag{12}$$

4. The regional bond markets and the world capital market clear at the world interest rate r_t, and the aggregate stocks of capital in each region satisfy

$$K_t^r + N_t^r + B_t^r = \sum_{i=2}^{I} \mu_{i-1,t-1}^r a_{i,t}^r. \tag{13}$$

5. The tax rates $\left\{\tau_{w,t}^r\right\}_{t=1}^{\infty}$ satisfy the consolidated budget constraint (9) in each region.

6. The allocations are feasible in each region, i.e., they satisfy the regional aggregate resource constraints

$$K^r_{t+1} - (1-\delta)\, K^r_t + N^r_{t+1} - (1+r_t)\, N^r_t = F(Z^r_t, K^r_t, H^r_t) - C^r_t - G^r_t. \quad (14)$$

Before concluding, it is useful to recall that aggregate gross investments in region r are given by

$$X^r_t = K^r_{t+1} - (1-\delta)\, K^r_t, \quad (15)$$

whereas aggregate (private plus public) savings in region r are,

$$S^r_t = F(Z^r_t, K^r_t, H^r_t) + r_t N^r_t - C^r_t - G^r_t.$$

As a result, the current account surplus of region r (or, the net capital outflow from region r into the rest of the world) is given by

$$S^r_t - X^r_t = CA^r_t = N^r_{t+1} - N^r_t, \quad (16)$$

and it equals the change in the net foreign asset position of region r. Moreover, in this five-region economy, $\sum_{r=1}^{5} CA^r_t = 0$.

3.3 A Discussion of Modelling Choices

As mentioned above, most of the modelling choices we used are reasonably standard in this literature. However, an important issue, which deserves some discussion, is the existence of heterogeneity in taste and technology across the various regions. We tried to discipline our choices by minimizing the use of arbitrary differences in preferences and technology to match the main differences across regions. However, the regions we consider are different, and we need to model these differences in a parsimonious fashion. In our model, the differences across the five regions we consider stem from three different sources: i) demographic trends and size of the labor force; ii) productivity; and iii) discount factors. We discuss these in turn. Notice that, given the nature of our model, we also need to take a stance on the path of these driving variables in the future.

Demographic trends and size of the labor force. We take the population size of the various regions and their demographic composition as an exogenous source of variation. We can directly use U.N. data to specify these differences, although we do not try to model them in terms of fertility choices or relate them to other economic choices, such as labor supply. As for the future, we take U.N. projections of demographic trends and use them throughout our exercises. It should be stressed that the nature of our exercise implies that the relative size of regions (in terms of population and in particular labor efficiency units) matters substantially for the results we obtain. As we do not explicitly model labor supply or labor force participation, we extrapolate, as we discuss below, observed trends. These projections are to some extent arbitrary, and we perform some robustness exercise to establish how our results change with changes in these projections.

Productivity trends. Differences in productivity among different regions are obvious and observable, so that, as we discuss below, we calibrate different levels of productivity in our model to match the differences we observe in the historical data. However, unlike demographic trends, it is not completely obvious how to forecast future trends in productivity and, in particular, differences among different regions. Differences in the relative size of labor efficiency units are key in the open economy exercises we perform to determine both equilibrium factor prices and capital flows. For this reason, we explore different alternative assumptions about the path of future productivity in different regions. While it is probably reasonable to assume that in the very long run there will be convergence, the speed of convergence and the relative paths of different regions will be very important. In our simulations we explore a few different alternatives.

Discount factors. As we mentioned above, while we try to keep differences in preference parameters at a minimum, historically, different regions have exhibited very different patterns of saving behavior, which is difficult to explain within the standard model we use. In particular, two facts stand out: the extremely high saving of China, especially in the last 30 years, and the relatively low saving of Latin America. The observed saving behavior of these regions is also reflected, to some extent, in relatively high and low levels of capital to output ratios. Probably the simplest way to replicate these differences within our model is to assume differences in the discount factor. In what follows, therefore, we assume that Chinese are considerably more patient than Latin Americans. These differences, of course, should not be interpreted literally and could proxy for more complex and maybe more realistic differences. One model, for instance, that has been proposed to explain the relatively high saving rates observed in China over a period of very rapid economic growth is one of habits. One could interpret a high level of patience as a proxy for such effects. If that is the case, however, one would not want to maintain the substantial differences in discount factors as a permanent feature of our model. For this reason, in what follows we explore two alternatives. First, we assume that in the future the difference in patience will stay constant. We then explore the consequences of having discount factors converging (slowly) over time.

A final point on the discount factor should be the observation that effective discount factors (that is the extent to which certain levels of future consumption are converted into utility) are also different across regions because of differences in mortality rates and adult equivalence scales, which in turn are affected by fertility patterns.

4 Calibration

Preliminaries We calibrate parameters of the model using demographic and economic data that are available for periods between 1990 and 2010 in the five regions. We assume that all demographic and productivity parameters in the five regions converge to the same values by 2200, thus all regions converge to the same balanced growth path some time after 2200. We then let our world economy transit between the two steady states by imposing a gradually converging path of mortality, fertility and female participation rates as well as the level of aggregate and individual productivities. The model's period is set to 5 years.[2]

The Five Regions The world in our model consists of five regions that differ in the timing of demographic transitions. *High Income region* includes the United States, Canada, Europe and Japan, plus Australia and New Zealand. *Middle Income region* encompasses countries that recently experienced high economic growth and includes India, Russia, South Africa, South Korea, Taiwan, Thailand and Turkey. *Low Income region* includes countries in Africa (except for South Africa), other Asia

[2]The calibration strategy matches a set of moments in the data with the model's counterparts in the *closed economy* equilibrium. The open economy equilibrium assumes the exact same parametrization and therefore has different levels of aggregate variables, such as output and capital stock.

and Oceania. The fourth region is China. *Latin America and Caribbean (LAC)* includes countries in Central America, South America and the Caribbean.

Technological Parameters We choose a Cobb-Douglas specification

$$F(Z_t^r, K_t^r, H_t^r) = Z_t^r (K_t^r)^\alpha (H_t^r)^{1-\alpha},$$

for the production function with capital share $\alpha = 0.30$ and its constant depreciation rate of 5 percent on an annual basis. The growth rate of TFP, λ_t^r in each region is set so that the region achieves the target average per capita output growth rate, as computed from the World Bank's *World Development Indicators* (WDI) for the period 1990-2010. We assume a constant growth rate until 2010 to match the historical average.

We set the initial value of TFP in High Income region Z_0^H in order to normalize income per capita to 1 in the first steady state. Based on the WDI data, income per capita in High Income region was approximately three times larger than that of LAC region in 2010, and we set the value of Z_0^{LAC}, productivity in the initial steady state, to match this ratio. Similarly, GDP per capita of Middle Income region, Low Income region and China were 0.19, 0.12 and 0.22, respectively, relative to that of High Income region. We set the TFP level of each region accordingly to match the relative size of GDP per capita. We assume that both the TFP level and the growth rate in the five regions converge to common values by 2150. We let the TFP growth rate of High Income region gradually converge to the long-run value of 1.5 percent by 2150. We assume that the TFP level of the other four regions will also converge to the level of High Income region by 2150 and thereafter all regions have the same TFP level and the long-run growth rate of 1.5 percent. Calibrated parameters are summarized in Table 1.

Demographic Parameters Since each model-period corresponds to five years, we set $I^d = 3$ so that agents become adults and economically active at age 17, and we set $I = \bar{I} - I^d = 24 - 3 = 21$, so that households can live a maximum of 24 periods (120 years). We also set the retirement age $I^R = 11$, which corresponds to age 67. All these parameters are common in the five regions.

Age-specific fertility rates are based on the UN data and projections for 1990-2100. For the periods beyond 2100, we assume that fertility rates at each age converge by 2200 to those of High Income region projected for 2100.

Table 1: Growth rate of TFP 1990-2010

Region	GDP per capita growth, WDI 1990-2010, data	TFP growth rate λ_t^r 1990-2010 calibrated	GDP per capita level, WDI 2010, data	Initial TFP level Z_0^r calibrated
1. High Income	1.3%	0.54%	1 (normalization)	1.372
2. Middle Income	3.4%	1.85%	0.19	0.407
3. Low Income	2.1%	1.08%	0.12	0.414
4. China	9.6%	6.62%	0.22	0.155
5. LAC	2.0%	0.49%	0.32	0.718

Age-specific surviving probabilities in the five regions for the period 1950-2100 are computed based on the actual and projected data on population shares by age-group in the UN database. After 2100, we make the surviving rates smoothly converge to those of High Income region by 2200.

Another major demographic trend is the growth in female labor force participation rates. Our main data sources here come from historical labor market data of the International Labour Organization (ILO). In order to estimate the recent trend, we focus on ILO data since the 1970s, when we have more comprehensive coverage of the countries and population in each region. Figure 3 displays the trend in female labor force participation rates in the past five decades. Note that there are two data points available for China. In order to capture the long-run time trend in the female labor supply, separately from the time requirements and impact of dependent children on their labor supply, we estimate the following equation outside of the model for the participation rate of women $P_{i,t}^r \in (0,1)$ with an exponential trend for all regions except for China.

$$P_{i,t}^r(\mathbf{d}_{i,t}^r) = \psi_0^r + (\overline{P} + \overline{T}_i - \psi_0^r)\{1 - \exp[-\psi_1^r * (t-1)]\} + \sum_{j=1}^{I^d} \hat{\alpha}_j d_{i,j,t}^r, \tag{17}$$

where ψ_0^r measures the participation rate for a female worker with no children in 1950.[3] $\overline{P} = 0.68$ is the long-run female participation rate, based on the projection of the Bureau of Labor Statistics (BLS) for the United States in 2020; $\overline{T}_i$ is

[3]Substituting $t = 1$ and $d_{i,j,t}^r$ in equation (17) yields $P_{i,t}^r(\mathbf{d}_{i,t}^r) = \psi_0^r$. Note that the model period starts in 1990 and the formula for the participation rates are adjusted accordingly.

the long-run value of time devoted by a woman of age i to child care (common across regions) computed from the final steady-state value of the number of dependent children at age j, $d_{i,j,\infty}$ and the estimated time to take care of children $\hat{\alpha}_j$, i.e., $\overline{T_i} = -\sum_{j=1}^{I^d} \hat{\alpha}_j d^r_{i,j,\infty.}$; the parameter ψ^r_1 regulates the speed of convergence towards the long-run rate $\overline{P}$. The estimated parameters for High, Middle and Low Income and LAC regions are $(\psi^H_0, \psi^M_0, \psi^L_0, \psi^{LAC}_0) = (0.4191, 0.4276, 0.4248, 0.2349)$ and $(\psi^H_1, \psi^M_1, \psi^L_1, \psi^{LAC}_1) = (0.1686, 0.0527, 0.0810, 0.1294)$, respectively.

For China, female participation rates at available data points in the last few decades are high and remain stable at about 78 percent in the 1980s and 1990s, declining slightly to 76 percent in 2000s. Therefore we estimate the function (17) without a time trend until 2000 and make the female participation rates change only through the time-varying vector $\mathbf{d}^r_{i,t}$ that indicates the number of dependent children until 2000. Thereafter, we assume that the participation rates of women without children will linearly converge to the level so that the average participation rate will reach the same long-run value of $\overline{P} = 0.68$ in the final steady state.[4]

Once female participation rates $P^r_{i,t}(\mathbf{d}^r_{i,t})$ are computed for each region, we can derive $\Lambda^r_{i,t}(\mathbf{d}^r_{i,t})$, the fraction of the time endowment (normalized to one) worked by the wife, i.e., $\Lambda^r_{i,t}(\mathbf{d}^r_{i,t}) = 0.5[1 + P^r_{i,t}(\mathbf{d}^r_{i,t})]$, where the husband is assumed to work full time.

As in Attanasio, Kitao and Violante (2006), the data from the *Consumer Expenditure Survey* (CEX) are used to estimate the marginal effects α_j of the presence of a pair of dependent children at age j (0-4, 5-9 and 10-14 years old) on women's probability of participation. The Probit regression, which controls for several individual characteristics including age, race and education, yields $\alpha_{0-4} = -0.146$, $\alpha_{5-9} = -0.0960$, $\alpha_{10-14} = -0.0464$. The coefficients are negative and significant, and younger children have a stronger impact on the probability of female participation. Figure 4 displays the estimated participation rates of females from 1950 to 2200 in each region as well as the contribution of the fertility trend, relative to the

[4] Although we do not have the decomposition of the participation rates by occupations or regions, it is possible that high female workers' involvement in the farming sector contributed to high female labor force participation in earlier data, which may shift in future as a result of urbanization and a change in Chinese industrial structure. Therefore, we assumed that the labor force participation rate will decline and converge to that of other regions in the long run, rather than assuming it to remain high at around 80 percent.

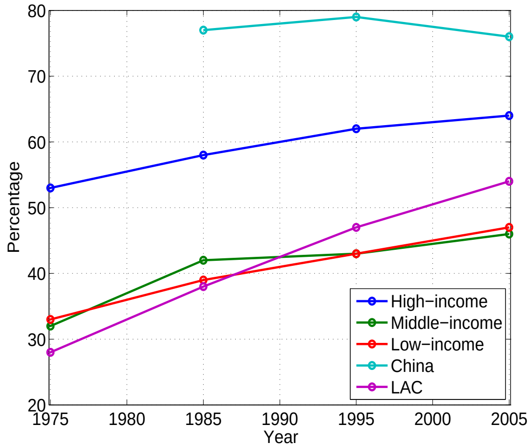


Figure 3: Female labor force participation rate in five regions: ILO data

value in 1950, which is set at zero.

We normalize the total population in High Income region in 1990 to one and set the initial population size for the other four regions to 1.2024, 1.4425, 1.0967 and 0.4267, respectively, based on U.N. population data for 1990. During the transition away from the initial steady-state, the population size in the five regions is determined by the evolution of age-specific fertility rates $\phi^r_{i,t}$ and survival rates $s^r_{i,t}$.

Preferences and Endowments Parameters Following the bulk of the literature on consumption (for a survey, see Attanasio, 1999), we set $\theta = 2$. The weight parameter of children in the utility of adult parents is set to match the commonly used consumption adult-equivalent scales. The micro-evidence on equivalence scales summarized in Fernández-Villaverde and Krueger (2007, Table 1) points at a ratio between the consumption of a household with 1, 2 and 3 children compared to a household without children of 1.231, 1.470, and 1.694, respectively. Using equation (2), it is easy to see that our function $\omega\left(d^r_{i,t}\right)$ should satisfy the three moment conditions

$$\begin{aligned} \omega\,(0.5)^{\frac{1}{\theta}} &= (1.231-1)\,/0.5, \\ \omega\,(1)^{\frac{1}{\theta}} &= (1.470-1)\,, \\ \omega\,(1.5)^{\frac{1}{\theta}} &= (1.694-1)\,/1.5. \end{aligned}$$

Note that we need to make an adjustment for the fact that in our model children come in pairs. Given $\theta = 2$, setting $\omega = 0.216$ independently of the number of

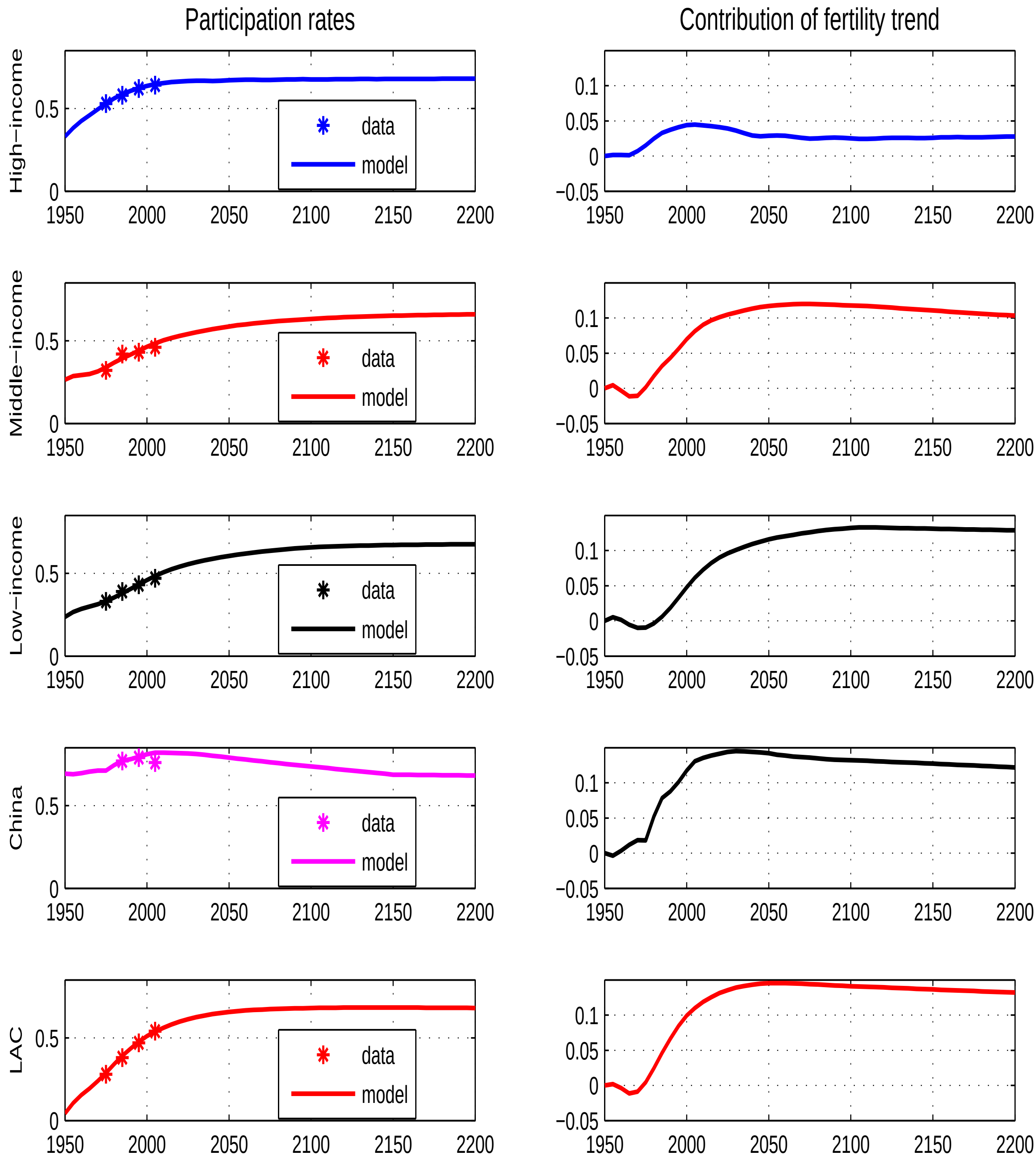


Figure 4: Estimated female labor force participation rate in five regions

children yields an excellent fit.

We set β^r to match the target capital-output ratio in each region in 2010. The annual discount factors are $\{1.0260, 1.0292, 1.0315, 1.1059, 1.0123\}$ for each of the five regions (High Income, Middle Income, Low Income, China and LAC), which are set to match the target capital-output ratio of $\{3.7, 2.8, 3.1, 3.3, 3.3\}$, respectively.[5]

We chose to use a region-specific discount factor since the model is better able to approximate heterogeneity in saving intensity across regions by assuming heterogeneous degrees of impatience across regions. Region-specific discount rates implicitly capture various factors that lead to different saving behaviors such as the stage of development in the financial market or policies that encourage or discourage saving, which are not explicitly modeled in our framework. We assume that the subjective discount factor in each region remains constant over time in the baseline simulations, but we conduct sensitivity analysis in Section 5.2, where we assume they will converge to a common value in the long run.

The calibration of the age profile of efficiency units is undertaken separately for each region. The age-efficiency profile for LAC region is estimated using Mexican micro data, *Encuesta Nacional de Ingreso y Gasto de los Hogares* (ENIGH), which is the equivalent of the U.S. CEX, using the 1989, 1992, 1994, 1996, 1998, and 2000 waves.[6] The sample, across both surveys, is the universe of married couples headed by males and aged 17-69, and the derived "household wage" is an average of male and female wage weighted by hours worked. For High Income region, we use weekly wage data from the U.S. CEX for the period 1982-1999. For Middle Income region, we assume the same profile as LAC region. For Low Income region, we use the age-efficiency profile in Bangladesh, estimated by Kapsos (2008), who uses a national occupational wage survey conducted by the Bangladesh Bureau of Statistics (BBS) in 2007 with the support of the ILO. We use the estimated coefficients of the hourly wage regression, which controls for age and education levels. Finally, for China we use *Chinese Household Income Project* (CHIP), a survey of Chinese households in urban and rural areas. We use individual data from the urban income,

[5] The capital-output ratio is based on data from the Penn World Table in 2010. For China, we use the average for 2000-2010, as the capital-output ratio has grown from less than 2.8 to 4.1 from 2000 to 2010 and it is difficult to find an equilibrium of the model if we assume that an extremely high discount factor that would match the ratio of 4.1 lasts indefinitely.

[6] See Attanasio and Székely (1999) for a detailed description of the Mexican survey data.

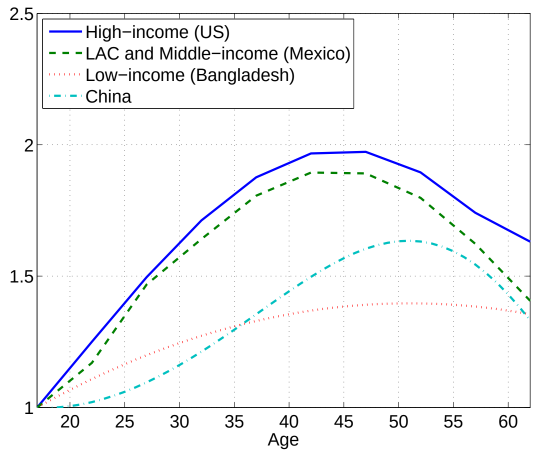


Figure 5: Wages over the life-cycle

consumption and employment questionnaire and estimate the wage profile using a sample of household heads aged 20-65 in the 1995 and 2002 waves of the survey. The regression includes the age and education of an individual, and we take the weighted average of spouses' wages to derive a household wage.

Figure 5 shows estimated profiles for the five regions, where the wage at age 17 is normalized to 1 in each region. High Income region has the steepest slope, followed by Middle Income region, China and Low Income region. The peak of the wage is at around 45-50 years old in High and Middle Income regions, while the profile is much flatter and a mild peak arrives at age above 50 in the other two regions. We assume that the age-wage profiles will remain as in Figure 5 until 2010, when they start to gradually converge to the profile of High Income region by 2200.

Government Policy Parameters We obtain the ratio of the government debt B_t^r as a fraction of GDP from the IMF's *World Economic Outlook Database* (WEO). We use the net debt variable that represents gross debt net of financial assets. In the LAC region, the average over the period 1990-2010 was 34 percent of GDP. The net debt level was 48 percent, 39 percent and 51 percent in High, Middle and Low Income regions, respectively. For China, data are available only for gross debt, which is 13.8 percent of GDP. Since we do not have data for the government's financial assets, we assume net debt of 10 percent of GDP in the baseline calibration.

The total government expenditures as a fraction of GDP are also obtained from the WEO, available since the 1980s. The average over 1980-2000 was 24 percent in LAC region and 39 percent, 24 percent, 22 percent and 20 percent of GDP in High, Middle and Low Income regions and China, respectively. Since these figures represent general public expenditures, which include spending for social security and interest payments, we compute the ratio of the government expenditures G_t^r to GDP so that the total expenditures match the ratios from the WEO database as reported above. The ratio of G_t^r to GDP was 26.4 percent for LAC and 30.0 percent, 24.5 percent, 23.7 percent and 18.3 percent for High, Middle and Low Income regions and China, respectively.

Based on OECD (2013), the replacement rate of pensions to the average earnings is set at $\kappa_t^r = 58.0\%$ in High Income region. Unfortunately, similar systematic studies on the replacement rates for other regions are not available. The average replacement rate is likely to be much lower than in High Income region due to two factors. First, the disproportionate role of self-employment and informal production means that a vast part of the working population is not covered by a public pension system. Second, the involvement of governments in the pension sphere is limited: in Asia, only Korea and Taiwan operate a defined benefits PAYG scheme with universal coverage, while Latin America is the region with the largest number of pension systems already reformed towards substantial privatization (see Mohan, 2004, for the Asian experience; see Corbo, 2004, for the Latin American experience). We set the replacement rate κ_t^r in the other four regions at 10 percent, which is also the value used in Attanasio, Kitao and Violante (2006 and 2007) for the area that encompasses the countries in the four regions.

For tax rates of each region, we use various data sources for the period 2000-2010 and estimate effective tax rates following the method of Mendoza, et al. (1994). We use the OECD *Revenue Statistics* database for tax revenues, in particular for High Income and Latin American countries, integrated with consistent data from IMF *Government Finance Statistics* for Low and other Middle Income countries. Detailed national accounts data on households, enterprises and government are taken from the OECD *National Accounts Statistics* and the UN *National Accounts Statistics* databases. The consumption tax rate τ_c^r is set at 9.7 percent, 15.6 percent, 6.3 percent and 16.4 percent for High Income, Middle Income and Low Income region and LAC, respectively. The capital income tax rate τ_a^r is 35.7 percent, 18.4, 13.5 percent and 11.5 percent for High Income, Middle Income and Low Income region and LAC, respectively. For China, we use the estimates of Cui, Wang and Guan (2011) and set the consumption tax at 7.7 percent and the capital income tax at 25.7 percent.

In the benchmark experiment, the labor income tax $\tau^r_{w,t}$ in each region adjusts along the equilibrium path of the model to balance the government budget.

5 Numerical Results

In this section, we present results for a number of simulations where we compare transition dynamics under two scenarios: open and closed economies. We study the evolution of key economic variables in the five regions of the world we have described above: High Income, Middle Income, Low Income, China and LAC. The economic variables we look at include capital, output, saving, saving rates, interest rates, wage rates, equilibrium tax rates, current account and external wealth. We will first carefully examine features of the baseline scenario and then conduct several additional exercises to understand the driving force of saving dynamics over the transition periods and sensitivity of our results to alternative assumptions of the model.

5.1 Baseline Scenario

Figure 6 shows the paths of the interest rate in the five regions when the economy is closed without capital mobility, together with the path of the world interest rate when there is full capital mobility. We focus on and display results for the time period of 2010-2100. In the closed economy scenario, LAC, Low Income and Middle Income regions start with higher interest rates than in High Income region and China. In the former three regions, capital is more scarce relative to labor than in the latter two and therefore interest rates are higher. The interest rate will start to decline after 2010 in all five regions because of the demographic trends we saw in Section 1. An increase in longevity increases savings to cover consumption expenditures for a longer retirement period. Lower fertility rates and fewer dependent children in a household imply a larger fraction of disposable income allocated to savings. As the demographic transition stabilizes and fertility rates increase, interest

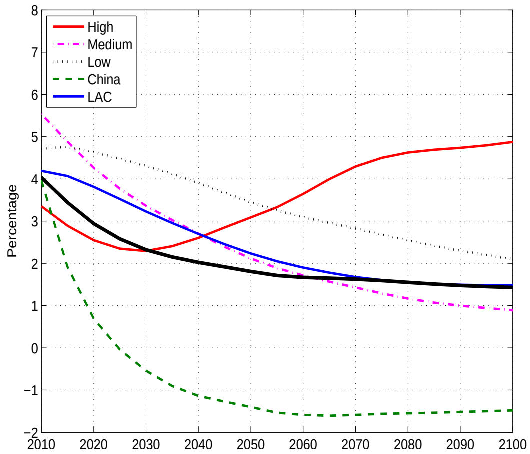


Figure 6: Baseline scenario: interest rates of the world. The thick solid line (black) represents open economy.

rate starts to rise in the mid-2020s in High Income region, but the decline continues until much later in other regions of the world.

Figure 7 extracts from Figure 6 the closed and open economy interest rate in LAC. Our model projects interest rates to decline throughout the century in LAC and fall from above 4 percent in 2010 to almost 1.5 percent in the closed economy. The trend is driven by a decline in fertility rates, which will continue until the middle of the century, and a rise in life expectancy. In our model, the open economy interest rate declines as well, but the path always lies below that of the closed economy, implying that capital will flow into LAC from other regions of the world in the open economy and capital becomes more abundant relative to labor.

Figure 8 shows the path of the equilibrium wage rate in LAC generated by our model in closed and open economies. The inflow of capital into LAC makes labor more scarce and capital more abundant and therefore wage rates are higher in the open economy, exactly the opposite of the path of the interest rate.

Figure 9 presents our simulation results for the equilibrium tax rates in LAC in closed and open economies. Tax rates are derived in equilibrium so that the consolidated government budget constraint is satisfied in each period. Tax rates rise gradually in both closed and open economies as the old age dependency ratio rises and expenditures for social security payment increase. The change, however, is not very large, rising from about 26 percent to 30 percent in the closed economy

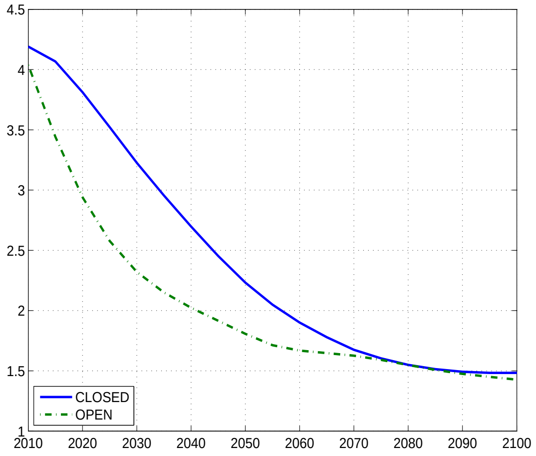


Figure 7: Baseline scenario: interest rates in LAC

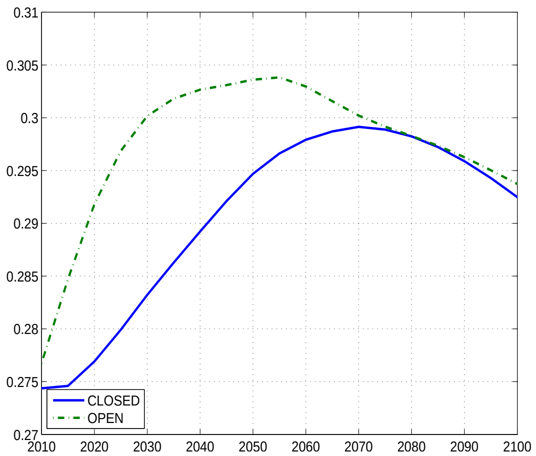


Figure 8: Baseline scenario: wage rates in LAC

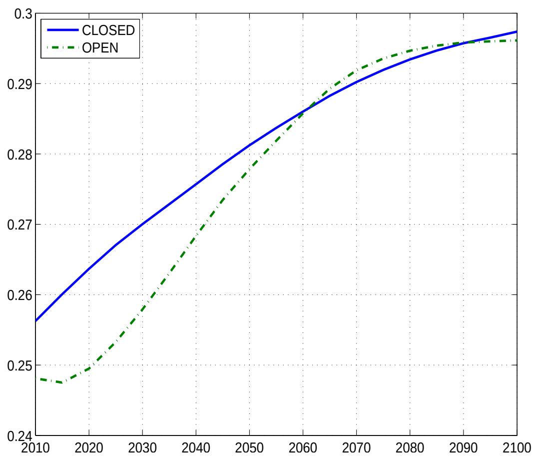


Figure 9: Baseline scenario: labor income tax rates in LAC

and from 25 percent to 30 percent in the open economy, since we assume that the replacement rate is and will remain relatively low at 10 percent. In Section 5.2, we will conduct an experiment in which the social security replacement rate is higher and assess the effect on equilibrium labor income taxes.

Tax rates in the open economy are lower than in the closed economy until about 2060, although the difference is not very significant, at less than 2 percent at most. In LAC, the main tax revenues come from labor taxes. Although the interest rate is lower and the capital tax revenue is smaller in the open economy, the wage is higher, as we saw in Figure 8, which makes the budget-balancing labor tax rate lower in the open economy.

Since, in our model, there will be more capital in the open economy due to capital inflow from other regions, capital used in production is higher in the open economy, as shown in Figure 10. Figure 11 shows the paths of output per capita, which shows the similar difference between closed and open economies as in the path of capital.

Figure 12 displays how the current account evolves in LAC under the open economy scenario. The current account is defined as the difference between aggregate domestic savings and aggregate gross investments in the region. A surplus indicates a net capital outflow from the region and an increase in the external wealth held by the region. Our model simulations predict that LAC will run a deficit during the initial two decades of the transition before attaining a surplus in the late 2020s. The current account will remain positive for several decades until the region starts

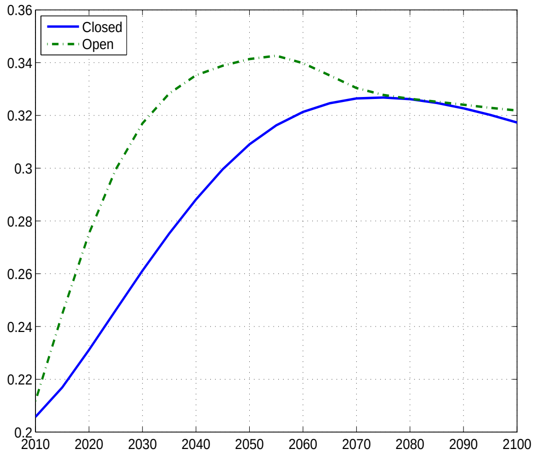


Figure 10: Baseline scenario: capital per capita in LAC

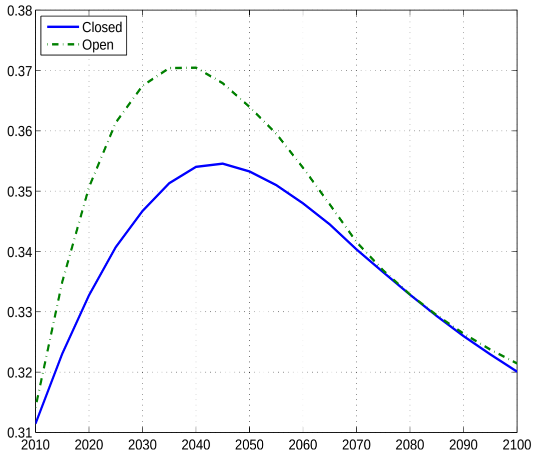


Figure 11: Baseline scenario: output per capita in LAC

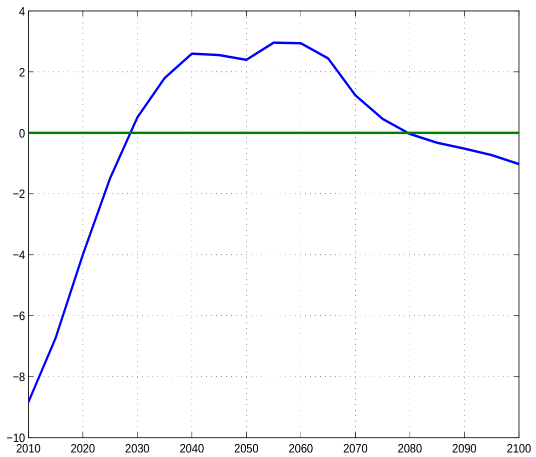


Figure 12: Baseline scenario: current account as percentage of GDP in LAC

to run a deficit in around 2080. The underlying stocks of external wealth are shown in Figure 13, where external wealth is shown as a percentage of GDP in LAC.

Figure 14 shows the paths of the saving per capita and saving rates. Saving is defined as $Y_t - C_t - G_t$ in the closed economy and $Y_t - C_t - G_t + r_t N_t$ in the open economy. Saving rates are computed as the ratio of saving to total income, that is, Y_t and $Y_t + r_t N_t$ in the closed and open economies, respectively.

As the fraction of old-age individuals, who are consumers rather than savers, rises, saving rates in our model tend to decline. The effect is offset by an increase in savings associated with a decline in fertility rates and stronger saving motives for retirement with longer life expectancy. Fertility rates decline in the first half of the century but stabilize and increase slowly thereafter. The model predicts a rise in saving rates in the next few decades, which is followed by a moderate decline in the closed economy. In the open economy, saving rates rise more rapidly since there will be more capital used in production in the region because capital inflow and output are higher than in the closed economy.

Figures 15 to 18 show the path of four variables in closed and open economies in the other four regions. Both High Income region and China will have capital outflow initially and, as shown in Figure 15, the wage rate is lower in the closed economy as labor becomes more abundant relative to capital in the open economy. The open economy wage rate will be higher after the 2030s in High Income region as capital starts to flow into the region. China continues to be a capital exporter,

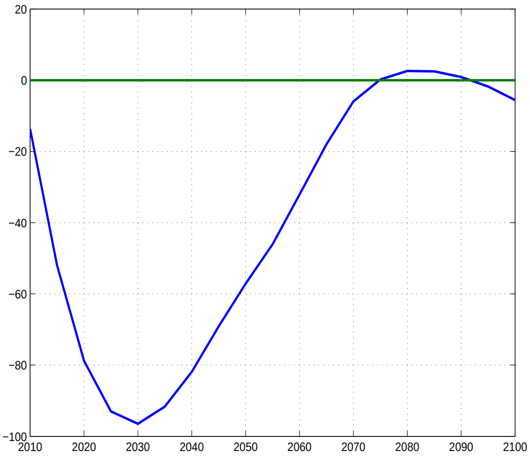
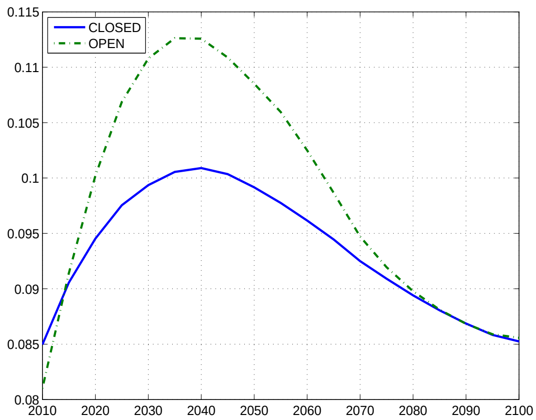
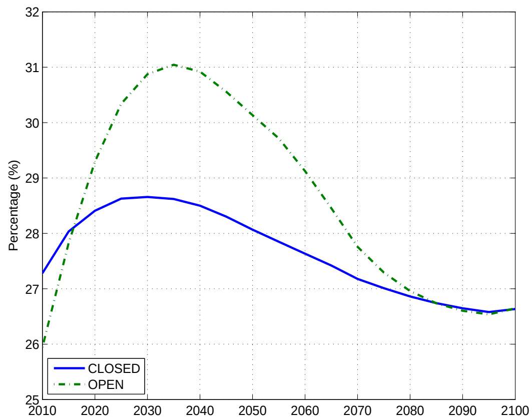


Figure 13: Baseline scenario: external wealth as percentage of GDP in LAC



(a) Saving per capita



(b) Saving rate

Figure 14: Baseline scenario: saving in LAC.

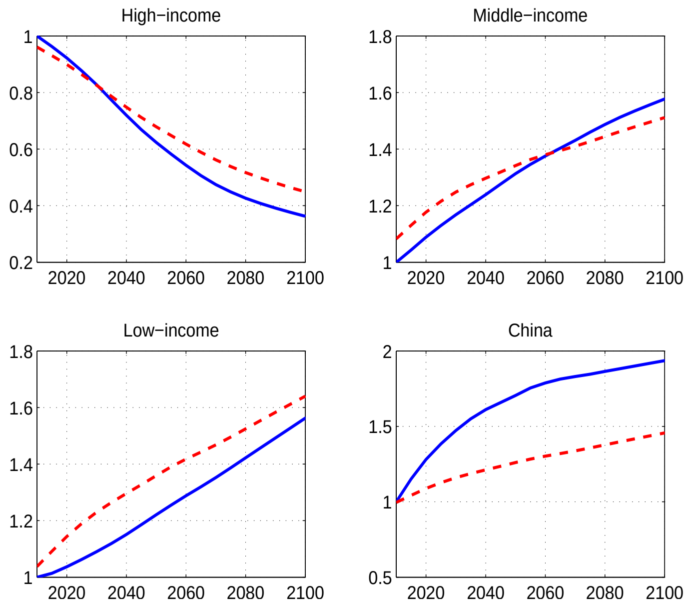


Figure 15: Baseline scenario: wage rates in other four regions. Solid lines represent closed economy and dashed lines represent open economy.

and the wage rate will remain below the level in the closed economy throughout the century. Labor income tax rates will rise rapidly in High Income region, as it becomes increasingly more costly to finance its generous social security system, as shown in Figure 16. The tax will be lower in the open economy as the wages are higher than in the closed economy.

Figure 17 shows the path of capital per capita in the four regions. The economy will initially possess more capital in Middle Income and Low Income regions, thanks to investment from abroad. Middle Income region will switch to a capital exporter in about 2060 and start to earn capital income from investment in other regions of the world. Figure 18 shows the dynamics of the current account and changes in the external wealth of the four regions.

5.2 Experiments

In this section we will simulate our model under alternative assumptions about calibrated parameters and the path of demographic variables in order to understand better the determinants of key economic variables.

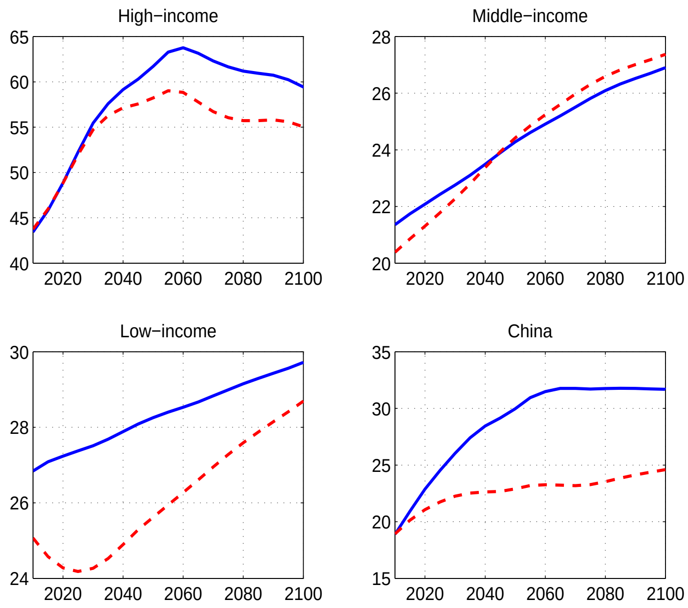


Figure 16: Baseline scenario: labor income tax rates in other four regions. Solid lines represent closed economy and dashed lines represent open economy.

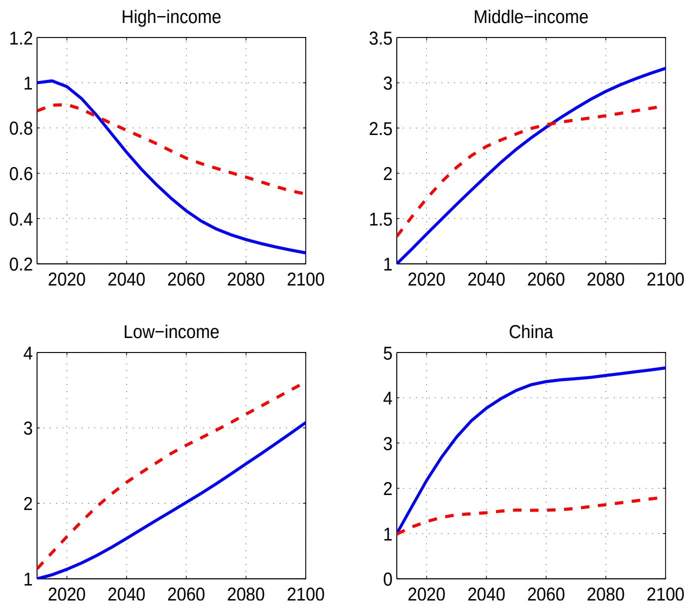


Figure 17: Baseline scenario: capital per capita in other four regions. Solid lines represent closed economy and dashed lines represent open economy.

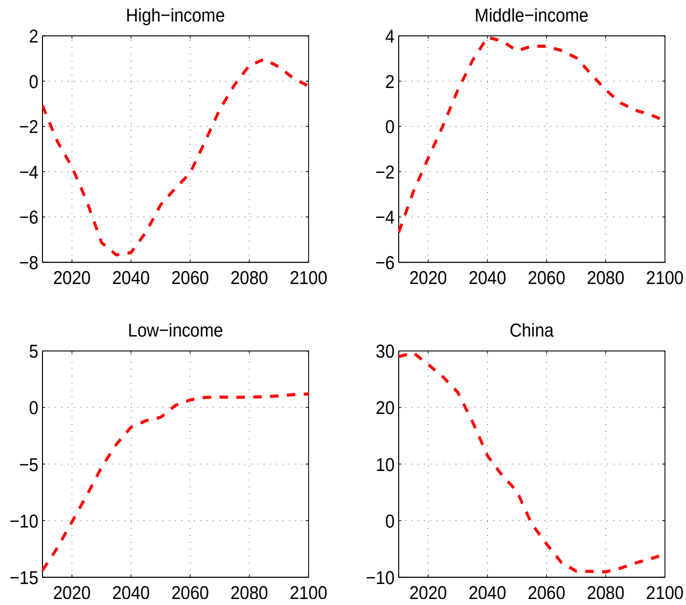


Figure 18: Baseline scenario: current account in other four regions. Solid lines represent closed economy and dashed lines represent open economy.

5.2.1 Convergence of the Discount Factor β_t^r

In the baseline model, we calibrated the subjective discount factor β_t^r in each region so that the model matches the capital output ratio as in the data and assumed that the discount factor will stay constant over time. In this section, we simulate the model assuming that the discount factor will converge to a common value, the calibrated discount factor of High Income region. We let the convergence take place gradually so that they will all reach the common value by 2150.

Given the calibrated discount factors of $\{1.0260, 1.0292, 1.0315, 1.1059, 1.0123\}$ in the five regions (High, Middle, Low Income, China and LAC), convergence implies a slight decline in the discount factor for Middle and Low Income regions, a major decrease for China and a moderate increase for LAC. As shown in Figure 19, the interest rate in the closed economy will be higher in LAC than in the baseline scenario of a constant discount factor, since households are more patient and try to increase saving to consume more in the future, on which they place a higher preference weight. The interest rate will be lower in China when we assume that the discount factors converge, as households will become less patient over time and

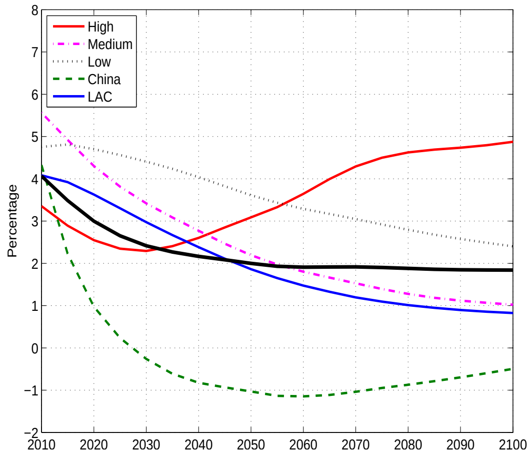


Figure 19: Convergence in discount factor: interest rates of the world. The thick solid line (black) represents open economy.

saving will decline.

Figure 20 shows that the interest rate in the closed economy in LAC is much lower than in the open economy in the region, which is due to stronger saving incentives and a greater amount of capital, as shown in Figure 21. Households in LAC will invest more in other regions of the world in the open economy and, as shown in Figure 22, LAC will start to run a current account surplus in 2025, several years earlier than in the benchmark, and the balance remains positive until the early 2090s, much later than the 2070s indicated in the benchmark.

Figure 23 shows that saving is much higher in the closed economy when the discount factor converges to a higher level, about 10 percent above the peak level in the benchmark. The saving rate is also 2 to 4 percentage points higher throughout the transition.

5.2.2 Effects of Demographic Transition

In order to understand the role played by changes in demographic parameters, we compute transition dynamics under two alternative assumptions about demographic variables. In the first, we assume that survival rates are fixed at the level of 2010 in all five regions of the world throughout the transition. In the second, we fix fertility rates at the initial steady-state level. The exercise will help quantify the roles of

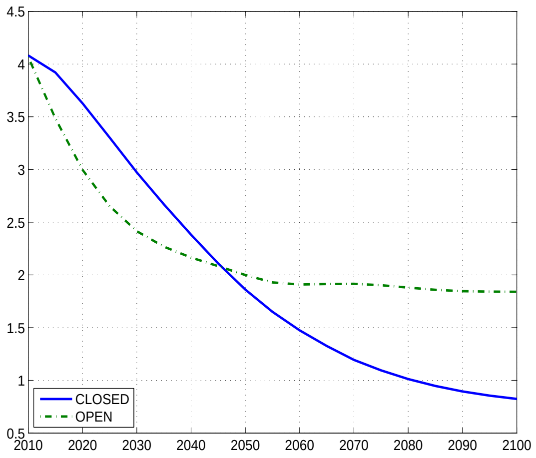


Figure 20: Convergence in discount factor: interest rates in LAC

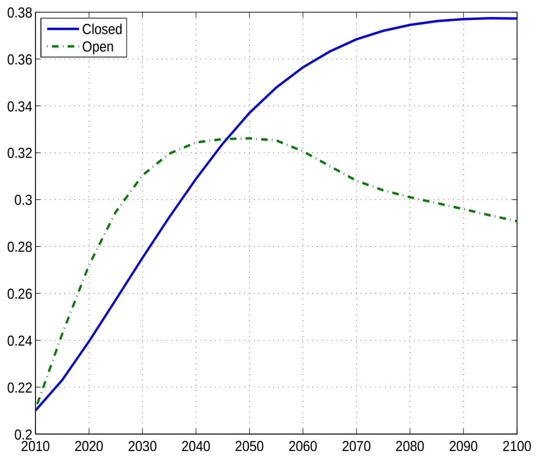


Figure 21: Convergence in discount factor: capital per capita in LAC

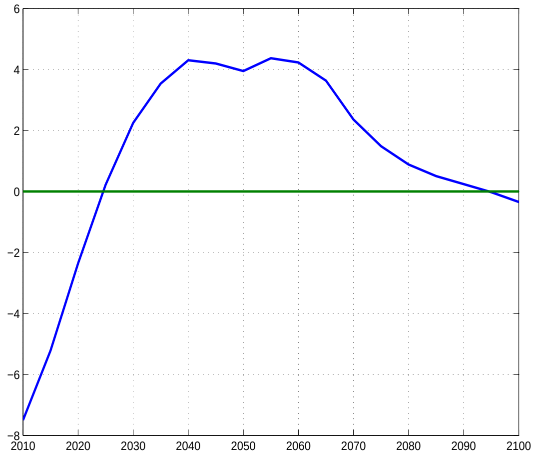
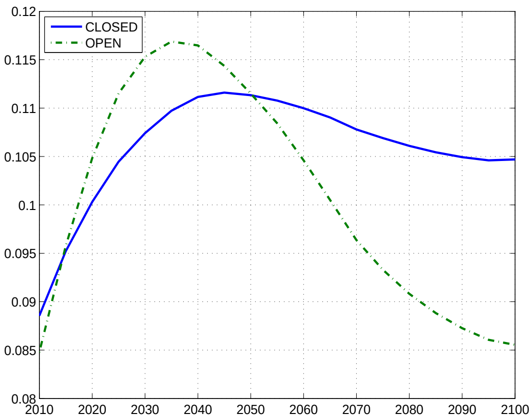
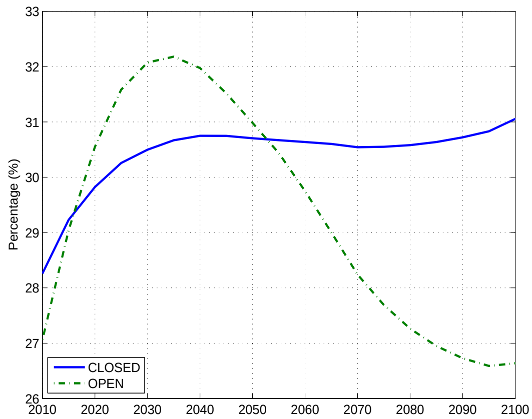


Figure 22: Convergence in discount factor: current account as percentage of GDP in LAC



(a) Saving per capita



(b) Saving rate

Figure 23: Convergence in discount factor: saving in LAC.

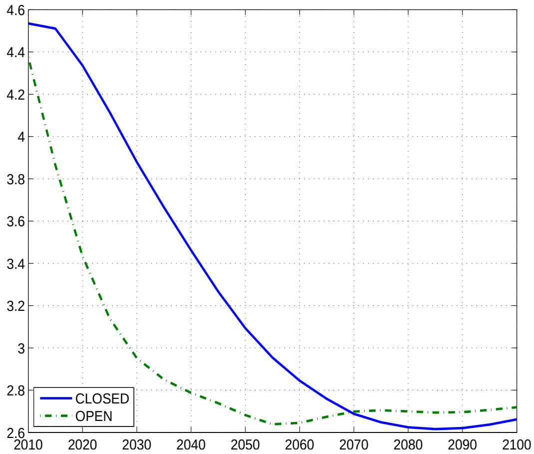


Figure 24: Constant survival rates: interest rates in LAC

each factor and decompose the changes in key macroeconomic variables including saving rates.

Roles of Rising Survival Rates Figures 24 and 25 show the paths of the interest rate and capital per capita in LAC, respectively, when we fix the survival rates unchanged throughout the transition. Saving will be much lower without the increase in longevity, and it is about 10 percent lower at the peak of the closed economy compared to the benchmark economy. The interest rate does not decline as sharply as in the benchmark, and the lowest interest rate is about 2.6 percent, reached in the 2080s, rather than the 1.5 percent rate in the benchmark.

As a result of fewer incentives to save for retirement because of shorter life expectancy than in the benchmark, the saving rates are lower, at about 26 percent at the peak and declining sharply thereafter to fall below 22 percent by the end of the century in the closed economy, while the saving rate in the benchmark economy stays in the range of 26 to 29 percent throughout the transition.

A Case of Low "Subjective" Survival Rates What if households in LAC underestimate survival rates and make life-cycle decisions accordingly? We simulate a model assuming that households underestimate their life expectancy and continue to hold the belief even if they see a distribution of mortality risks that deviates from their belief. More precisely, we assume that households think survival rates are lower

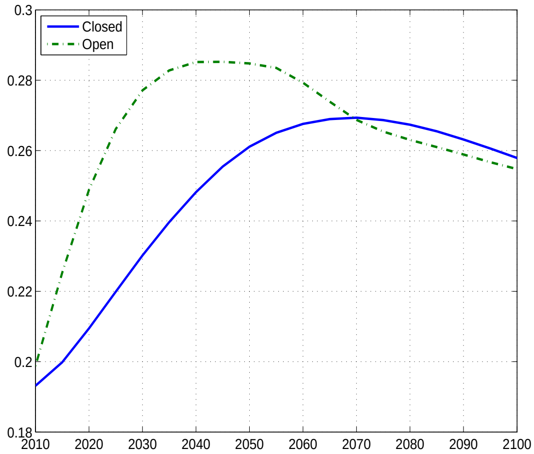
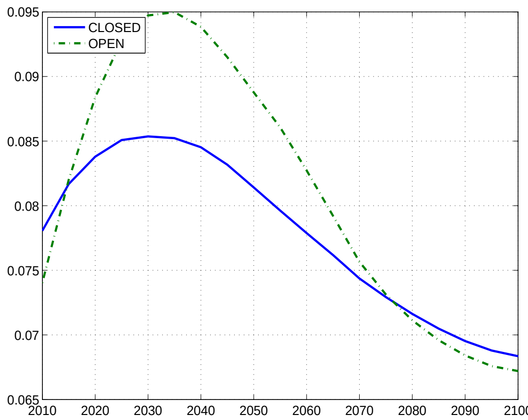
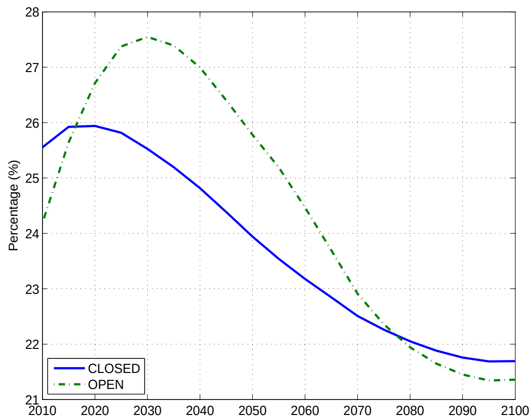


Figure 25: Constant survival rates: capital per capita in LAC



(a) Saving per capita



(b) Saving rate

Figure 26: Constant survival rates: saving in LAC.

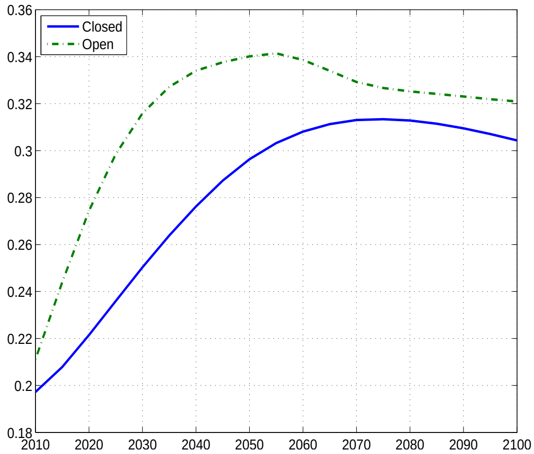


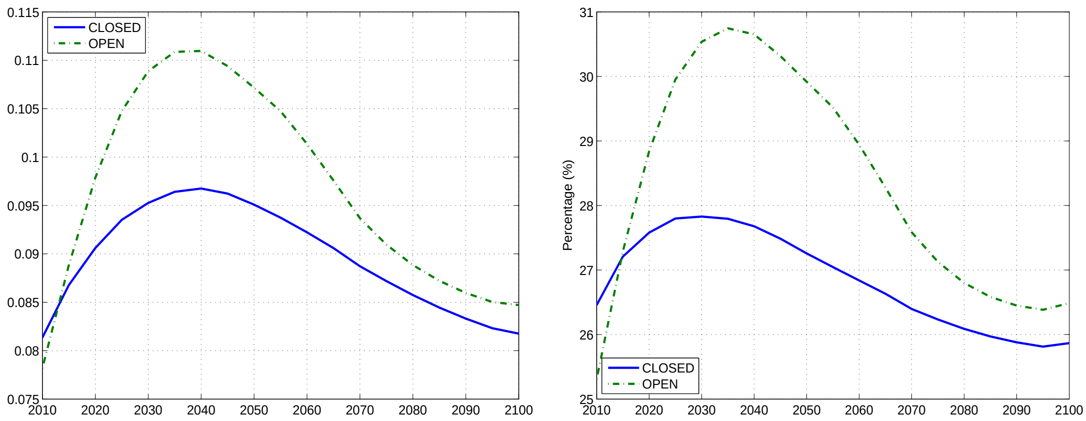
Figure 27: Underestimated survival rates: capital per capita in LAC

by 1 percent than actual rates at each age, which implies that life expectancy at the end of the century will be about 7 years shorter than in the benchmark.

Such underestimation will have qualitatively similar effects as the scenario of constant survival rates we studied above. Figure 27 shows the path of capital per capita, which is lower than in the benchmark. We are assuming that only households in LAC underestimate longevity in this experiment and that capital in the open economy is not very different from that in the benchmark. As shown in Figure 28, saving is also lower than in the benchmark closed economy, as households mistakenly think that their life expectancy is low and face fewer incentives to save for retirement.

Role of Changing Fertility Rates As we saw in Figure 1, the total fertility rate is projected to decline further from about 2.2 in 2010 to less than 1.8 in 2040 in LAC, when it starts to rise gradually towards the end of the century, though it only recovers to about 1.9, much lower than the initial level in 2010. In this section, we simulate our model assuming that fertility rates will remain constant and fixed at the high level of 2010 throughout the transition, in order to assess the roles of the fertility rate dynamics.

As shown in Figure 29, in the closed economy capital will be lower throughout the century with a constant and high fertility rate. Households need to allocate more of their disposable income for consumption to support a larger number of children in a family.



(a) Saving per capita

(b) Saving rate

Figure 28: Underestimated survival rates: saving in LAC.

In China and High Income regions, where fertility rates are projected to rise, the experiment will hold fertility rates at a lower level than the projected level. In these regions, capital will be higher and the interest rates are even lower than in the benchmark economy. As a result, there will be a greater divergence of interest rates between the closed and open economies, and a large capital inflow from the regions of low interest rate to LAC is observed. Capital and saving in the open economy will be much higher than in the benchmark economy, as shown in Figure 29, an opposite result from what we observe in the closed economy.

5.2.3 Pension Replacement Rate

In this section we compute an equilibrium transition path assuming that LAC has a more generous public social security system. We set the pension replacement rate of LAC at 30 percent, instead of 10 percent in the benchmark economy. This experiment also approximates the scenario in which the government can better measure and tax earnings of individuals for the purpose of providing public pension benefits.

With a rise in pension benefits, equilibrium tax rates will be higher, as shown in Figure 31. Tax keeps rising throughout the century and reaches about 37 percent of GDP in 2100, compared to less than 30 percent in the benchmark economy.

As shown in Figure 32, capital per capita is much lower than in the benchmark closed economy. In 2060, for example, capital per capita is 17 percent lower when the

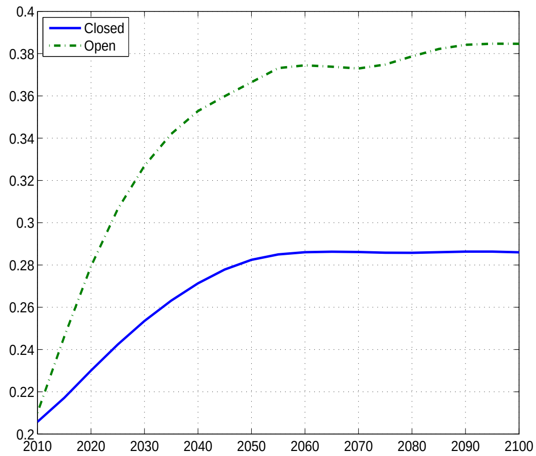
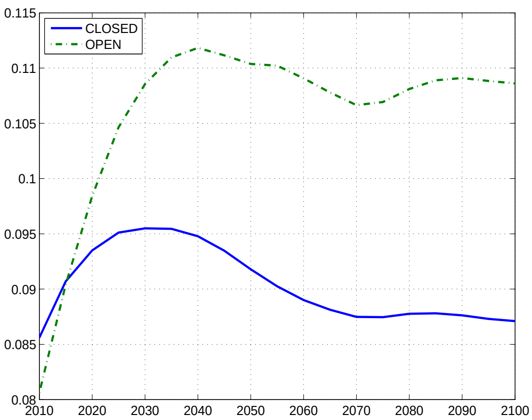
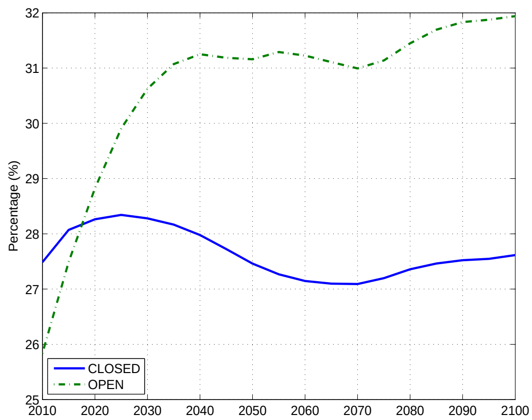


Figure 29: Fixed fertility rates: capital per capita in LAC



(a) Saving per capita



(b) Saving rate

Figure 30: Fixed fertility rates: saving in LAC.

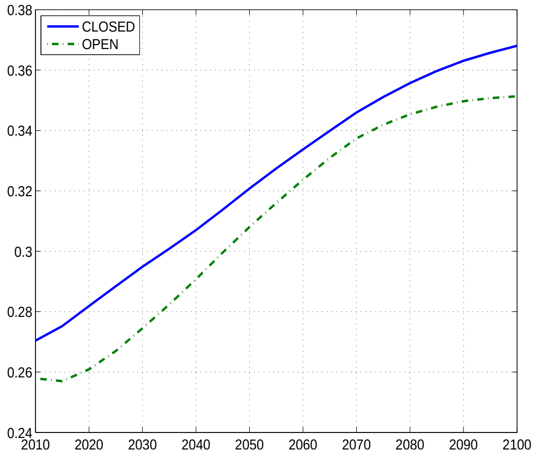


Figure 31: More generous social security: labor income tax rate in LAC

pension replacement rate is higher at 30 percent. As households expect to receive more generous retirement benefits from the government, they have fewer incentives to save for their own for retirement. As a result, aggregate capital declines, and so does the output of the economy. Figure 33 shows the effects on saving. The saving rate in the closed economy is much lower than in the benchmark, falling below 22 percent of GDP by 2100, while it was above 26 percent in the benchmark.

5.2.4 Alternative Fiscal Adjustment

In the baseline simulations, we adjusted labor income tax in each period of the transition so that the government budget is satisfied. In this section we consider alternative scenarios of financing the demographic transition.

In the first, we use consumption tax instead of labor income tax to achieve fiscal balance. Figure 34 shows the path of equilibrium consumption tax rates in closed and open economies in LAC. The consumption tax rate would have to rise from about 17 percent in 2010 to 24 percent in 2100, with an increase of 8 percentage points in the closed economy. An increase of similar magnitude is needed in the open economy as well. Compared to the transition financed by labor income tax, capital is slightly higher during the transition, but the difference is small. Rising consumption taxes will make the tax-inclusive cost of consumption higher in the future and induce households to consume more upfront and save less for future, but

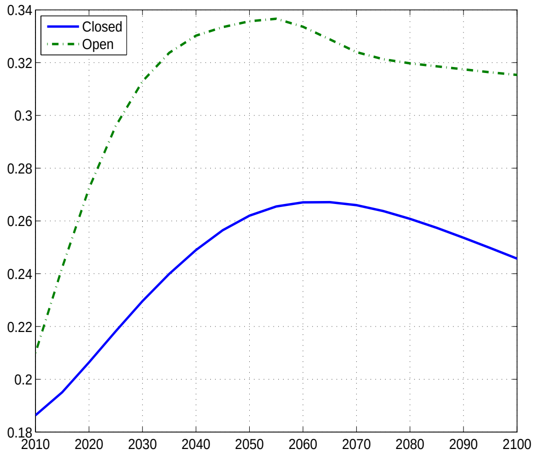
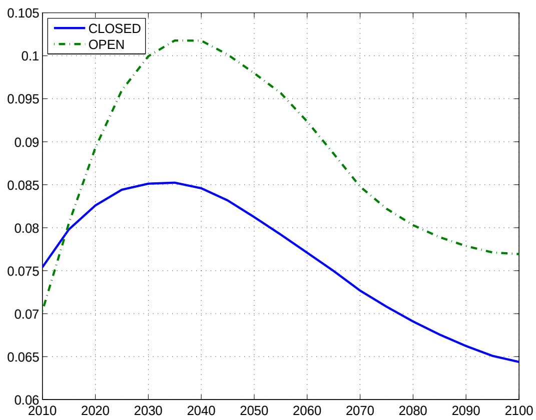
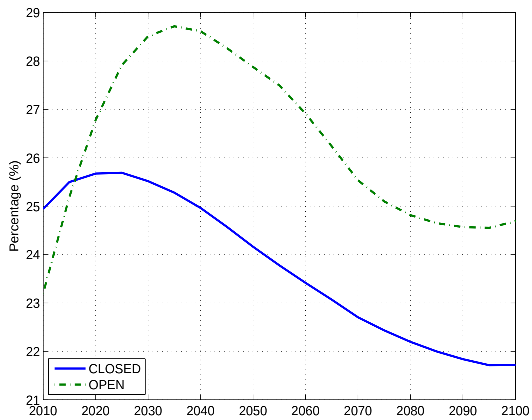


Figure 32: More generous social security: capital per capita in LAC



(a) Saving per capita



(b) Saving rate

Figure 33: More generous social security: saving in LAC.

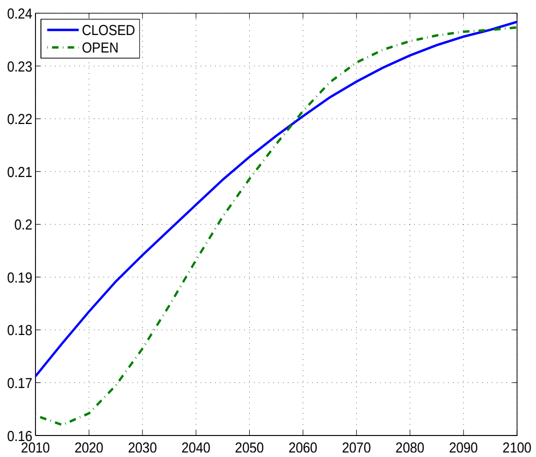


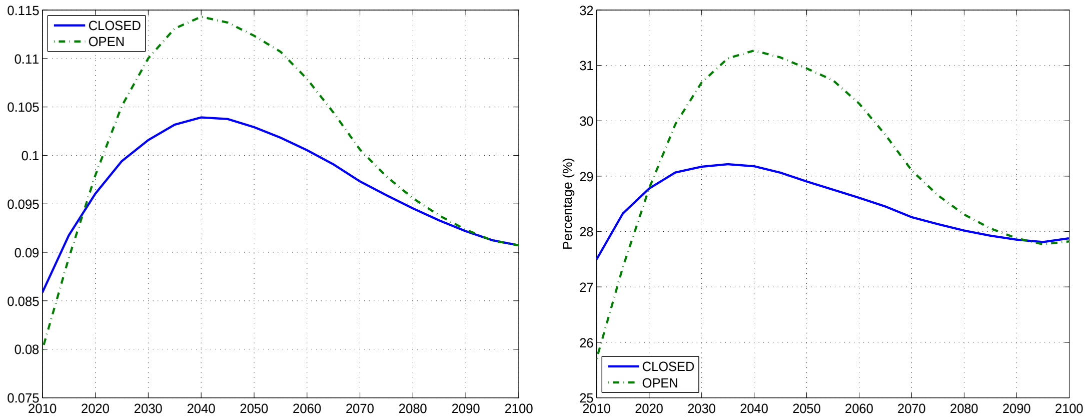
Figure 34: Transition financed by consumption tax: consumption tax rate in LAC

at the same time, they face incentives to save more to smooth consumption over time periods, which offsets the initial negative effects on savings. As shown in Figure 35, the savings are slightly higher than in the baseline case, but the difference is small.

Note that in our model labor supply is exogenously set over the life cycle, and there may be more actions in response to a change in labor income taxes if a model endogenizes labor supply.

Next, we consider an increase in the debt to GDP ratio during the transition. Given a rapid rise in expenditures with aging demographics, we find that debt alone cannot cover the rising imbalance in the government budget. Therefore, we exogenously set the path of the debt to GDP ratio and use labor income tax to absorb the residual expenditures of the government, in the same way as in the benchmark simulations. We assume that the debt will triple and rise gradually from 34 percent of GDP in 2010 to 102 percent of GDP by 2150.

As shown in Figure 36, the labor income tax rate is lower than in the benchmark, as a larger amount of newly issued debt will absorb part of rising public expenditures. At the same time, however, the cost of servicing the debt will increase, and the difference in the labor income tax turns out to be very small, about 1 percentage point at the end of the century. As debt will absorb more of households' savings in the closed economy, capital used in production is lower than in the benchmark economy, as shown in Figure 37.



(a) Saving per capita

(b) Saving rate

Figure 35: Transition financed by consumption tax: saving in LAC.

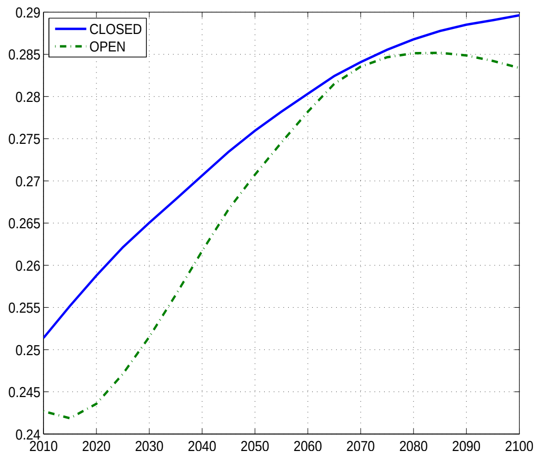


Figure 36: Higher debt during the transition: labor income tax rate in LAC

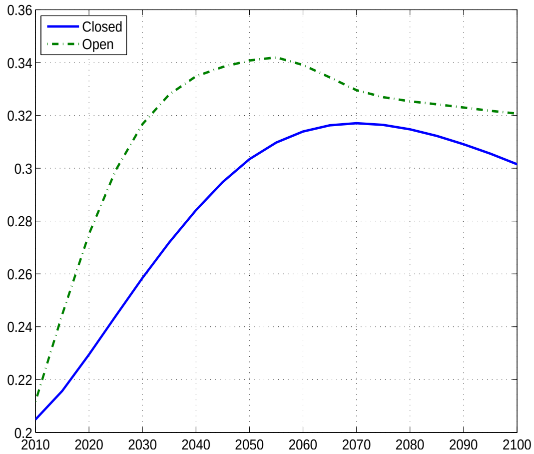


Figure 37: Higher debt during the transition: capital per capita in LAC

5.3 Discussion

The main purpose of this paper was to explore the effects of dramatic demographic trends on saving and other economic variables, including interest rates and wages, in a general equilibrium model of Latin America and other regions of the world. Obviously our exercise abstracts from a large number of important issues, such as endogenous labour supply, migration and so on. However, our results are illuminating about the important role that the demographic transition could play in the coming decades. Some of the effects we stress might be counterbalanced by other forces. However, it is clear that the dramatic demographic transition should imply a strong tendency towards higher saving rates in the coming decades in Latin America. In the open economy case, this implies a progressive improvement in the current account that, starting from a large deficit at the beginning of the period, becomes a surplus in 2030. This is true even in the baseline scenario when discount factors are kept at a low level for Latin America. If we assume convergence in discount factors, so that Latin American and Caribbean households become progressively more patient, this trend is faster and more marked as saving and saving rates increase faster in LAC countries.

Obviously these results should be taken with a grain of salt and could be changed by a variety of other factors. However, it is clear that demographic trends, particularly the increase in longevity, should push saving rates up.

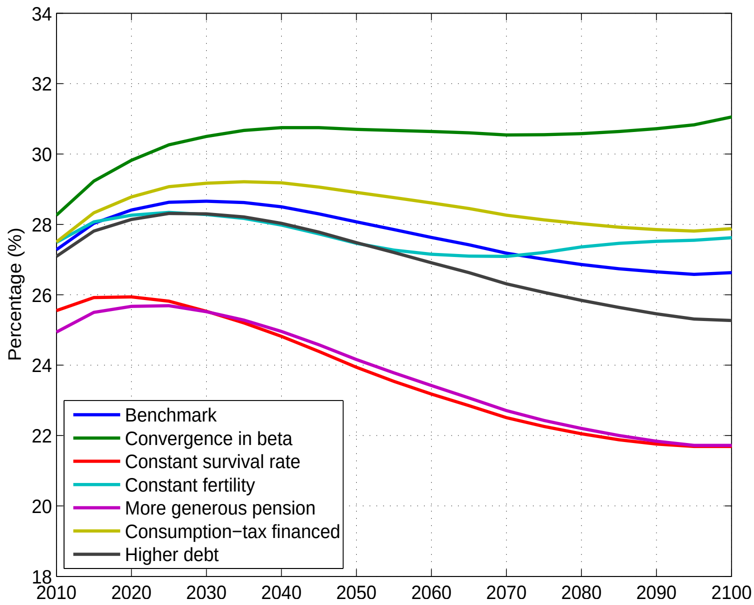


Figure 38: Saving rates in closed economy

An interesting exercise we performed is that of increasing the generosity of the social security system. As set forth in our model, this change could proxy for an increase in the coverage of PAYG schemes or the complementing of funded schemes with basic social pensions. In recent years, many countries in the region, such as Chile, Mexico and Peru, have been experimenting with increases in the unfunded component of their pension system. Changes of this type will limit the increase in saving observed in the baseline experiment.

Figures 38 and 39 summarize the paths of the saving rates in the benchmark model and under various alternative assumptions about the demographics, preference and fiscal policies that we examined in the paper, in the closed economy and the open economy, respectively.

6 Conclusion

In this paper we build a large-scale, full-blown overlapping generation model of households with five different regions of the world. We calibrated the model to match key macro and microeconomic features of each region, as well as the projections of

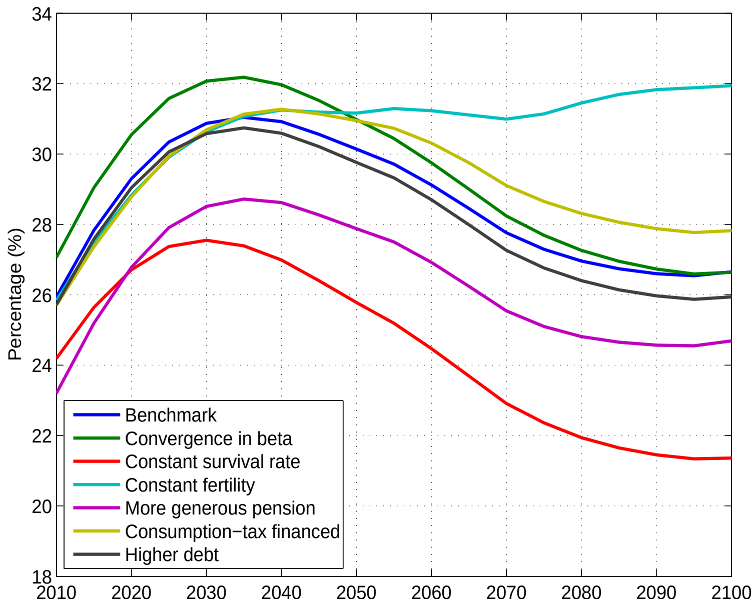


Figure 39: Saving rates in open economy

demographic variables including age-specific survival rates and fertility rates. With a rise in longevity and a decline in fertility rates over the next few decades, LAC will experience an increase in savings. In the open economy, saving will rise even more rapidly because higher interest rates in LAC attract capital inflow from other regions of the world that have lower interest rates. As life expectancy starts to stabilize and fertility rates begin to recover and increase, saving rates will start to decline.

In order to understand determinants of saving and key factors of the model that determine the dynamics of saving in LAC, we conduct a number of experiments. If the discount factor of LAC converges with that of High Income region, the saving rate will be much higher and the region will run a current account surplus for a much longer period in the open economy. We also simulate the model hypothetically, assuming that the survival rates and fertility rates are fixed to decompose the contribution of demographic variables. We also simulate a few policy experiments. If, for example, LAC implements more generous pension systems, saving will be significantly reduced as households rely more on public transfers to finance old-age consumption than on their own savings. When a consumption tax is used instead of a labor income tax to finance the transition and absorb rising government expenditures, capital will be higher but the difference is small. Issuing more debt to partially cover the rising cost of aging demographics will help lower the labor income tax, but the effect is small since there will be additional expenditures to service the debt.

The model we have constructed and presented in this paper constitutes a useful tool for the analysis of the impact of large changes in demographics and has allowed us to perform interesting policy experiments. However, it should be stressed that the model is not without limitations, despite our efforts to calibrate it to match some of the observed facts. Its results should therefore be taken with some caution. We note, in particular, the necessity of calibrating a relatively high discount rate (or low discount factor) for LAC in order to account for the historically low level of capital output ratio in the region. Probably the best interpretation of our results is the identification of some basic economic forces that, given demographic forecasts, should lead to increases in aggregate saving in the LAC region. There might, however, be other factors that could prevent the sources of impact that we have discussed in this paper. Some of the demographic transition that generates the increase in saving that we have discussed has already occurred, for instance, and so far LAC saving rates have not increased much. Future research should focus on why saving rates in the region have been so much lower than what would be predicted by a standard general equilibrium model.

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