CHAPTER 4

Global Demographic Trends: Consumption, Saving, and International Capital Flows

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Abstract

In this chapter we review the recent literature on the effects of changing global demographic trends on consumption, factor prices and social security. We also construct an overlapping generation model with four regions of the world. The model is calibrated so that we match some basic statistics of the last few decades. We assume that the model was in a steady state in 1990, input projected demographic trends, which converge to common values across regions by 2200, and make suitable assumptions on productivity profiles and total factor productivity. This allows us to study the evolution of factor prices, current accounts, and welfare during the transition and explore the differences between open and closed economies, when we limit factor mobility to capital mobility and make different assumptions about future trends in demographics and productivity.

Keywords

Capital flows, Demographic trends, Overlapping generations model, Social security reform, China

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E21, F21, F41, J11

1. INTRODUCTION

Demographic trends in the last century or so have changed dramatically the size and composition of the world population. Developed and mature economies have experienced significant reductions in fertility rates and increases in longevity. Middle-Income countries have started on similar trajectories, although there is a sizeable delay in these trends. Developing countries still have relatively high fertility rates and lag behind in mortality but they are projected to reduce the former and increase the latter. China, which currently accounts for a large fraction of the world population, has gone through the most dramatic changes, induced by the one child policy, which has been followed until very recently. This implies large changes in the relative composition of the world population and its age structure in several regions over the next few decades.

At the same time, many developing countries have experienced a very high rate of growth that caused their level of output and productivity to start to converge toward that of the developed countries. The experiences of China, India, and other middle-income countries have contributed to reduce the number of people living in poverty substantially over the past 25 years and changed the role that these countries play in the world, both in terms of their economic and political weight.

The economic, political, and human consequences of these changes are far reaching. Deaton (2013) in his book *The Great Escape* vividly discusses some of the impacts that recent developments have had on the health, income, and more generally the well-being of very many people around the world. In a world that is ever becoming more connected and integrated, the interlinkages between the developments in different countries are of fundamental importance. The demand of raw materials sparked by the investment in China has had profound consequences on the performance of some parts of Africa. The demographic trends in Western Europe and the United States imply strong incentives to factor mobility (both labor and capital). And the list could continue.

It may be useful, at the outset of this chapter that investigates the economic implications of international demographic trends to discuss some of the main channels through which these trends will affect economic variables. In a stationary equilibrium, in which the new cohorts that enter the economy and start a life cycle in which their productivity increases and then declines up to a point in which they retire from work, the length of the working life of a single individual and their productivity determines the amount that it is necessary to save to maintain certain standard of living in the last period of life. The way in which these savings are made affects in an important fashion various economic variables. For instance, depending on whether consumption during retirement is financed through individual savings held in real assets or through a Pay-As-You-Go (PAYG) pension system in which part of the earnings of the current work are given to pensioners, the level of the capital stock (and the returns to capital and wages) will be different. Notice that when individual savings are important, during their working lives individuals acquire (through savings) assets, which they will sell (presumably to younger cohorts) during retirement. Dramatic shifts in demographic trends induce important changes in such a situation, regardless of how retirement consumption is financed. A large cohort that enters the economy will presumably face a market where labor is relatively abundant. If such a cohort is followed by a relatively small one, when it retires, it will face relatively unfavorable asset markets, and, therefore, realize relatively low rates of returns on their investment. If pensions, on the other hand, are financed via a PAYG system, the consequences for the large generation are not too dissimilar: there will be a small number of workers to finance each retiree. Indeed, a PAYG system has some similarities with a system financed by individual savings: one can consider the payments into the systems as investment whose return is directly linked to the rate of growth of the population. With declining or negative growth rates, the return to PAYG systems can be very low or negative.

Until now we have sketched the issues faced by a closed economy whose demographic trends change. Particularly salient are changes brought about by a reduction in fertility and an increase in longevity. The situation becomes even more complicated if one considers open economies where demographic trends are relatively unsynchronized and where only some of the factors of production are (partly) mobile. In such a situation, the relative size of different economies, the productivity of their factors of production, and the degree of mobility of those factors are only relevant to establish the consequences that a certain set of demographic trends have on the economic welfare of the citizens of different countries and regions.

There are many ways in which the economic impacts of demographic trends could be analyzed. One could, for instance, rely on a simple descriptive analysis which exploits variation across countries and over time to establish the relationship between demographic trends and economic variables. Such an analysis, however, would not provide an understanding of the mechanisms behind certain correlations. And, given the slow-moving nature of demographic trend, it would be difficult to extrapolate. Alternative theoretical models that consider the presence of individuals of different cohorts include dynastic models and the so-called model of perpetual youth used by Yaari (1965) and Blanchard (1985). In the former, individuals care about their offspring so that, under certain assumptions, a dynasty of individuals behaves like an infinitely lived agent. In the latter, in each year a fraction of the population currently alive dies and is replaced by new individuals. Both of these models, however, make very strong assumptions that all but preclude an in-depth analysis of changes in demographic trends.[a] The overlapping generation (OLG) model, instead, despite the many unrealistic assumptions that are typically made to make it tractable (analytically or even numerically), provides the natural theoretical structure to synthesize the changes of demographic trends.

In this chapter, we will focus on the OLG model, which has been used widely in the literature. The model has a long history, starting with Samuelson (1958) and has been used in a variety of contexts, both to generate theoretical insights and for the empirical analysis of policy reform. The model, or at least the most sophisticated versions of it, makes the demographic structure of the economy under study very explicit, and it seems one of the most appropriate tools for analyzing changing demographic trends. We will therefore discuss both the use that the literature has made of the OLG model and present a quantitative exercise where we use it to understand the impacts of unsynchronized demographic trends in different regions of the world.

A general theme that will be central to this chapter is the fact that a global view is key to a proper understanding of the phenomena we are studying, especially if one wants to draw

[a] Bloom et al. (2007) use the perpetual youth model to investigate the effects of increased longevity on savings. They find that, when retirement age is fixed, longer lives generate more savings. When retirement age is flexible, savings do not change.

the implications for the design of economic and social policies. It could be extremely misleading to study the implications of the aging of Western societies and Japan for the design of, say, pension and health care reforms, ignoring what is happening to the demographic trends and to economic productivity in other parts of the world. Analogously, when studying the design of tax and benefit systems in middle-income countries where the informal sector still plays an important role, one needs to keep in mind the structure of world demand and the international mobility of factors. The global trends will move factor prices and modify the incentives of individual agents in reaction to specific policies.

In a world with perfect mobility of production factors (labor and capital), one would expect factor prices to be quickly equalized, as a result of massive labor migration from high fertility, low capital areas to low fertility, high capital areas. In reality, however, one has to take into account obstacles to factor mobility, ranging from the costs of migration and adaptation, to the financial and political institutions that would guarantee capital mobility.

In such a situation, economic models that are sufficiently sophisticated and able to capture the essence of the main economic forces at play are extremely useful and important. Obviously, the perfect model, representing all details and facets of a complex and ever-changing reality does not exist. But the very complexity of the world makes the construction of abstract and simplified models that are able to isolate the main factors affecting the impact of economic policies absolutely essential.

This chapter is divided into two parts. We first discuss the existing literature on the use of large OLG models to understand demographic trends. We give examples of how the basic model has been extended in recent years to study global demographic trends and their impacts. We then construct one such model and discuss the results we obtain from calibrating it and simulating transition dynamics.

In Part I we start by revisiting the multigeneration OLG model proposed by Auerbach and Kotlikoff (1987) that is ideally suited to study the general equilibrium of an economy that goes through profound demographic changes. We recall the main ideas of this model and discuss what can be learned from it. We then discuss the extensions that one needs to consider to the simplest model to make it sufficiently rich to capture some salient aspects of reality. We also discuss some of the methodological and computational challenges that one faces when developing such a model. We first focus on a closed economy, then explain how the model has been extended to study the global economy.

In Part II, we present our calibrated model. This model explores the consequences of the high growth of China (and the high level of Chinese saving) and the possible outcomes of different scenarios for the growth of other regions, such as Africa, with very different demographics. It improves upon earlier work by Attanasio et al. (2006, 2007) that distinguished between developed and developing countries by adding two more world regions to the analysis. We consider explicitly four different regions in the world that have been previously aggregated: "High Income," "Middle Income," "Low Income," and China. We keep separate regions that are at different stages of the demographic transition and have different levels of productivity and productivity growth.

PART I. THE OVERLAPPING GENERATIONS MODEL

As mentioned in the introduction, there are many ways to study the impact that demographic trends have on economic variables. In this chapter, we chose to focus on the OLG model, as it provides a natural framework to incorporate demographic trends in a meaningful and coherent economic analysis. OLG models have been used in economics for a long time. Since Samuelson (1958) contribution, economists realized that this type of models provide a very powerful tool that can be used effectively to describe complex dynamics in economic variables. For instance, the famous paper by Diamond (1965) illustrates how such a model can be used in a very parsimonious way to describe the impact of incomplete markets and the introduction of social security and government debt.

Even in very simple incarnations, OLG models can generate extremely complex dynamics. In such models, factor prices are determined by the equilibrium in the capital market. The equilibrium interest rate guarantees that the supply of savings equals the demand for capital, which, at the same time is a factor of production and a way to move resources over time. This dual role of the capital stock and the fact that it is impossible to trade with future generations give a rise to the possibility of dynamic inefficiencies, as discussed, for instance, in Abel et al. (1989).[b]

2. THE AUERBACH AND KOTLIKOFF (1987) MODEL

While the main economic forces at play in such models are evident even in the simplest version, where individuals live for two periods, interacting with their parents when young and with their children when old, to derive their quantitative implications and possibly to bring the models to bear on real world issues, it is necessary to complicate them considerably. The first contribution in a large literature that has extended the simple model to make it reasonably realistic and suitable for policy analysis is the monograph by Auerbach and Kotlikoff (1987) (AK henceforth).

AK consider individuals living for 55 periods. In each period, a generation dies and is replaced by a newly born one. At each period, therefore, there are 55 different generations alive. Each individual generation makes consumption and labor supply choices, as in a standard inter-temporal model. Life cycle utility is an additively separable function of single period utilities (discounted geometrically at rate β) that depend on consumption and leisure in each period. Individuals are endowed with an exogenous productivity profile, which reflects the fact that their earning capacity varies with age. Declines in individual productivity (and possibly the presence of a social security system) will induce individuals to retire, that is, not to supply labor. Declines in productivity and therefore earnings over the last part of the life cycle will induce individuals to save in the earlier part

[b] Dynamic inefficiency cannot arise when there is a fixed factor of production, such as land. Whenever the interest rate falls, the price of land rises, and this absorbs the saving of young cohorts, leaving no room for overaccumulation of capital. See Imrohoroglu et al. (1999).

of it. The level of savings will obviously depend on the presence of social security (see Feldstein, 1974). There is no uncertainty in the model: individuals know their productivity, their date of death, their wages, and interest rates until the end of their lives as well as government policies.

The model considers two other sets of agents: firms and the government. Firms, which are owned by households, produce homogenous output with a neoclassical constant return to scale production function which uses capital and labor. Output can be used as consumption or as capital. Capital accumulates subject to some adjustment costs. Goods and labor markets are competitive, implying that wages are equal to the marginal cost of labor while the interest rate is equal to the marginal product of capital. Wages are also equal to the marginal disutility of labor. The government levies taxes on labor and capital income and consumption. The government might need to finance an exogenous flow of expenditure and might also run a pension (social security) system. The government is infinitely lived and subject to an infinite horizon budget constraint that rules out Ponzi schemes: the present discounted value of government revenues has to equal the present discounted value of its layouts.

While extremely stylized, this model constituted an important contribution as it allowed the use of OLG models to analyze a number of policy-relevant issues, ranging from the effects of different demographic trends on the sustainability of the US Social Security system, to the choice of different fiscal instruments, in a realistic and quantitatively salient fashion. Obviously, even with the assumptions on the utility function (such as the CES specification AK use to represent preferences over consumption and leisure), the possibility of corner solutions in leisure (so that individuals retire) implies that it is not possible to derive analytical solutions for the equilibrium of the model. One of the innovations introduced by AK was a relatively simple and intuitive solution method that allows the simulation of this class of models and their use for policy analysis.

2.1 Steady States and Transitions

The solution method proposed by AK starts with the derivation of the steady states of the model under different policies or demographic trends. The transition between the steady states is then computed exploiting the intuition that the evolution of the system can be summarized by a single state variable: the capital/labor ratio. Such variable determines factor prices, that is, interest rates and wages. Given a path of factor prices, individual households will choose labor supply, consumption, and savings. Aggregating the savings of different generations and their labor supply then generates the aggregate capital stock and aggregate labor supply. The equilibrium is determined by finding a fixed point in the capital labor ratio.

While the solution method proposed by AK is very attractive, partly because it is very intuitive, it relies heavily on the assumption that a single state variable determines factor prices and, effectively, the supply and demand of capital and labor. Whenever such an assumption is violated, the method cannot be applied. There are many situations in which such an assumption is violated. An important case we discuss briefly below is the presence of aggregate uncertainty. Another interesting case, which we also mention below, is when demographic variables are themselves slow-moving random variables. In this situation, the current state of the demographic variables (which could be multidimensional) would also constitute an additional state variable.

2.2 Market Structure and Intergenerational Links

In the basic model, the only asset available to individual households to transfer resources to the future (for instance to finance consumption in the last part of life when individual earning capacity declines) is the capital stock. Individuals therefore will accumulate capital in the first part of the life cycle and decumulate it in its last part. The relatively young will purchase capital from the relatively old. The net supply of capital and the demand for it by firms will determine the equilibrium capital stock which, together with the equilibrium labor supply, will determine the equilibrium interest rates and wages.

This very simple market structure already imbeds, in a fairly natural way, a substantial deviation from the complete market paradigm that is sometimes used in aggregate models. The fact that is not possible to trade with future generation, as mentioned above, is at the origin of potentially important dynamic efficiency. With certain preference, specifications and assumptions about the production function can generate dynamic inefficiencies, situations where "too much capital" is accumulated to finance consumption in old age determining an inefficiently low level of the interest rate, possibly below the rate of growth of the population. In such a situation, as noted by Diamond (1965) the introduction of national debt or a social security system can alleviate and even eliminate the dynamic inefficiencies. The availability of national debt constitutes an alternative tool to move resources to the future which reduces this role of the capital stock. The introduction of an unfunded social security system, where social security contributions from individuals currently working are used to pay the pensions of individuals currently retired, reduces the incentive to save and, again, increases the equilibrium interest rate.

2.3 OLG Models and Demographic Trends

Even the simplest OLG model has a well-specified demographic structure. It is relatively simple to introduce age-specific mortality and fertility rates. The model therefore constitutes a natural vehicle to study demographic trends. Individuals belonging to different generations will be on different sides of the market for assets. Therefore, changes in the size of different cohorts will have important consequences for the equilibrium in these markets, and therefore on the return to capital and, given the standard assumptions on the production function, on wages and labor income. Population aging induced by increases in longevity and reduction in fertility, can have particularly substantial effects especially during the transition from a steady state to another, as a large cohort is followed by a relatively smaller one.

The AK model provides a useful tool to quantify these effects in a realistic fashion. A number of studies have looked at these effects, such as Geanakoplos et al. (1998), Abel (2001a,b, 2003), and Poterba (2001, 2004). In what follows we will explore similar ideas, using the basic intuition that demographic changes affect, on the one hand, the supply of labor and, on the other, the supply of saving. In a standard model, in the absence of pension systems, the young are savers and the old are dissavers. The relative sizes of these groups determine the supply of aggregate savings and, together with the supply of labor, the equilibrium interest rate.

Demographic trends are important in the OLG model because they determine the supply and demand of production factors and, therefore, their prices. The papers cited so far have often focused on domestic demographic trends, often in the context of large developed economies, such as the United States. In the presence of large demographic shifts that might not be fully synchronized across different regions of the world, if there is some degree of factor mobility (either labor or capital—and possibly even commodities), it becomes important to consider the evolution of global demographic trends. To quantify the effects of these global shifts, however, it will be necessary to take a stance on the degree of factor mobility, on the specific old age arrangements in different regions, and on the level of factor productivity in different countries. We discuss these issues in detail in Section 4.

3. EXTENSIONS TO THE MODEL AND METHODOLOGICAL CHALLENGES

While the model presented by AK is a rich one, it is also very stylized in many dimensions. In this section we briefly discuss extensions to the basic framework that have been considered in the literature. Some of these extensions present important methodological and numerical problems.

3.1 Expectations of Demographic Trends and Institutional Arrangements

In most models in the literature, economic agents are endowed with rational expectations or perfect foresight about most of the model's variables. However, they might be completely surprised by changes in demographic trends or public policies, in that they did not consider even the possibility of such changes. The standard OLG model starts from a steady-state equilibrium where agents assume that the current equilibrium (with certain fertility and mortality rates, pension arrangements, and taxation) will persist forever. These beliefs matter for their choices because, of course, future factor prices, including wages and interest rates, are affected by the behavior of future demographic trends and policy variables. Agents are, to an extent, not fully rational because they do not consider the possibility of such changes. That is, in the initial equilibrium they do not consider the possibility that the demographic structure of the economy (fertility and mortality rates) might change. When it does change it is the realization of a zero probability event. More sophisticated agents might take into account the fact that demographic variables (fertility, longevity) move, slowly, over time in an uncertain way.

One of the few papers that addresses this issue is Rios-Rull (2001) that models demographic trends as slow-moving random variables over which economic agents form rational expectations. While it is debatable whether agents actually form expectations over such variables, fully understanding what their effects on future factor prices would be, such an approach is certainly intellectually coherent.

Similar issues arise when considering the institutional environment. For instance, certain institutional arrangements for public pensions might be clearly financially unsustainable and should imply substantial adjustments in terms of benefit payments or contribution rates. However, these adjustments can occur in many dimensions. From the point of view of an individual agent belonging to a certain cohort, the consequences of a reduction of future benefits vs an increase of future contributions can be radically different. Boersch-Supan et al. (2006), for instance, consider the different consequences of reforming a PAYG pension system reducing benefits or increasing contributions. And yet, it is not clear how to model the way individuals perceive the possibilities of these alternative reforms. Some of these issues are obviously related to the political economy of economic reforms, as they affect different groups in the population differently. A few papers, such as Galasso (1999), have addressed this type of problems (see also Galasso and Profeta, 2002, for a survey).

3.2 Heterogeneity Within Cohorts

Many of the papers that simulate large-scale OLG models focus on heterogeneity across cohorts (in, say, life expectancy or fertility) but assume that the members of a given cohort are homogeneous. For the analysis of certain policies, however, such as different ways of financing deficits or pension programs or pension reforms, it is important to allow for heterogeneity within a cohort. In the literature, there are important exceptions. The paper by Altig et al. (2001), for instance, allows for a substantial amount of heterogeneity within a cohort. In particular, Altig et al. assume that each cohort is made of 12 different groups of individuals that differ in term of their endowment of human capital and the rate of growth of human capital over the life cycle. These groups, which also differ in their preferences on bequests, are meant to capture different education groups in the population, whose earnings-age profile differ in shape and level. Labor supply is determined within the same maximization problem that determines consumption and saving choices: the utility function is assumed to depend on hours of leisure and consumption. Armed with this model, the authors consider the implications of different tax structures in the United States. This is an interesting study as it presents the consequences of alternative policies within a coherent framework which incorporates many different incentives and distortions, from the incentives to supply labor to the incentives to save. This paper, however, does not analyze the impact of changes in demographic trends, as it is focused on the differential effects of alternative taxation policies.

Another strong assumption made in the Altig et al. (2001)'s paper is the presence of a unique type of human capital. In other words, different skills are perfect substitutes in the production function and different individuals differ only for the total amount of skills that they command. Alternatively, one could assume that different skills are less than perfect substitutes in the production function and, therefore, introduce another important margin of adjustment. In this case, one would have different wages for each skill type that would depend on the relative demand and supply of such skills as well as the parameters of the production function. This type of models can be particularly useful in modeling the impacts of the accumulation of different types of skills. Binelli (2014), for instance, uses an OLG models where individuals can acquire different levels of education and where the production function uses four different types of labor. She uses this model to explain what she calls the "convexification" of the returns to education in Latin America. A similar structure could be used to study the impact of different demographic trends in a richer way.

Another interesting dimension of heterogeneity is that in preferences. Individuals within a cohort or in different countries might be different because of differences in discount factors, risk attitudes, or aspects such as altruism and reciprocity. In a recent paper, Falk et al. (2015) document important and systematic differences in preferences as elicited in a large and rigorous survey. Such evidence could be used in future research when building large global models. Differences in discount factors could, for instance, be able to match differences in observed capital labor ratios across different regions. The consideration of this level of heterogeneity, however, also involves some modeling challenges, especially when considering long-run simulations. For instance, if one allows for different level of discount factors in different regions, in the very long run, most of the capital stock will be allocated into the more patient region.

3.3 Aggregate and Idiosyncratic Uncertainty

In the standard AK model, there is no uncertainty. Some sources of uncertainty, such as that about life span, are easily introduced into the model. Further elements of uncertainty, such as uncertainty about individual productivity, can also be introduced in a relatively straightforward manner, as long as there is no aggregate uncertainty. This is done, for instance, in Imrohoroglu et al. (1995) and Conesa and Krueger (1999).

The introduction of aggregate shocks in general equilibrium models where markets are incomplete, however, is very hard. The difficulty arises because with aggregate shocks, factor prices are uncertain and depend not only on aggregate supply and demand of capital but also on their distribution in the population. Therefore, factor prices will depend on an infinitely dimensioned object.

Krusell and Smith (1998) introduced an ingenious and useful solution method that allows the treatment of models with aggregate uncertainty and incomplete markets. In particular, they approximate the solution to the model assuming that, rather than on the entire distribution of assets in the cross section, aggregate prices depend on a few moments of the same distribution. This approximation allows a substantial reduction in the dimension of the problem and, therefore, the numerical study of this class of models.

Krusell and Smith (1998) study an economy populated by infinitely lived consumers. In that context, the difficulty arises because the absence of complete markets does not allow the diversification of idiosyncratic risk. In the case of OLG models, market incompleteness arises naturally given the impossibility of writing contracts with future generations. In this context, several studies have considered different numerical methods to obtain a solution of the equilibrium. Storesletten et al. (2007), for instance, apply the Krusell and Smith method to OLG models. Krueger and Kubler (2003) use alternative numerical methods to solve this class of models. While we are not aware of multi country OLG models with aggregate uncertainty of the type we are considering below, it might be an interesting exercise to explore the extent to which some of the predictions of the existing models are robust to the introduction of these features. An important issue, of course, is the extent to which aggregate shocks are insured across countries. There exists a large empirical literature (see, for instance, Becker and Hoffmann, 2006; Kim et al., 2006; Kose et al., 2009; Baxter, 2012; Fuleky et al., 2015) that shows only very limited risk sharing of country-specific shocks.

3.4 Moving Away From the Simplest Preferences: Labor Supply and Habits

The stylized (or stripped-down) version of the life-cycle model assumes that consumers supply labor inelastically (they work full time until they reach retirement age, then stop working completely, irrespective of the wage rate). This strong assumption is relaxed in the AK model, where consumption and leisure enter nonadditively in each period's utility function—the elasticity of substitution between consumption and leisure governs the response of labor supply to the real wage rate, at least until retirement age (after retirement age consumers are not allowed to work any longer). Boersch-Supan et al. (2006) show that the exact value of this parameter is very important in assessing the response to—for instance—a pension reform that shifts the burden of a PAYG pension system from the workers (higher contributions) to the newly retired (lower benefits). Of course, once labor supply is endogenously determined one needs to be explicit about the way productivity (and wages) varies with age: endogenous retirement will occur if the wage offer is sufficiently low that the consumer prefers not to work (fixed participation costs may also play a role).

There is a large literature in labor economics that discusses the importance of extensive margins, especially when considering female labor supply (see, for instance, Chetty et al., 2013, for a recent contribution and citations). Family labor supply is rarely considered within large OLG models. And to a large extent, many contributions focus primarily on the intensive labor supply margin, rather than the extensive one. The reason for this simplification, of course, is that the individual decision problem becomes much more complex if one allows for different labor supply decisions.[c] And yet, labor supply is key to determine the extent to which certain demographic trends (such as the aging of the population) trickle into implications for factor prices and, ultimately, for the welfare of different generations. In some countries, the effect of the aging of the population on the size of the labor force might be muted if it is accompanied by an increase in the labor force participation by women. Moreover, reductions in fertility are likely to be associated with increases in labor force participation by women (opening up what is sometimes called "the demographic window"). Much work needs to be done in this dimension.

All papers that follow the AK approach assume that preferences are additive over time, thus ruling out the type of history dependence in utility that is required for durability and habits (see Hayashi, 1985, for an early paper that argues history dependence is important). Habits in preferences have instead been extensively assumed in the macrofinance literature. For instance, Campbell and Cochrane (1999) show that a particular form of habit dependence (known as external habits) is required to explain a variety of dynamic asset pricing phenomena, including the equity premium puzzle.

Habits in preferences can also explain some of the extremely high savings observed across all age groups in fast-developing countries like China, as pointed out in Attanasio and Weber (2010). A possible explanation for the tendency by older individuals in fast growing economies to keep saving is that their desired consumption level is heavily influenced by the low standard of living they were used to in their early years. If we add a bequest motive to the model we would predict that they keep saving in old age and then bequeath considerable wealth to their children, despite the fact that their children are much better off in a life-cycle sense than them. The model we present in Part II takes into account the existence of different propensities to save across world regions that converge to a common value in the very long run, but does not explicitly take habits into account.

4. DEMOGRAPHIC TRENDS AND SAVINGS

As mentioned above, the OLG model is a very useful tool to study the impact of changes in demographic trends on various economic variables. In such a model (and in reality), as

[c] Another dimension that is neglected is how decisions are made within the household. Much evidence rejects the unitary model of individual decisions—see Browning et al. (2014) for a recent appraisal. We are not aware of any studies that have considered alternative intrahousehold allocation models within an OLG framework.

individuals go through their life cycle they will accumulate and decumulate assets. This behavior, which is likely to be affected by pension arrangements and social security, will determine the demand and supply of assets in the economy. In this chapter we will briefly discuss the implications of demographic trends for savings and for the sustainability of different pension systems.

In a closed economy, the demographic trends of that particular economy will determine, in conjunction with its institutional arrangements (such as the pension and social security system, the availability of annuity markets to diversify individual longevity risks), the demand and supply of assets and, therefore, will affect the equilibrium factor prices. The main forces at play will be the relative supply of human capital (possibly of different types of human capital) and physical capital, which is accumulated as the result of saving decisions by individual households, as well as changes in Total Factor Productivity, as emphasized in Chen et al. (2007). The link between demographic trends and the welfare of different generations is intuitive and very direct. In general, a large size generation, preceded and followed by smaller generations, due, for instance, to a temporary increase in fertility rates (as it happened with the baby boom), is likely to suffer in the OLG model: their relatively large size will imply relatively low wages during their active years. On the other hand, when they retire and live off their savings, capital will be relatively abundant and its return will be low.

In an open economy these impacts can be reversed or attenuated if the demographic trends are not similar across countries or regions. The effects will depend on the relative size of the trends as well as on the specific institutions that limit (or facilitate) factor mobility. In what follows, we discuss some of the existing contributions that have looked at this set of issues. In our opinion, this is an area of research in which much progress is needed to incorporate more realistic models of factor mobility. Before discussing the studies that have analyzed open economies, however, we briefly summarize some of the papers that have considered demographic trends within closed economies.

4.1 Closed Economy

The approaching retirement age of the baby boom generation (coupled with a marked overall increase in longevity) raises a concern on the sustainability of all Pay-As-You-Go public pension systems. The US Social Security System, for instance, would start paying out ever larger benefits, and this would require increasing contributions for currently working younger generations. De Nardi et al. (1999) tackle this issue by building a closed-economy applied general equilibrium model and incorporating the population projections made by the Social Security Administration to evaluate the macroeconomic and welfare implications of alternative fiscal responses to the retirement of the baby boomers. They calculate that maintaining benefits at (the then) current levels would be difficult because the increases in distortionary taxes required to finance them would reduce private saving and labor supply.

A possible response to this concern has been to push for privatization of the Social Security System, as discussed in the influential volume by Feldstein (1998) that also documents the experience of five countries that have taken this path in recent years. Geanakoplos et al. (1998) note that "advocates of social security privatization argue that rates of return under a defined contribution individual account system would be much higher for all than they are under the current social security system." This claim, however, ignores accrued benefits already promised based on past payroll taxes, and underestimates the riskiness of stock investments. It is true that a reform toward a fully funded system would let the large fraction of (constrained) individuals, who do not own stocks reap the benefits of the equity premium, but this would raise current stock prices and lower future returns, thus hurting young (unconstrained) households. Abel (2001a) in fact notes that the aggregate capital stock could be reduced as a result. Suppose the fully funded defined-contribution Social Security system tries to exploit the equity premium by selling a dollar of bonds per capita and buying a dollar of equity per capita. In this context, consumers who save but do not participate in the stock market increase their consumption. The general equilibrium response to this policy could be a reduction of the aggregate capital stock that Abel computes to be about 50 cents per capita.

The issue of whether a move toward a privatized social security system is welfare enhancing has been addressed in other papers, that explicitly consider the labor supply effects of such a reform, and stress the importance of the nature of the stochastic income process. Nishiyama and Smetters (2007) analyze one specific reform of the US Social Security system (a 50% privatization) and find that privatizing social security can not only produce efficiency gains by improving labor supply incentives but also reduce risk sharing. When there is purely idiosyncratic risk in wages and the earning process is dominated by transitory shocks they find that privatization produces small or no efficiency gains. Huggett and Parra (2010) consider not only the optimal reform of the Social Security and income tax systems together for a given cohort but also a more limited reform that chooses the Social Security benefit function but keeps income tax as is. In the more radical case, the social planner chooses a life-time income tax (that is present value neutral to the current system) under incentive compatibility constraints. The incentive problem arises because the social planner observes earnings but not hours of work or hourly wages. They also focus on idiosyncratic risk and find large efficiency gains when all shocks are permanent: high productivity workers work too little and low productivity workers work too much under the current US system compared to the solution of the planning problem. However, if all (or most) shocks are temporary, the radical reform produces almost no gain; the more limited one produces only a small gain.[d]

[d] McGrattan and Prescott (2015) address the politically sensitive issue of how to ensure that the transition toward a privatized system does not penalize the older cohorts, that are already retired and would not benefit from reduced payroll tax.

The other concern that the retirement of the baby boom generation has raised has to do with the so-called "asset market meltdown" hypothesis. Financial market analysts associate the aging of this cohort to the rise in US asset values during the 1990s, and predict asset price declines when this group reaches retirement age and begins to decumulate its wealth. Abel (2001b, 2003) has used a two-period OLG model to analyze this issue—in this context, the price of capital first increases and then falls, in agreement with the hypothesis. Poterba (2001, 2004) argues that this type of models fails to capture the notion that most individuals do not in fact decumulate their assets in old age as fast as the OLG model assumes, and shows that demographic effects on asset prices are relatively minor. He concludes that there is "modest support, at best, for the view that asset prices could decline as the share of households over the age of 65 increases."

Pensions and the arrangement to finance the consumption of retirees are only one consequence of changing demographic trends and population aging in particular. The latter is likely to increase the need for medical care and health expenditure. Although in the exercise we perform we do not focus on this issue a number of recent interesting papers have looked at this set of issues. Kitao (2014), for instance, present reform options to make social security system in the US sustainable under aging demographics. Braun and Joines (2015) and Kitao (2015) investigate the fiscal imbalances due to population aging in Japan, considering both the increase in pensions and health care spending. Attanasio et al. (2011) study consequences of Medicare reforms. De Nardi et al. (2010) consider a model where medical expenses play an important role in the saving behavior of the old. Kopecky and Koreshkova (2014) study effects of nursing home expenses on life-cycle savings and Braun et al. (2016) consider welfare effects of social insurance at old ages. Recent papers address the issue of the likely increase in health care spending brought about by increased longevity—Dobrescu (2015) investigates its consequences on household saving once the choice between formal and informal insurance is considered, whereas De Nardi et al. (2016) investigate the distributional consequences of existing public programs, such as Medicaid.

4.2 Open Economy

When considering the effect of changes in demographic trends it is important to consider the global economy, made of different regions with different levels of technological progress and factor endowments, especially if the focus of the analysis is on the impacts that demographic trends have on economic variables and intergenerational welfare under different fiscal policies and pension arrangements. A naive approach would be to consider the entire world as a closed economy. However, in the presence of limitations to production factors mobility (either labor or capital), such an analysis would be very misleading even if different levels of productivity are somehow allowed for using efficiency units. An important point to notice is that when considering a global model with some but not full factor mobility and productivity differentials even when making the assumption of constant return to scale on production, the size of different economies will matter to determine the equilibrium factor prices.

4.2.1 Labor Mobility

A few papers have considered the role of immigration policies aimed at countering the adverse effects of the retirement of the baby boom generation on the government budget and on the economy as a whole. For instance, Storesletten (2000) uses a calibrated general equilibrium OLG model of the AK type to investigate whether a reform of immigration policies could resolve the fiscal problems associated with the aging of the baby boom generation. His model captures the first-order effects of immigration: an inflow of working-age immigrants increases tax revenues per capita and reduces government debt and government expenditures per capita. When immigrants retire, these effects are reversed. A general equilibrium analysis is required since the government budget is also affected through increases in interest rates and decreases in wages due to a decline in capital–labor ratio (if capital does not flow into the country in response to immigration). Higher interest rates increase the cost of servicing the public debt, and lower wages reduce tax revenues. Storesletten notes that both age and skill levels of the new immigrants are potentially important. In fact, given the progressivity of the tax system, if skilled workers immigrate and pay taxes, the net fiscal effects are large and positive, even when the gains are traded off with the subsequent costs of retirement. Young immigrants, on the other hand, alleviate the demographic imbalance that characterizes most developed countries, but without a period of childhood. Therefore Storesletten argues that selective immigration can mitigate some of the fiscal burden associated with the aging of the baby boom generation and serve as an alternative to tax hikes or spending cuts for financing future fiscal deficits. Storesletten finds that an increased inflow of working age high- and medium-skilled immigrants can work.

Fehr et al. (2004) question some of the policy implications of Storesletten's analysis. They develop a three-region dynamic general equilibrium OLG model to analyze immigration policies during the demographic transition. They focus their analysis on three developed regions (the United States, Japan, and the EU)—the effects of migration on the developing (donor) countries are not considered. In this context, various factors are at play in general equilibrium that may limit the role played by immigration. First, increased immigration not only raises the size of the labor force but also lowers real wages. This limits the increase in the taxable wage base due to immigration. Second, Fehr et al. assume that immigrants arrive with some capital and they also accumulate more capital as they age, which raises labor productivity. Third, immigrants require public goods and become eligible for welfare state benefits. As pointed out by Storesletten, immigration of high-skilled workers is more beneficial for the government because taxes and transfer payments are collected and distributed on a progressive basis. Fehr at al.'s model confirms this point, but shows that a significant expansion of immigration, whether across all skill groups or among particular skill groups, does little to alter the major capital shortage, tax hikes, and reductions in real wages that can characterize the demographic transition. According to Fehr et al. (2004), even a doubling of high-skilled immigrants would leave the developed world with a major fiscal crisis in its hands. They also notice that increasing skilled immigration sounds easy, but is not. Most skilled workers live in the United States, the EU, and Japan: moving a high-skilled worker from one of these regions to another is not a solution for the developed world as a whole. In a follow-up paper, Fehr et al. (2006) add a fourth region to their model: China. This has a dramatic impact on their model's predictions. In fact, even though China is aging rapidly, its saving behavior, growth rate, and fiscal policies are very different from those of developed countries. If this continues to be the case, China eventually becomes the world's saver and helps resolve the developed world's problems in terms of long-run supply of capital and general equilibrium prospects.

4.2.2 Capital Mobility

Labor mobility is a possible solution to population aging of developed countries, but large-scale immigration poses important political and social challenges to the receiving, developed countries. Also, the supply of high-skilled workers that developed countries would ideally want to attract from developing countries is limited, and migration flows of this type of workers from developing to developed countries may increase world regional imbalances and threaten world growth and peace.

A much less challenging solution to the demographic imbalance of the developed countries is capital mobility. Rather than importing labor, developed countries can invest part of their capital in developing countries, thus contributing to their growth now and generating capital income flows for their retirees in the future.

Early papers that link the demographic world imbalances to capital flows across world regions include Miles (1999), Brooks (2000, 2003), and Lim and Weil (2003). Attanasio et al. (2006, 2007) and Boersch-Supan et al. (2006), instead, address the issue of pension reforms in a world with capital mobility but no, or limited, labor mobility.

Attanasio et al. (2006, 2007) develop a two-region general equilibrium OLG model calibrated to the North (more developed countries) and the South (less developed countries). In their 2006 paper, Attanasio et al. evaluate quantitatively the impact of the observed demographic transition on aggregate variables (factor prices, saving rate, output growth), and on inter-generational welfare in developing economies. They find that the effects of the demographic trends for less developed regions depend on the degree of international capital mobility and the extent to which the large Pay-As-You-Go systems in place in the more developed world are reformed. In their 2007 paper, Attanasio et al. investigate the sustainability of the current social security systems in the developed economies, given the projected demographic trends, still using the two-region model

(South and North) of the world economy described above in the two polar cases where capital cannot or can freely flow across regions. Every country in the developed world (the North) faces quantitatively similar demographic trends and the same issue of how to reform their PAYG pension system. In contrast, in the developing world (the South), large-scale social security systems are absent and the demographic trends are markedly different from those of the North. Roughly speaking, the demographic transition in the South lags the one in the North by seven or eight decades. This lack of synchronization in the demographic trends between North and South generates, in a two-region open-economy model, major economic forces, that are suppressed in the closed economy model. The objective of the paper is to study whether the quantitative implications of various social security reforms for policy variables, factor prices, macroeconomic aggregates, and welfare of different cohorts in the North are sensitive to the benchmark adopted, i.e., closed vs. open economy. Attanasio et al. perform two types of policy experiments. First, they assume that the North retains a PAYG scheme and examines several options to finance the system through the demographic transition. Second, they assume that the PAYG will be gradually transformed into a fully funded system, and study alternative ways of financing this privatization. They perform all these experiments under both scenarios (open and closed economy). Their main conclusion is that if one is interested in quantifying the path of the fiscal variables needed to keep the social security system viable or to finance a transition toward a fully funded system, then these two scenarios yield similar results. However, if the focus is on quantifying the path of factor prices, aggregate variables and, ultimately, welfare, then the two scenarios can diverge significantly.

Boersch-Supan et al. (2006) develop a multicountry computational general equilibrium model and discuss its public pension reform implications with special reference to three large European economies. They feed their multicountry overlapping-generations model with long-term demographic projections for seven world regions, and consider different degrees of flexibility in international capital markets (from no international capital flows allowed to full capital mobility across all regions, going through intermediate cases where capital mobility is restricted to the EU, or to EU and OECD countries only). They find that population aging and pension reform have profound effects on international capital markets. Aging results in decreases in saving rates when the baby boomers decumulate their assets. International capital flows follow this trend. The countries most affected by aging, such as those in the European Union, will initially be capital exporters, while countries less affected by aging, such as the United States and other OECD regions, will import capital. However, since it is older households that decumulate their assets, capital exports from the rapidly aging countries will decrease, and by around the year 2020, such countries are projected to start importing capital. Pension reforms with higher degrees of prefunding induce more capital exports; they also increase labor supply considerably, while their effects on the rate of return to capital are small. While the rate of return on capital is projected to decline in response to population aging, no 'asset market meltdown' is predicted. In their analysis of pension reform (from PAYG to fully funded systems in the three European countries under investigation), Boersch-Supan et al. highlight the role of labor supply responses. If the elasticity of substitution between leisure and consumption is sufficiently high, the effects of the reform are largely absorbed by changes in labor supply.

Krueger and Ludwig (2007) also employ a multicountry large-scale OLG model to quantify the impact of the demographic transition toward an older population in industrialized countries on worldwide rates of return, international capital flows, and the distribution of wealth and welfare in the OECD. Their model has two key features: capital flows freely within the OECD (but not outside it), and there is uninsurable labor productivity and mortality risk. Uninsurable idiosyncratic uncertainty implies that some agents derive most of their income from returns to capital, while others mainly have labor income. This heterogeneity allows a meaningful analysis of the distributional consequences of changes in factor prices. They find that for the United States as an open economy, rates of return are predicted to decline by 86 basis points between 2005 and 2080 and wages increase by about 4.1%. Remarkably, they find that if the United States were a closed economy, rates of return would decline and wages increase by less. This is due to the fact that other regions in the OECD tend to age even more rapidly; therefore the United States is "importing" the more severe demographic transition from the rest of the OECD in the form of larger factor price changes. In terms of welfare, their model suggests that young agents with little assets and currently low labor productivity gain, up to 1% in consumption, from higher wages associated with population aging. Older, asset-rich households tend to lose because of the predicted decline in real returns to capital. The case of incomplete capital market mobility (subject to adjustment costs) is considered in other papers, such as Fehr et al. (2008).[e]

PART II. A MULTIREGION MODEL OF THE WORLD ECONOMY

In this part of the chapter, we build and analyze a multiregion model of the world, where labor mobility is restricted, and compare what happens with and without capital mobility. Labor and capital prices are set competitively, and consumption goods are allowed to

[e] Fehr et al. (2013) instead use a model with three different skill levels of workers across five world regions to study the impact on income inequality of the worldwide increase in low-skill labor force brought about by the demographic transition. They assume that in each region the proportions of workers by skill level do not change over time and there are both tradable and nontradable goods. They compare the case where factor prices are equalized across regions (offshoring) to the case where they are instead region specific. Their key finding is that offshoring raises GDP and increases growth rates, but has a major negative effect on low-skill workers in developed countries (and a smaller, positive effect on low-skill workers in developing countries).

travel without restrictions in the open economy. We take into account the existence of social security systems that are much more generous in developed countries compared to developing countries. We explicitly consider the presence of a large, fast developing country, China, that has a rapidly aging population structure due to much lower fertility than other countries at a similar stage of economic development. The purpose of this exercise is to provide a rigorous and quantitative account of the impacts that demographic changes can have on a variety of economic variables, ranging from wages and interest rates, to the life cycle welfare of different generations. While we are forced to make a number of simplifying assumptions to make the analysis feasible, the model we build and calibrate is useful because it allows us to perform a number of counterfactual exercises where we can vary both different demographic trends and different variables that determine the policy environment.

We extend several papers that we discussed in the literature review part of this chapter, starting from the seminal contribution by Auerbach and Kotlikoff (1987). In particular, we build upon the existing general equilibrium, two-region OLG model pioneered in papers by Attanasio et al. (2006, 2007) by using more recent and more disaggregated data on demographic trends and economic growth in four different world regions.

We also explore the consequences of the growth in China (and the Chinese saving behavior) and the possible outcomes of different scenarios for the growth of developing regions, such as Africa, with very different demographics. These issues are important at different levels. In equilibrium models with several regions, their relative size (which evolves as a consequence of differential demographic trends and differential productivity growth) matters both for factor flows and for their prices. And of course, the outcomes will depend on the degree of capital and labor mobility.

In developing countries, where fertility rates are still relatively high but are projected to decrease quickly, there is also the issue of the so-called demographic window. It has been argued that decreases in fertility are associated with increased participation in the labor market by women, which might have important aggregate consequences in factor prices.

To take into account these new developments we consider explicitly four different regions in the world that previously had been aggregated. The level of aggregation depends on the synchronization of projected demographic trends and productivity growth. We keep separate regions that are at different stages of the demographic transition and have different levels of productivity and productivity growth. Even though we do not explicitly model labor supply (and in particular female labor supply), we take into account that decreased fertility, and to a lesser extent increased longevity, may result in increased labor force participation. This demographic window is a mechanic consequence of the new demographic structure since there are more working age individuals in the overall population. An additional input to the demographic window can be the result of changes in female labor force participation, brought about by reduced child-care needs. The former mechanism has long exhausted its growth potential in most developed countries, but is playing an increasingly important role in many developing countries. The latter mechanism largely depends on how real wages change in response to population trends, the process of industrialization that is taking place in developing countries at the moment and capital as well as labor flows across the various world regions.

Taking into account all these factors, we split the world in four regions: "High Income" (United States, Europe, Japan, Canada, Australia, and New Zealand), "Middle Income" (Latin America and the Caribbean, Russia, Turkey, India, South Korea, Taiwan, Thailand, and South Africa), "Low Income" (the rest of Africa, other parts of Asia, and Oceania), and China.

Changes in demographic trends have important implications on factor prices and, as a consequence, on the relative welfare of different generations. The same trends that make Pay-As-You-Go systems unsustainable in the long run (or imply very high levels of labor taxation) induce, in closed economies with unfunded pension systems, factor prices movements that hurt certain generations. In particular, baby boomers are hurt in the labor market through lower wages and in the capital market after they retire through lower interest rate. But in open economies factor mobility may attenuate these effects if demographic trends are not fully synchronized. This is one of the issues we explore in this part.

To summarize, in this part we construct an OLG model with four regions of the world. The model is calibrated so that we match some basic statistics of the last few decades. We start the model simulations in a steady state that approximates the economy of the four regions in 1960, input projected demographic trends and assume that a new steady state is reached in some hundred years, and make suitable assumptions on productivity profiles and total factor productivity. This allows us to study the evolution of factor prices, current accounts, and welfare during the transition and explore the differences in factor prices, current accounts, and welfare between open and closed economies, when we limit factor mobility to capital mobility and make different assumptions about future trends in demographics and productivity.

5. DEMOGRAPHIC DATA AND PROJECTIONS

In this section we present some projections that motivate our choice to consider a four-region model of the world economy. In the first graph (see Fig. 1) we show total fertility rates from 1950 until 2100. The bold line represents High-Income countries: we see a marked decline in fertility over the second half of last century, from a number close to three in 1950 to 1.5 in the 1990s. The demographic projections we use assume a slow convergence to the 2.1 fertility rate that is consistent with a steady population in a closed economy with stable life expectancy. The Middle Income dotted curve starts around 5.5 in 1950, but has already reached the 2.1 mark by the beginning of this century—the

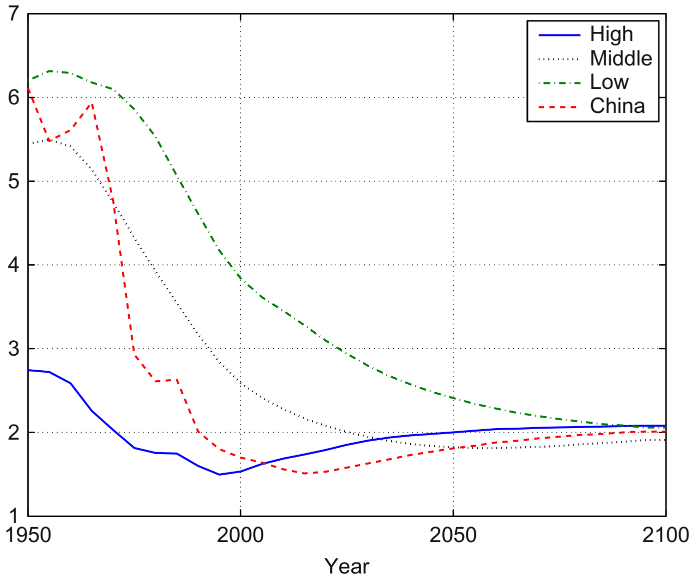

Fig. 1 Total fertility rates.

countries of this region have fully enjoyed the effects of the demographic window, and now face a fairly stable fertility path. Low-Income countries (represented by a broken line) saw a peak in their fertility rate around 1960—at a very high value (exceeding 6)—and are now experiencing a rapid decrease in fertility, but are still well above the 2.1 mark that will not be reached until the end of the century. Finally, China displays the most interesting fertility pattern: after a dip in the 1950s, there was an increase to values close to six, followed by an abrupt fall in the 1960s and 1970s, as a result of draconian governmental policies to limit population growth (the so-called one-child policy). This drop has continued in the first decade of this century—following mass migration from the rural to urban areas.

The life expectancy patterns at birth of the four regions are displayed in Fig. 2. Life expectancy in High-Income region has grown from a number just below 70 in 1950, to over 80 in the 2010, and is projected to further increase to 87 years of age by 2100. Middle- and Low-Income countries are on lower, but similarly smooth increasing paths. China instead presents a marked dip in the 1950s, followed by a sudden rise in the next two decades, and is now on a steadily increasing path just above Middle-Income countries.

The combination of fertility and longevity, together with migration, generates the population growth patterns displayed in Fig. 3. This picture takes into consideration a longer time period (until the year 2200). High-Income countries are currently experiencing small, negative population growth rates—Low- and Middle-Income

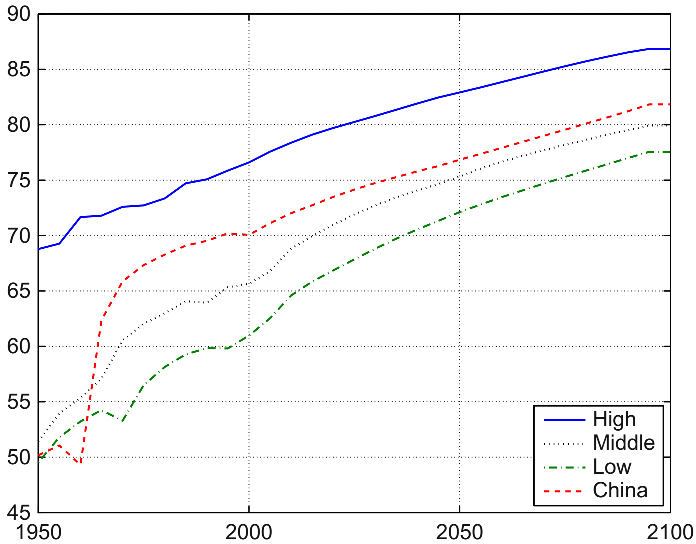

Fig. 2 Life expectancy.

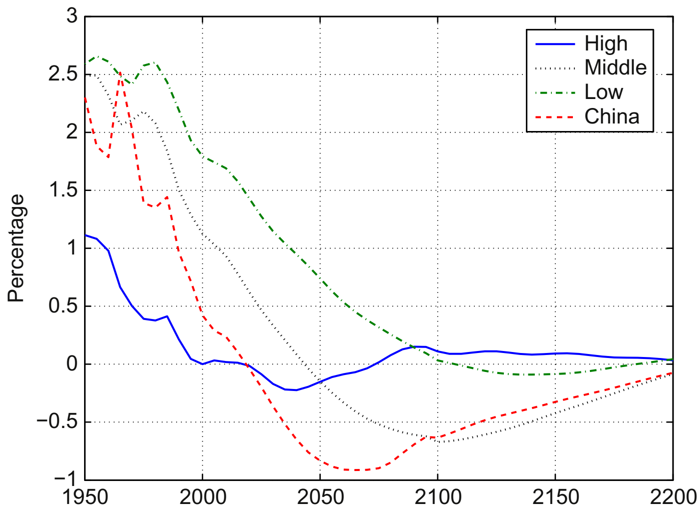

Fig. 3 Population growth.

regions are instead growing at rates of 1% or more. Large negative growth rates are expected for China over the whole rest of this century, and Middle-Income countries will also see negative population growth from 2050 onward. The population levels consistent with these projections are shown in Fig. 4. The most striking feature is the massive decrease in the Chinese population that should fall back to 0.5 billion by the end of next

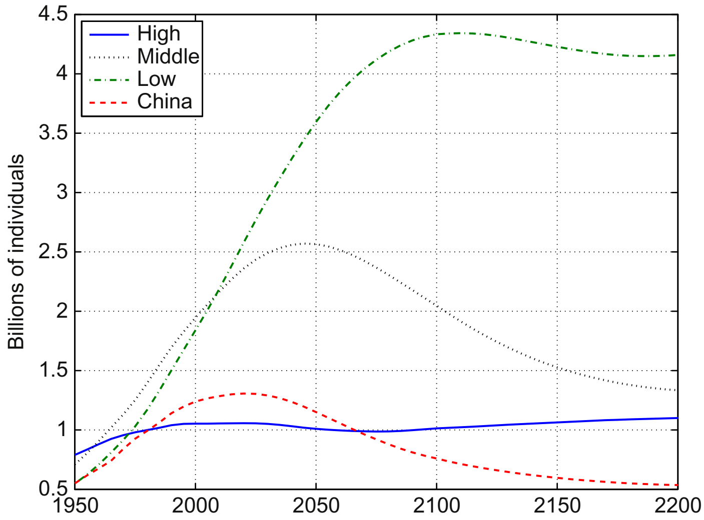

Fig. 4 Population levels.

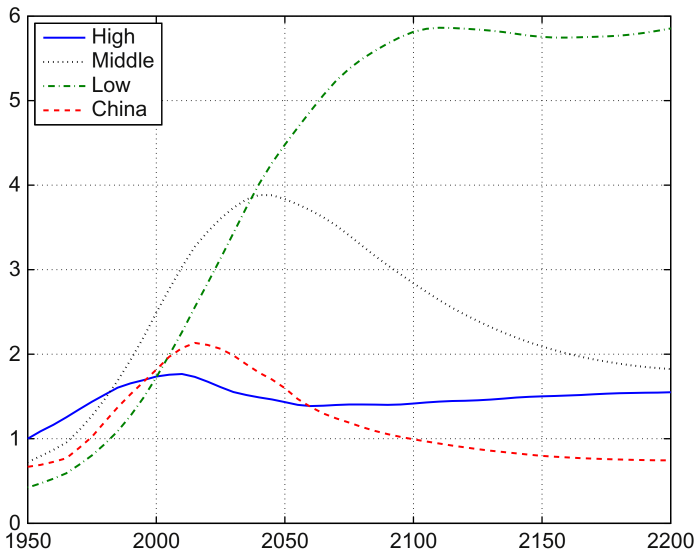

Fig. 5 Labor supply.

century, and the predominant role of Low-Income countries, that will account for more than a half of the world's population already before the end of this century. The implications of these patterns for labor supply are shown in Fig. 5, under some assumptions that are detailed in the next section. In this figure, labor supply is expressed in efficiency units, and is normalized to unity in High-Income region in the initial year (1950). The most striking features are a steady increase in labor supply in Low-Income region until it reaches a plateau around the year 2100, and the bell shapes of labor supply in China (peaking around 2020) and Middle-Income countries (with a later peak around the year 2045). High-Income countries are much more stable over time, where after some growth over the 1950–2000 period, we observe a gentle decline until 2050 and a slow recovery afterward.

6. MODEL

The model we present in this part updates and extends the one developed by Attanasio et al. (2006, 2007). It is a general equilibrium, OLG model of four 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).

6.1 Economic Environment

6.1.1 Preliminaries

The world economy is composed by four regions, (1) High-Income region H, (2) Middle-Income region M, (3) Low-Income region L, and (4) China C. The four regions differ in demographic structure, total factor productivity level, individual endowment profiles, and fiscal institutions. In what follows these differences are spelled out more in 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 four regions, with $r \in \{H, M, L, C\}$.

6.1.2 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 aggregate labor supply (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.

6.1.3 Demographics

Each region is populated by OLG of ex-ante identical "pairs of individuals" who may live for a maximum of $\bar{I}$ periods and their age is indexed by $i = 1, 2, \ldots, \bar{I}$. Pairs of individuals are dependent children for the first I^d periods of their life and then they turn adult and form a household. For a pair of individuals born in region r, denote by $s^r_{i,t}$ 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

$$S^r_{i,t} = \prod_{j=1}^{i} s^r_{j,t+(j-i)},$$

where $S^r_{1,t} = s^r_{1,t} \equiv 1$ 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 $\phi^r_{i,t}$. During childhood, i.e., until age I^d, fertility is assumed to be zero. For what follows, it is useful to define $d^r_{i,t}$ as the total number of (pairs of) dependent children living in a (adult) household of age i at time t, i.e.,

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

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

$$\Gamma^r_t = \begin{bmatrix} \phi^r_{1,t} & \phi^r_{2,t} & \cdots & \cdots & \phi^r_{\bar{I},t} \\ s^r_{2,t+1} & 0 & \cdots & \cdots & 0 \\ 0 & s^r_{3,t+1} & 0 & \cdots & 0 \\ 0 & 0 & \ddots & \ddots & 0 \\ 0 & 0 & \cdots & s^r_{\bar{I},t+1} & 0 \end{bmatrix}.$$

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^r_t is the growth rate of the population between time t and $t+1$, which we denote as γ^r_t (see also Rios-Rull, 2001).

Since we are interested in the economically active population, we reshape the matrix Γ^r_t and the vector $\boldsymbol{\mu}^r_t$ down to size $I = \bar{I} - I^d$ and 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^r_t to converge across regions as t becomes large, in order to generate a common long-run growth rate of the population γ.[f]

[f] 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.

6.1.4 Household Preferences

Households of age i at time t in region r are composed by 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 based on the intra-period utility function

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

where $c_{i,t}^a$ denotes consumption for the adults, $c_{i,t}^d$ consumption per dependent child, and $\omega\left(d_{i,t}^r\right)$ 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 to express utility only as a function of the total consumption of the household $c_{i,t} = c_{i,t}^a + d_{i,t}^r c_{i,t}^d$. From the optimality condition of the household with respect to $c_{i,t}^d$ one obtains

$$c_{i,t}^d = c_{i,t}^a \omega\left(d_{i,t}^r\right)^{\frac{1}{\theta}}, \tag{2}$$

which sets optimally 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

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

where $\boldsymbol{\Omega}_{i,t}^r = \left[1 + \omega\left(d_{i,t}^r\right)^{\frac{1}{\theta}} d_{i,t}^r\right]^{\theta}$ and acts like an age- and time-dependent preference shifter. To conclude, the intertemporal preference ordering for households born (adult of age $i = 1$) at time t is given by

$$U^r = \sum_{i=1}^{I} \beta^{i-1} S_{i,t+i-1}^r \boldsymbol{\Omega}_{i,t+i-1}^r \frac{c_{i,t+i-1}^{1-\theta}}{1-\theta}, \tag{4}$$

where β is the subjective discount factor. There is no explicit altruistic motive.

6.1.5 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 $\mathbf{d}_{i,t}^r$ 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

$$l_{i,t}^r = \begin{cases} \Lambda_t^r\left(\mathbf{d}_{i,t}^r\right) & \text{if } i < I^R \\ 0 & \text{otherwise,} \end{cases} \tag{5}$$

$\Lambda_t^r\left(\mathbf{d}_{i,t}^r\right)$ is an exogenous fraction of time that each household of age i in region r devotes to the market work at time t. The function $\Lambda_t^r\left(\mathbf{d}_{i,t}^r\right)$ 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 $\varepsilon_{i,t}^r$ efficiency units of labor for each unit of time worked in the market. Finally, we assume that the initial asset holding of each household is zero, i.e., $a_{1,t} = 0$ for any t in all regions.

6.1.6 Household Budget Constraint

Let $a_{i,t}^r$ 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:

$$\left(1+\tau_{c,t}^r\right)c_{i,t}^r + s_{i+1,t+1}^r a_{i+1,t+1}^r = y_{i,t}^r + \left[1+\left(1-\tau_{a,t}^r\right)r_t\right]a_{i,t}^r. \tag{6}$$

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

$$y_{i,t}^r = \begin{cases} \left(1-\tau_{w,t}^r\right)w_t^r \varepsilon_{i,t}^r l_{i,t}^r = \left(1-\tau_{w,t}^r\right)\widetilde{y}_{i,t}^r & \text{if } i < I^R, \\ p_{i,t}^r & \text{if } i \geq I^R, \end{cases} \tag{7}$$

where w_t^r is the wage rate, $\varepsilon_{i,t}^r$ is the efficiency units of labor of an individual of age i, and $p_{i,t}^r$ is pension income. $\widetilde{y}_{i,t}^r$ is the before-tax labor income. Households pay taxes $\tau_{c,t}^r$ on consumption, $\tau_{a,t}^r$ on capital income, and $\tau_{w,t}^r$ 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

$$p_{i,t}^r = \kappa_t^r \frac{W_{i,t}^r}{I^R - 1},$$

where κ_t^r is the replacement ratio of average past earnings. Cumulated past gross earnings $W_{i,t}^r$ are defined recursively as

$$W_{i,t}^r = \begin{cases} \widetilde{y}_{1,t}^r & \text{if } i = 1 \\ \widetilde{y}_{i,t}^r + W_{i-1,t-1}^r & \text{if } 1 < i < I^R \\ W_{i-1,t-1}^r & \text{if } i \geq I^R. \end{cases} \tag{8}$$

6.1.7 Government Budget Constraint

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

$$G^r_t + (1+r_t)B^r_t + \sum_{i=I^R}^{I} p^r_{i,t}\mu^r_{i,t} = \tau^r_{w,t} w^r_t \sum_{i=1}^{I^R-1} \mu^r_{i,t}\varepsilon^r_{i,t}\Lambda^r_{i,t} + \sum_{i=1}^{I} \mu^r_{i,t}\left(\tau^r_{a,t} r_t a^r_{i,t} + \tau^r_{c,t} c^r_{i,t}\right) + B^r_{t+1}. \tag{9}$$

6.1.8 Commodities, Assets, and Markets

There are three goods in the world economy: a final good which can be used either for consumption or investment, the services of labor, and the services of capital. The price of the final good (homogeneous across the four 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 four regions, so there is one world market for capital. We denote as N^r_t 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 the positive and negative external wealth across regions is zero by definition, that is, $\sum_{r=1}^{4} N^r_t = 0$ 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 imply that the return on all regional bonds is equal to the return on physical capital, r_t, as we have already implicitly assumed when we wrote the budget constraints of the government and households.[g]

6.2 Equilibrium

Before stating the definition of equilibrium, it is useful to point out that, without further restrictions, the equilibrium path of the fiscal variables $\left\{G^r_t, \kappa^r_t, \tau^r_{w,t}, \tau^r_{a,t}, \tau^r_{c,t}, B^r_t\right\}_{t=1}^{\infty}$ 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 $\left\{\tau^r_{w,t}\right\}_{t=1}^{\infty}$. 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.

[g] In analogy with the definition of equilibrium stated in the next section, we report throughout the chapter the open economy interest rate r_t, which by definition is equal in each region r to the world interest rate.

A *Competitive Equilibrium of the Four-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 $\{G_t^r, \kappa_t^r, \tau_{a,t}^r, \tau_{c,t}^r, B_t^r\}_{t=1}^{\infty}$, is a sequence of: (i) households' choices $\left\{\{c_{i,t}^r, a_{i,t}^r\}_{i=1}^{I}\right\}_{t=1}^{\infty}$, (ii) labor income tax rates $\{\tau_{w,t}^r\}_{t=1}^{\infty}$, (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 $\left\{\{c_{i,t}^r, a_{i,t}^r\}_{i=1}^{I}\right\}_{t=1}^{\infty}$, 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 labor supply 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 $\{\tau_{w,t}^r\}_{t=1}^{\infty}$ 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

$$K_{t+1}^r - (1-\delta)K_t^r + N_{t+1}^r - (1+r_t)N_t^r = F(Z_t^r, K_t^r, H_t^r) - C_t^r - G_t^r. \tag{14}$$

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

$$X_t^r = K_{t+1}^r - (1-\delta)K_t^r, \tag{15}$$

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

$$S_t^r = F(Z_t^r, K_t^r, H_t^r) + r_t N_t^r - C_t^r - G_t^r. \tag{16}$$

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

$$S_t^r - X_t^r = CA_t^r = N_{t+1}^r - N_t^r, \tag{17}$$

and it equals the change in the net foreign asset position of region r. Moreover, in this four region economy, $\sum_{r=1}^{4} CA_t^r = 0$.

7. CALIBRATION

7.1 Preliminaries

We calibrate parameters of the model using demographic and economic data that are available for periods between 1960 and 2010 in the four regions. We assume that all demographic and productivity parameters in the four regions converge to the same values by 2200; thus all regions converge to the same balanced growth path some decades 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.[h]

7.2 The Four Regions

The world in our model consists of four regions that differ in the timing of demographic transitions and productivity growth. *High-Income region* includes United States, Canada, Europe, Japan, plus Australia and New Zealand. *Middle-Income region* encompasses countries that recently experienced high economic growth and includes those in Latin America and the Caribbean, as well as India, Russia, South Africa, South Korea, Taiwan, Thailand and Turkey. *Low-Income region* includes countries in Africa (except for South Africa), other Asia and Oceania. The fourth region is China.

7.3 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% 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, 2013) for the period of 1960–2010. We assume a constant growth rate until 2010 to match the historical average.

[h] 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 has the exact same parametrization, thus, for example, different levels of output, and capital stock.

The initial value of TFP in High-Income region Z_0^H is set to 1.0 for normalization. Based upon the WDI data, income per capita in High-Income region was approximately 4.5 × larger than that of Middle-Income region in 2010 and we set the value of Z_0^M, productivity in the initial steady state, to match this ratio. Similarly, High-Income region's GDP per capita was 8.3 × and 4.5 × as large as that of Low-Income region and China, respectively. 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 four regions converge to common values by 2200. We let the TFP growth rate of High-Income region remain the same after 2010 and calibrate the growth rate in each of the other three regions between 2010 and 2200 so that the TFP level will converge to that of High-Income region by 2200. Calibrated parameters are summarized in Table 1.

7.4 Demographic Parameters

Since each model period corresponds to 5 years, we set $I^d = 3$ so that agents become adults and economically active at the model age of 4, which corresponds to 15–19 years old. 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 $I^R = 11$ in the model, which corresponds to age 65–69. All these parameters are common in the four regions.

Age-specific fertility rates are taken from data and projections for 1960–2100 of the United Nations (UN) *World Population Prospects: The 2012 Revision* (2013a). For the periods beyond 2100, we assume that fertility rate at each age converge by 2200 to those of High-Income region projected for 2100, proportionally adjusted so that the total fertility rate is 2.1.

Age-specific surviving probabilities in the four regions for the period 1960–2100 are computed from 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 (2013, ILO). We focus on the ILO data since 1970s, when we have more comprehensive coverage of the countries and population in each region. Fig. 6 displays the trend in female labor force participation rates in the past four decades. Note that

Table 1 Growth rate of TFP 1960–2010

Region	GDP per capita growth, WDI 1960–2010, data (%)	TFP growth rate λ_t^r 1960–2010 calibrated (%)	GDP per capita level, WDI 2010, data	Initial TFP level Z_0^r calibrated
1. High income	2.4	1.64	1 (normalization)	1.00
2. Middle income	2.6	1.58	0.22	0.41
3. Low income	2.4	1.66	0.12	0.34
4. China	6.7	4.51	0.22	0.10

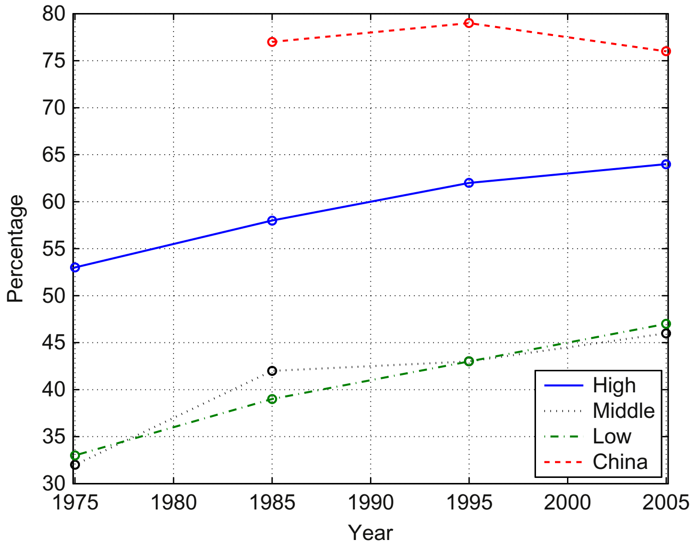

Fig. 6 Female labor force participation rate in four regions.

there are two data points available for China. In order to capture the 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 for the participation rate of women $P^r_{i,t} \in (0,1)$ with an exponential trend for all regions except for China.

$$P^r_{i,t}(\mathbf{d}^r_{i,t}) = \beta^r_0 + (\overline{P} + \overline{T_i} - \beta^r_0)\{1 - \exp[-\beta^r_1 * (t-1)]\} + \sum_{j=1}^{I^d} \hat{\alpha}_j d^r_{i,j,t}, \qquad (18)$$

where β^r_0 measures the participation rate for a female worker with no children in the initial period.[i] $\overline{P} = 0.68$ 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 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 β^r_1 regulates the speed of convergence toward the long-run rate $\overline{P}$. The estimated parameters for High-, Middle-, and Low-Income regions are $(\beta^H_0, \beta^M_0, \beta^L_0) = (0.4191, 0.4412, 0.4248)$ and $(\beta^H_1, \beta^M_1, \beta^L_1) = (0.1686, 0.0482, 0.0810)$, respectively.[j]

For China, female participation rates at available data points in the last few decades are high and remain stable at about 78% in 1980s and 1990s and decline slightly to 76% in 2000s.

[i] Substituting $t = 1$ and $d^r_{i,j,t}$ in Eq. (18) yields $P^r_{i,t}(\mathbf{d}^r_{i,t}) = \beta^r_0$.

[j] Values for β^r_0 represent the participation rate of female workers with no children in each region in 1950.

Therefore we estimate the function (18) without a time trend until 2000 and make the female participation rates change until 2000 only through the time-varying vector $\mathbf{d}_{i,t}^r$ that indicates the number of dependent children. Thereafter, we assume that the participation rate of women without children will linearly converge to the level so that the average participation rate will reach the same long-run value of $\bar{P}=0.68$ in the final steady state.[k]

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

As in Attanasio et al. (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 stronger impact on the probability of female participation. Fig. 7 displays the estimated participation rates of female from 1950 to 2200 in each region as well as the contribution of the fertility trend, relative to the value in 1950 which is set at zero.

We normalize the total population in High-Income region in 1960 to one and set the initial population size for the other three regions to 1.031, 0.807, and 0.769, respectively, based on the UN population data. During the transition away from the initial steady state, the population size in the four regions is determined by the evolution of age-specific fertility rates $\phi_{i,t}^r$ and survival rates $s_{i,t}^r$.

7.5 Preferences and Endowments Parameters

We assume that preferences are common across regions and do not vary over time. Following the bulk of the literature on consumption (for a survey, see Attanasio, 1999), we set $\theta=2$. We set the subjective discount factor β to match the capital output ratio of High-Income region in 2010 to 3.7, based on the data from *Penn World Table* (PWT, Feenstra et al., 2013).

The weight parameter of children in the utility of adult parents is set to match the commonly used consumption adult-equivalent scales. The microevidence on equivalence scales summarized in Fernandez-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

[k] 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 the high female labor force participation in earlier data, which may shift in future as a result of urbanization and a change in the Chinese industrial structure. Therefore, we assumed that the labor force participation rate will decline and converge to that of the other regions in the long run, rather than assuming it to remain high at around 80%.

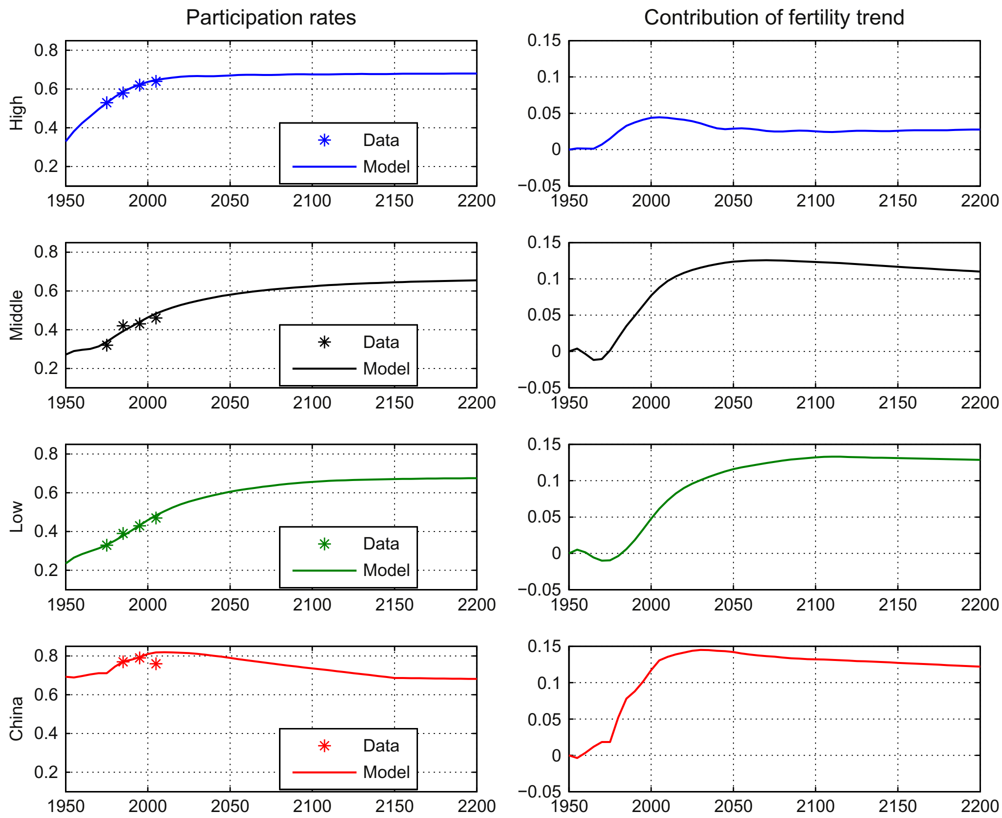

Fig. 7 Estimated female labor force participation rate in four regions.

household without children of 1.231, 1.470, and 1.694, respectively. Using equation (2), it is easy to see that our function $\omega\left(d_{i,t}^{r}\right)$ should satisfy the three moment conditions

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

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 children yields an excellent fit.

The calibration of the age profile of efficiency units is done separately for each region. The age-efficiency profile for High-Income region is estimated on weekly wage data from the US *Consumer Expenditure Survey* (CEX) for the period 1982–1999. For Middle-Income region, we have estimated an age-efficiency profile on Mexican data—precisely from the *Encuesta Nacional de Ingreso y Gasto de los Hogares* (ENIGH), which is the equivalent of the US CEX, using the 1989, 1992, 1994, 1996, 1998, and 2000 waves.[1] 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 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, that 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, 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.

Fig. 8 shows estimated profiles for the four 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 Fig. 8 until 2010, when they start to gradually converge to the profile of High-Income region by 2200.

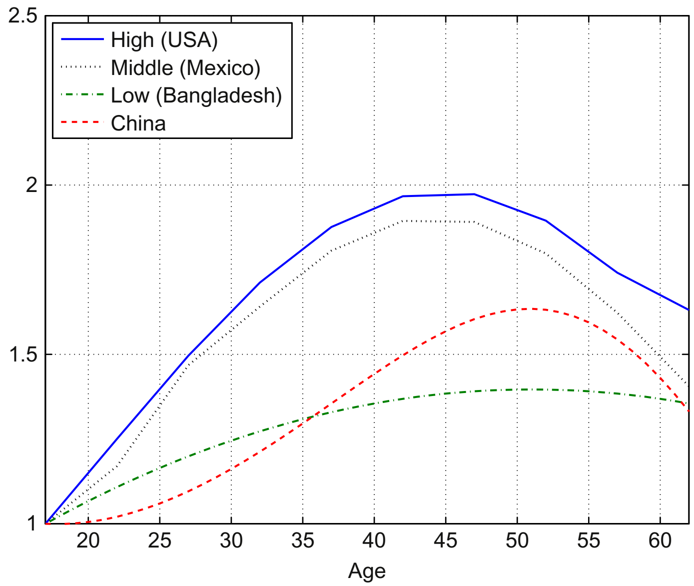

Fig. 8 Wages over the life-cycle.

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

7.6 Government Policy Parameters

We obtain the ratio of the government debt B_t^r as a fraction of GDP from the International Monetary Fund (IMF)'s *World Economic Outlook Database* (WEO, 2013). We use the net debt variable that represents the gross debt net of financial assets. The average over the period 1990–2010 was 48%, 37%, and 51% in High-, Middle-, and Low-Income regions. For China, only gross debt data is available, which is 14% of GDP. Since we do not have the data for the government's financial assets, we assume a net debt of 10% of GDP in the baseline calibration.

The total government expenditures as a fraction of GDP are obtained from the WEO for the period 1980–2010, and from the IMF *Government Finance Statistics* (GFS, 2014) and the *China Statistical Yearbook* of the National Bureau of Statistics of China (n.d.) for earlier years (1970–1980). The average over 1970–2010 was 36%, 23%, 30%, and 22% of GDP in each of the four regions, respectively. Since these figures represent general public expenditures, which include spendings for social security and interest payment, we compute the ratio of the government expenditures G_t^r to GDP so that the total expenditures match the ratios reported above. The ratios of G_t^r to GDP are 29.2%, 22.5%, 28.8% and 21.4% for each of the four regions.[m]

Based on the study of OECD, the replacement rate of pensions to the average earnings is set at $\kappa_t^H = 58\%$ in High-Income region.[n] 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; Latin America is the region with the largest number of pension systems already reformed toward substantial privatization (see Mohan, 2004, for the Asian experience; see Corbo, 2004, for the Latin American experience). We set the replacement rate of the three regions at $\kappa_t^r = 10\%$ in the first steady state, the value used in Attanasio et al. (2006).[o]

For tax rates of each region, we use various data sources for the period of 2000–2010 and estimate effective tax rates following the method of Mendoza et al. (1994). We use

[m] We assume that the ratio G_t^r/Y_t^r is constant throughout the transition in closed economy. We then take the path of the government expenditures G_t^r from the closed economy and assume that the same level of government expenditures in each year needs to be financed in the open economy. Our assumption is that the government expenditures do not vary with the openness of the economy and with the amount of capital flows across regions.

[n] OECD, Pensions at a Glance (2011).

[o] For the details on the scope of the public pension system in China, see He et al. (2015) on the replacement rate and the coverage of urban workers in China, and Song et al. (2015) on ongoing reforms of the nationwide pension system under aging demographics in China.

the OECD *Revenue Statistics* (2013a) database for tax revenues, in particular for High-Income and Latin American countries, integrated with consistent data from IMF GFS for Low and other Middle-Income countries. Detailed national accounts data on households, enterprizes, and government are taken from the OECD *National Accounts Statistics* (2013b) and the UN *National Accounts Statistics* (2013b) databases. Equivalent data for China are not available and we use the estimates of Cui et al. (2011) for the effective tax rates of the country. Capital income tax rates τ_a^r are 35.7% for High-Income region, 15.5% for Middle-Income region, 13.5% for Low-Income region and 25.7% for China. Consumption tax rates τ_c^r are set at 9.7%, 16.0%, 6.3%, and 7.7%, respectively. The labor income tax $\tau_{w,t}^r$ in each region is determined in the equilibrium path of the model to satisfy the government budget constraint, as presented and discussed in the next section.

8. NUMERICAL RESULTS

In this section, we present results for a number of simulations where we compare two scenarios: open and closed economies. We study the dynamics of key economic variables in the four regions of the world we have described above: High Income, Middle Income, Low Income, and China. The economic variables we look at include interest rates, wage rates, equilibrium tax rates, current account, and external wealth. On the basis of above, we shall be discussing some interesting welfare exercises. Comparing welfare along the transition path between the closed and the open economy scenarios allows us to quantify the importance of globalization (free capital mobility). After showing the results of the baseline model we described in the previous section, we shall consider different alternative scenarios for demographics and productivity.

8.1 Baseline Scenario

In Fig. 9 we show interest rate paths that characterize the four regions when the economies are closed, and the world interest rate when instead there is full capital mobility. Even though we let the model start in 1960 and demographic and productivity parameters converge in 2200, we focus on and display results for a shorter time period of 2010–2100. The main purpose for going as far back as 1960 is to approximate the current and projected demographic structure better during the period of our interest.

In the closed economy scenario, Low-Income region and China start with higher interest rates at around 5.7% and 8.2%, respectively.[p] The interest rate is lowest in High-Income countries to begin with. For several decades the interest rate continues

[p] According to Bai et al. (2006) the return to capital in China was very high in the period corresponding to the initial steady state, due to high TFP growth. Though, as stressed in Song et al. (2015), such high return seems not to be accessible to the government and most workers and employees. The large majority of Chinese households hold their wealth in bank deposits and bonds paying low returns, hence our equilibrium level of the real interest rate in closed economy seems to be a plausible figure.

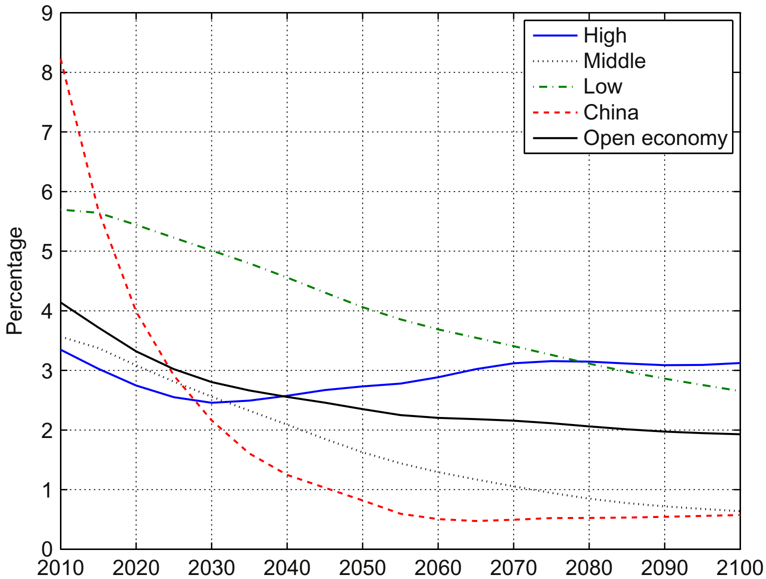

Fig. 9 Baseline scenario: interest rates. The thick solid line represents open economy.

to decline in all regions except High-Income region largely because of the demographic trends we saw in Section 5. Higher longevity calls for more saving to cover consumption expenditures for a longer retirement period. Lower fertility rates and fewer dependent children in households imply a larger fraction of disposable income allocated for savings. In High-Income region, fertility rates reached the bottom in 1990s and have been on the rise since then, which offsets the rise in savings driven by longer life expectancy. In the open economy scenario the world interest rate gently falls from slightly above 4% by about 2 percentage points over the century.

In Fig. 10 we display the equilibrium wage paths separately for each region, where the solid line corresponds to the closed economy and the dotted line corresponds to the open economy. Wage rates are normalized to one in 2010 under the closed economy scenario in each region. Comparing the closed and the open economy outcomes, we observe that wages in the first three decades are higher in the closed economy scenario for High-Income region workers. Only in around 2040 do wages benefit from capital mobility in this region. In Middle-Income region, wages are initially at similar levels in closed and open economies. Wages in the open economy eventually fall below the closed economy level as the capital starts to flow out of the region. Open economy wage rates remain above those of closed economy in Low-Income region throughout the century. In China, wages are higher in the open economy initially due to capital inflow, but the gap between wage rates in the two economies diminishes by mid-2020s and the trend reverses thereafter as more and more capital starts to flow out of China.

Fig. 11 presents our simulation results for the equilibrium tax rates, that is, the tax rates that balance the consolidated government budget constraint in each year. Of particular

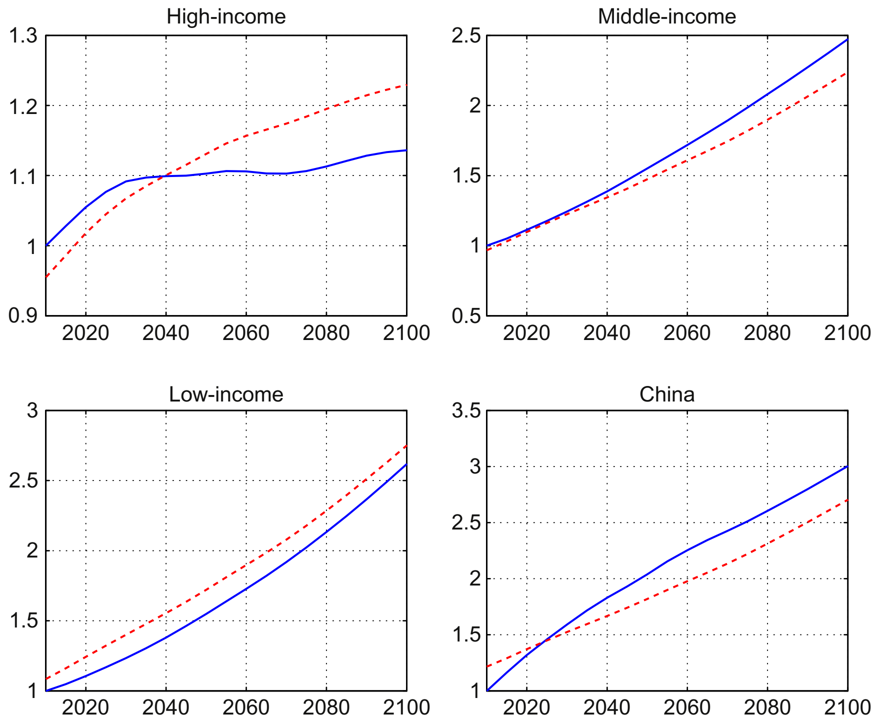

Fig. 10 Baseline scenario: wage rates. Solid lines represent closed economy. Dotted lines represent open economy.

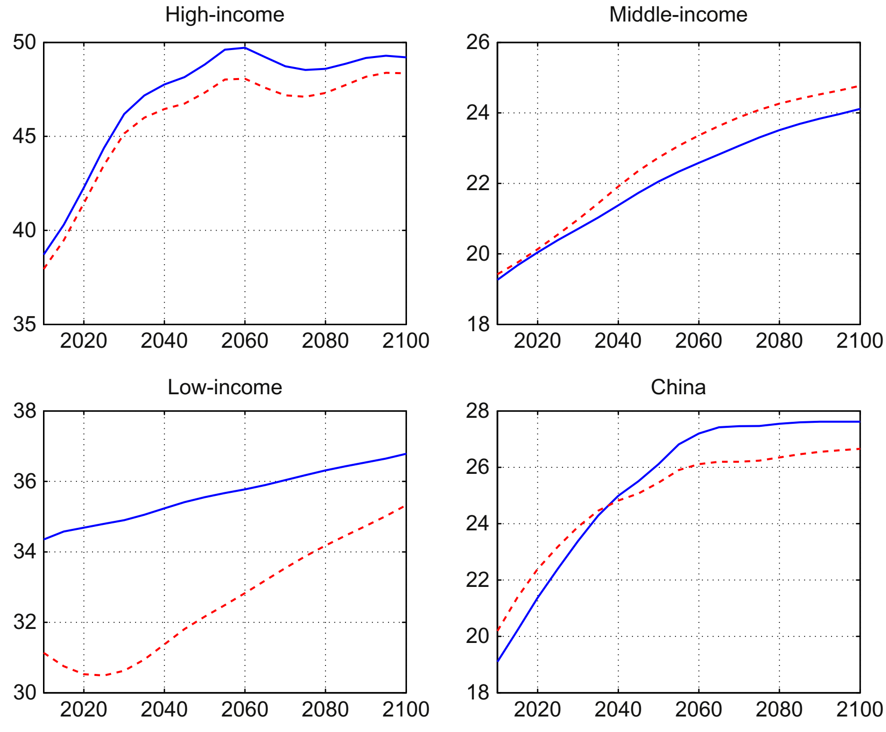

Fig. 11 Baseline scenario: equilibrium tax rates (in %). Solid lines represent closed economy. Dotted lines represent open economy.

interest is the difference in tax rates between closed and open economy scenarios. Taxes are lower in open economy for Low-Income region, even though the difference shrinks with time after 2020. In China the closed economy taxes are slightly lower until late 2030s but lie above the level in the open economy until the end of the century. In Middle-Income region, taxes are almost the same initially, but the tax rates in the open economy rise faster than in the closed economy. In High-Income region, taxes rise in both closed and open economies but the rates are lower in open economy.

To understand these results we should first of all note that government expenditures are computed as a fixed percentage of output in each year in the closed economy and the path of expenditures is kept at the same level in the open economy. Labor tax adjusts to clear the government budget and the budget clearing tax rate depends also on the revenues raised by other taxes, all of which are endogenously determined in equilibrium. In China, for example, wages are higher in the open economy initially but a large decline in interest rate in the open economy during the initial decades reduces capital income tax revenues and equilibrium tax rates are higher than in the closed economy. Of course, the equilibrium labor tax rate depends not only on the interest rate and wage rate, but also on the amount of savings, total consumption and number of workers that affect the size of the labor income tax base.

The dynamics of tax rates in High-Income region is largely driven by population aging. The rise in the old-age dependency ratio increases the fiscal burden to finance the region's generous social security program. The tax rate has to rise by about 15 percentage points in closed economy to cover the rising pension expenditures. In open economy, tax rates also rise but are lower than in closed economy by a few percentage points. As we saw in Fig. 9, the interest rates are higher and the government generates more capital income tax revenues in open economy until 2030s. After that, higher wages and an expansion of the labor income tax base make up for the lower capital tax revenues in the open economy.

In Fig. 12 we show how the current account evolves in the open economy scenario. Recall that the current account is defined as the difference between aggregate domestic savings and aggregate gross investments in each region. A surplus therefore indicates a net capital outflow from the region. Our model predicts a large surplus for China until 2060, a large negative balance for Low-Income countries until the middle of the century, an inflow for High-Income countries. Middle-Income countries start experiencing surpluses from 2020 onward. These capital flows and the underlying stocks (shown in Fig. 13, where external wealth is shown as a percentage of GDP) explain a lot of the differences between the closed and the open economy scenarios in terms of tax rates and capital per capita.

Looking at the paths of capital per capita in each of the four regions (shown in Fig. 14), we notice a major difference between closed and open economies in High-Income region. Capital first rises with an increase in longevity and then (after 2030) declines in the closed-economy case. In the open economy case, instead, capital will continue

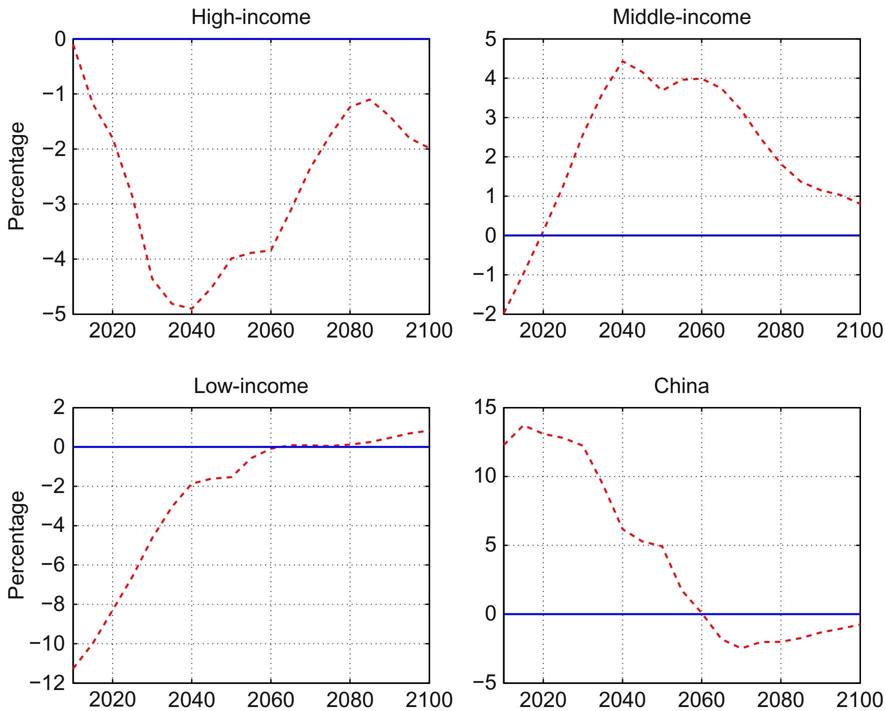

Fig. 12 Baseline scenario: current account as percentage of GDP.

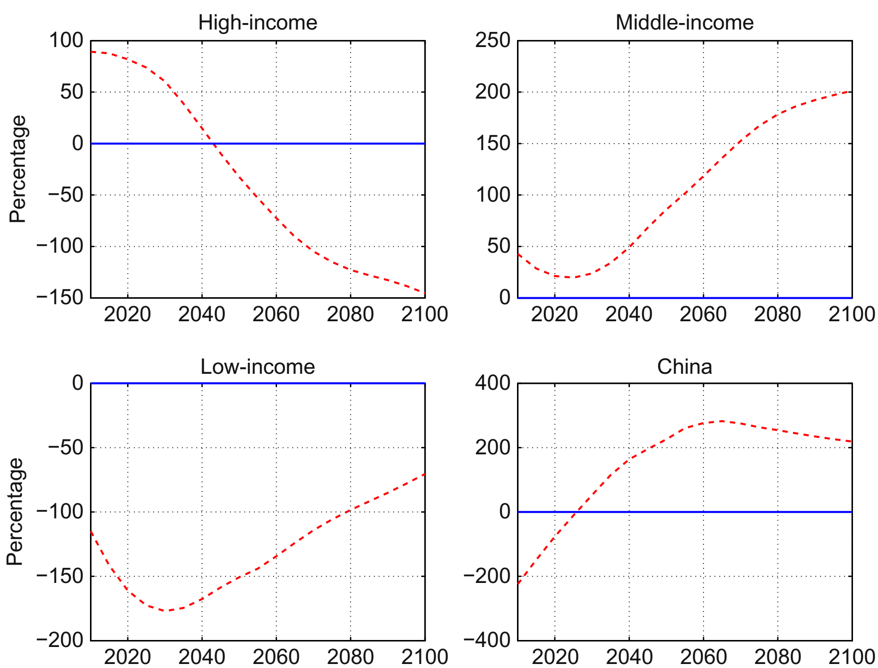

Fig. 13 Baseline scenario: external wealth as percentage of GDP.

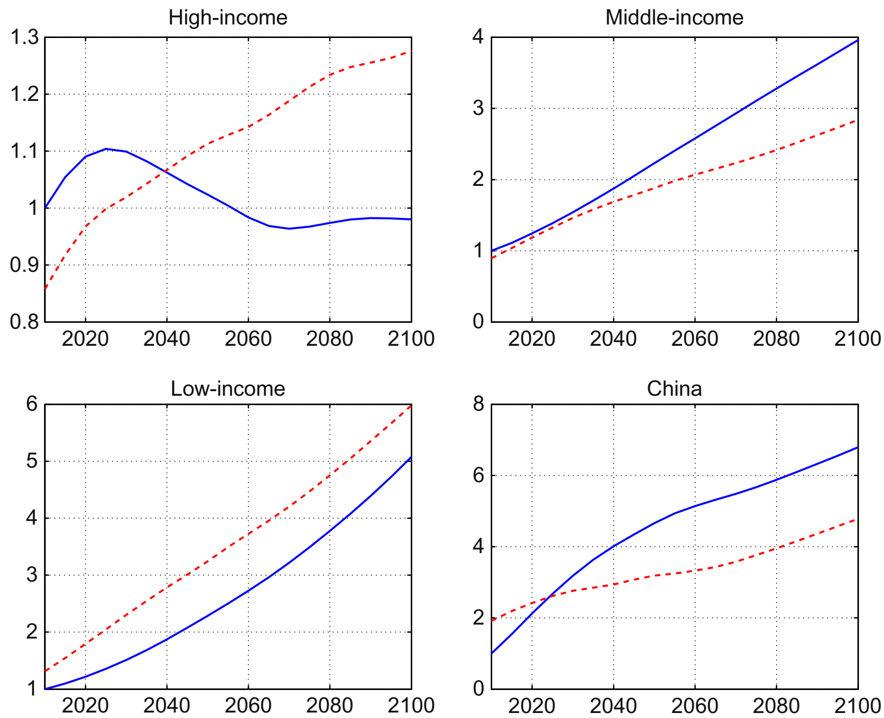

Fig. 14 Baseline scenario: capital per capita. Solid lines represent closed economy. Dotted lines represent open economy.

to rise throughout the century. The difference between these scenarios is driven by the current account balance, partly by the higher interest rates in the closed economy compared to the open economy after 2040 as shown in Figs. 9 and 12. Fig. 13 shows that the external wealth of High-Income region monotonically declines throughout the century, which contributes to a rise in domestic capital in open economy as observed in Fig. 14. After mid-2040s, the external wealth turns negative, that is, people in other regions of the world will start to own claims against capital used in High-Income region.

Open-economy capital in Middle-Income region starts at almost the same level as in the closed economy, but after 2030s it falls below the closed economy level as households start to shift the wealth abroad seeking higher returns. In the capital-starved Low-Income region, capital per capita is consistently higher in the open economy. Finally, in China capital per capita remains lower in open economy after mid-2020s as the country continues to be a lender of capital to the rest of the world.

Fig. 15 presents our computations on the welfare gains brought about by an open economy. The welfare gain of being in open economy is quantified in terms of consumption equivalence. We ask what is the percentage change in consumption at each age that makes a representative agent in each cohort indifferent between being born into an open economy

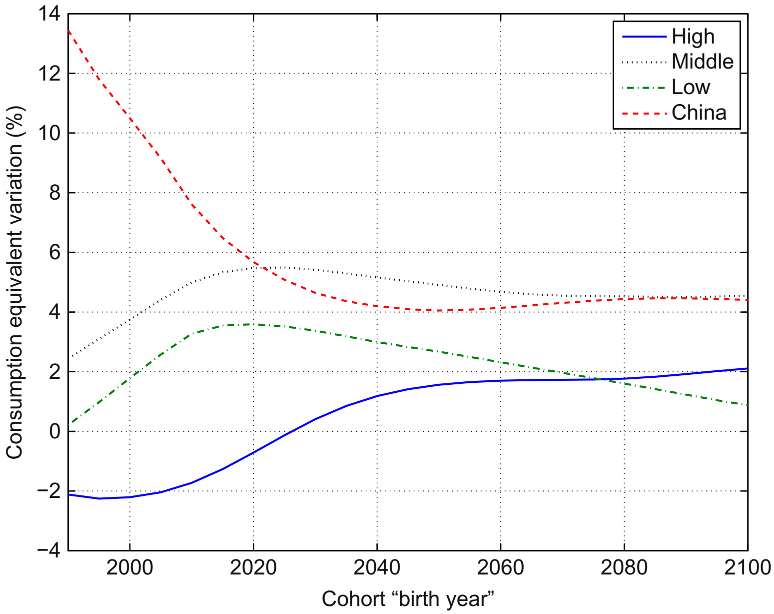

Fig. 15 Baseline scenario: welfare gains.

as opposed to a closed economy. A positive number implies that she likes the open economy better. Here "birth" is the age at which the agent enters the economy as an adult, which is 17.5 years (given that the first age group is defined to cover the age of 15–19). We notice that early cohorts in China gain significantly from being in open economy. This is due to the large capital inflow to the Chinese economy and increased economic activities and wages, as we saw in Figs. 10, 12, and 14. For opposite reasons, people in High-Income region currently alive will lose in the open economy, although generations entering the economy after mid 2020s will prefer the open economy due to the reversal of capital flow after 2040 and a rise in wages. Welfare effects on individuals in Low and Middle-Income region are smaller in magnitude but they all gain from the capital flow across regions. We also note that quantitative measures of welfare changes rely on the magnitude of capital that flows across regions and are sensitive to changes in economic environment. Changes in assumptions that affect cross-regional differences in saving incentives and interest rates, such as pension policies, heterogeneous preferences and factors that limit capital mobility, will affect the level of external wealth and welfare assessments.

8.2 Alternative Scenarios in Low-Income Region

In the benchmark case, Low-Income region is dramatically different from the rest of the world in terms of endowment, demographics and key economic indicators driven by them and remains so for a very long time. In the baseline model we assume that TFP levels and growth rates as well as all the demographic parameters and preferences converge to those of High-Income region slowly and the convergence will be complete by as late as the year 2200. In this section, we simulate our model under alternative scenarios of convergence in productivity and demographics in Low-Income region. We also run an experiment in which there is return risk to investment in capital located in Low-Income region.

8.2.1 Fast Productivity Convergence

The recent experience of China and of some Middle-Income countries (the so-called BRICS) suggests that convergence could very well be much faster than had been anticipated: after all, fertility rates are already dropping at a very high speed in most Low-Income countries, and it is perfectly possible that total factor productivity also catches up in a shorter time than we envisaged in our benchmark.

The experiment we consider here is one where the level and the growth rate of total factor productivity of Low-Income region converge to those of High-Income region by the year 2100, rather than 2200. All remaining features of the model are unchanged. To facilitate comparison of values between the benchmark case and the experiment, the level variables (wage and capital) are normalized by the closed economy value of the initial year, 2010, in the benchmark economy.

Fig. 16 compares the closed-economy interest rates in the four regions and the world interest rate of the open economy. Compared to the benchmark scenario shown in Fig. 9,

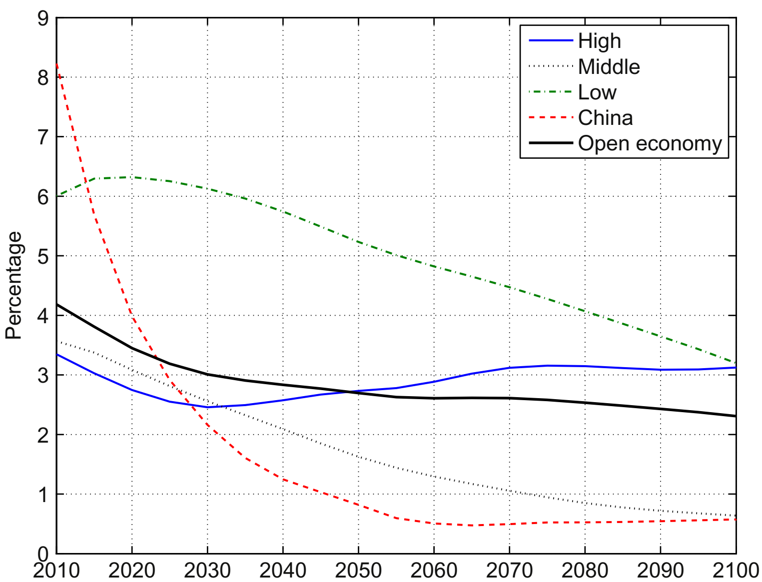

Fig. 16 Fast productivity convergence in Low-Income region: interest rates. The thick solid line represents open economy.

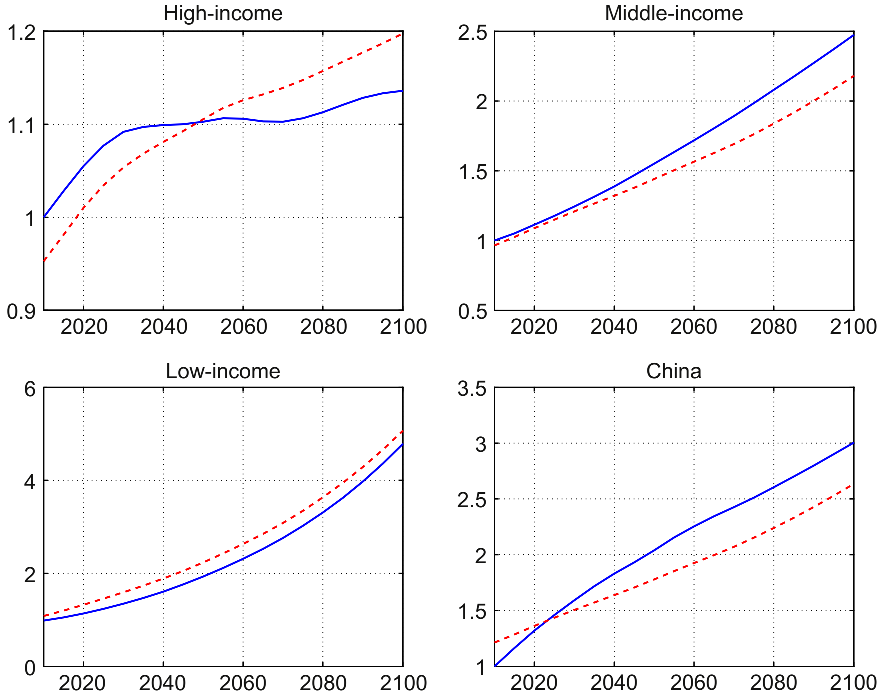

Fig. 17 Fast productivity convergence in Low-Income region: wage rates. Solid lines represent closed economy. Dotted lines represent open economy.

the interest rate initially rises for about a decade and then falls slowly in Low-Income region. Fig. 17 shows that Low-Income wage grows much faster in both closed and open economy scenarios, as one would expect with the higher productivity growth. The effects on other regions are only felt in the open economy case.

Equilibrium tax rates and the current account balances are not dramatically different from the benchmark scenario, with the noticeable exception of current account in Low-Income region, which starts at a much more negative level and reaches parity at a later date, as shown in Fig. 18. The current account deficit amounts to about 17% of GDP in 2010, while it was about 12% of GDP in the baseline case.

Important differences are observed when we look at capital per capita, shown in Fig. 19. In both closed and open economy scenarios, capital in Low-Income region grows much faster in this experiment compared to the benchmark case, and the difference between the two is also larger in percentage points of GDP as time goes by, since in the open economy scenario the region attracts larger capital inflows with the higher interest rates. Capital per capita is much lower in open economy compared to the benchmark case in High-Income region, Middle-Income region, and in China. The closed-economy interest rate of High-Income region does not exceed that of open economy

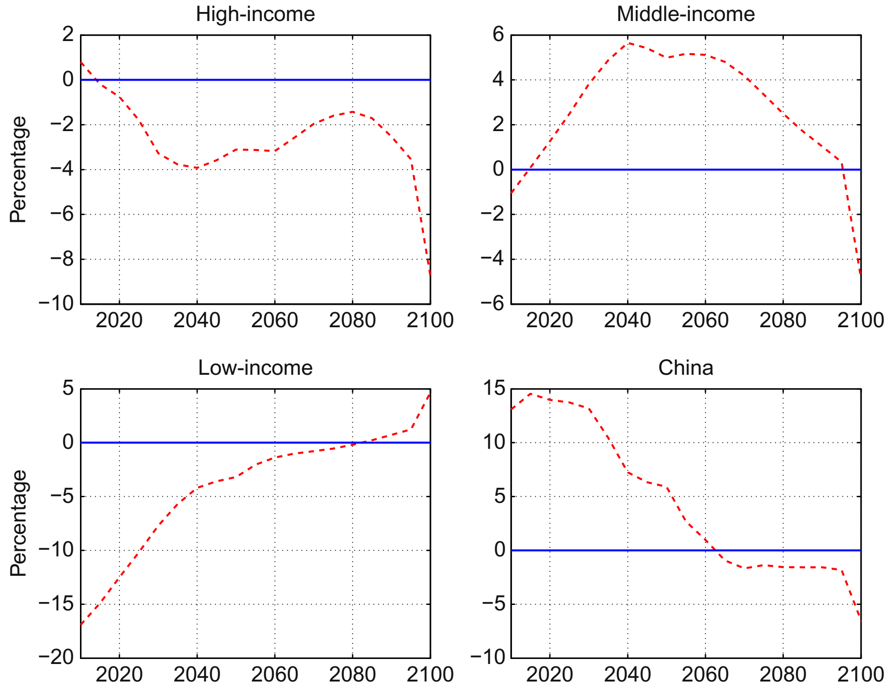

Fig. 18 Fast productivity convergence in Low-Income region: current account as percentage of GDP.

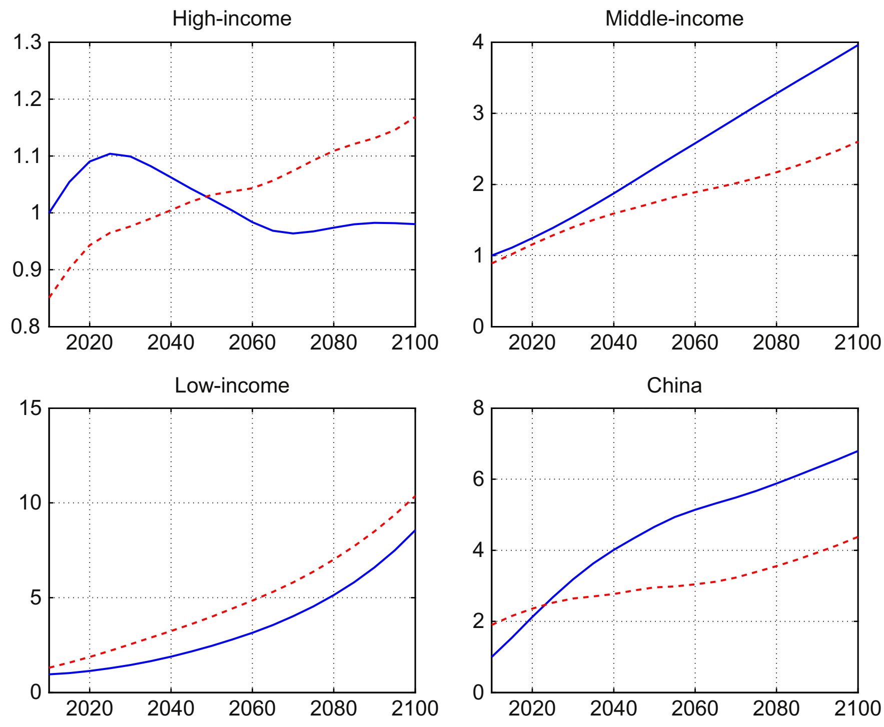

Fig. 19 Fast productivity convergence in Low-Income region: capital per capita. Solid lines represent closed economy. Dotted lines represent open economy.

until close to 2050, implying that the external wealth remains positive much longer in the region and remains higher throughout the century.

8.2.2 Fast Convergence in Longevity in Low-Income Region

Next we simulate a model assuming that the longevity in Low-Income region improves faster than in the baseline model and let the age-specific survival rates converge to the values of High-Income region by 2100, rather than 2200. The rapid increase in longevity strengthens saving motives of households in order to cover the cost of consumption for a longer retirement period. As shown in Fig. 20, closed economy interest rates of Low-Income region decline faster than in the baseline case. The interest rates go below those of High-Income region after 2060 and almost reach but do not yet intersect with the path of the open economy interest rates at the end of the century.

The current account turns positive by 2040 as shown in Fig. 21, while it remains negative until 2060 in the baseline model. Low-Income region remains as a large borrower throughout the century, but the level of borrowing is significantly smaller as shown in the smaller amount of external debt in Fig. 22 compared to the baseline model.

8.2.3 Investment Risk in Low-Income Region

In the baseline model we assumed free capital mobility with no risk involved in investment abroad. Here we introduce capital market risk in Low-Income region and assume

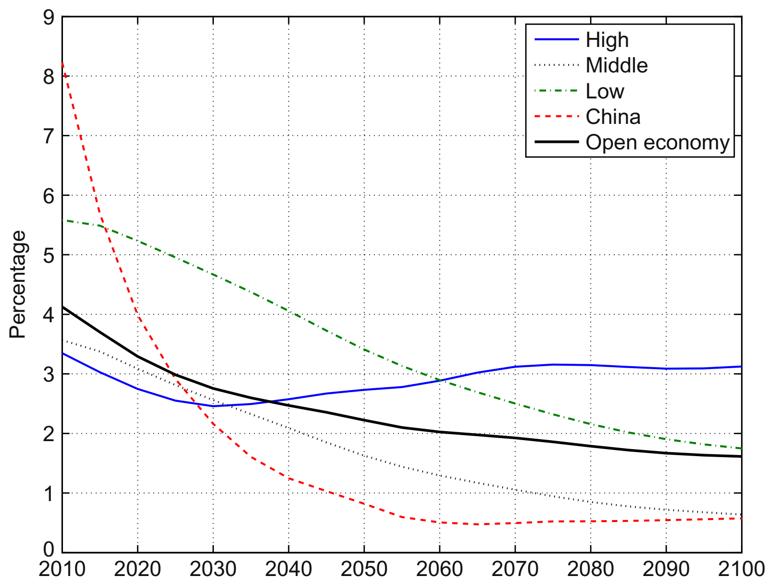

Fig. 20 Fast convergence of survival rates in Low-Income region: interest rates. The thick solid line represents open economy.

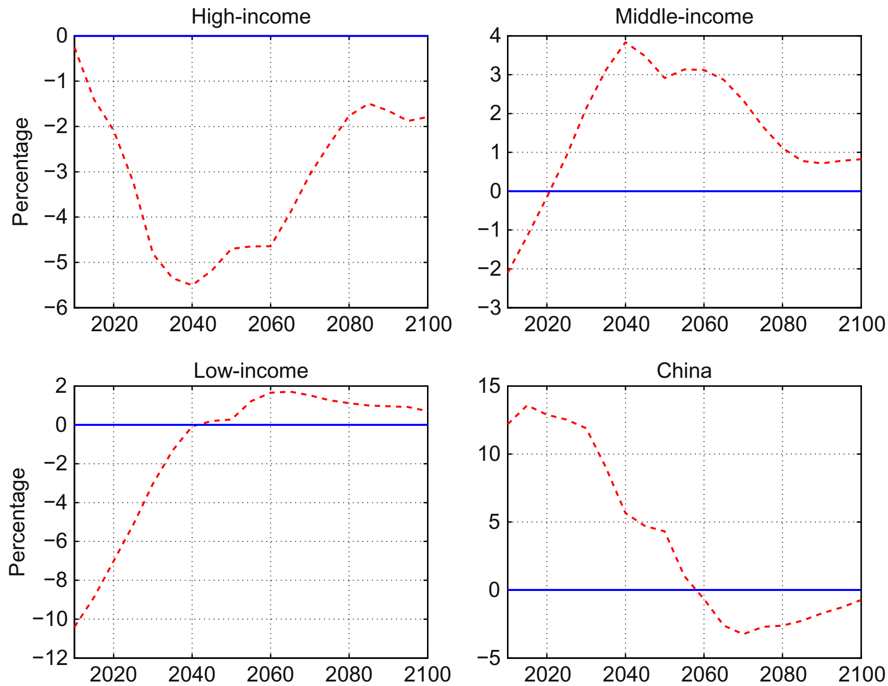

Fig. 21 Fast convergence of survival rates in Low-Income region: current account as percentage of GDP.

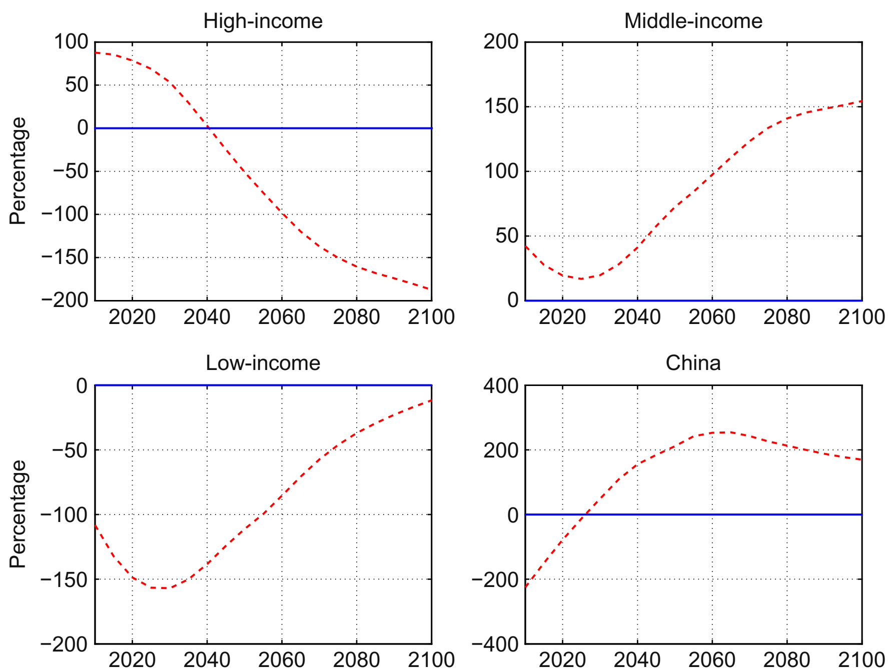

Fig. 22 Fast convergence of survival rates in Low-Income region: external wealth as percentage of GDP.

that lenders to the region receive a return from investment which is lower than the return in a frictionless market. More precisely, the actual interest rate paid to the owners of capital is 80% of the gross return implied by the marginal product of capital.

Fig. 23 shows the paths of interest rates, where the interest rates of Low-Income region represent the gross interest rates prior to the 20% reduction faced by the lenders. The capital will be lower with the investment risk and the gross return will be higher in Low-Income region than in the baseline case. In the open economy, Low-Income region will have less capital owned by foreigners and the current account improves slightly, as shown in Fig. 24.

8.2.4 Additional Experiments

We simulated our model under a variety of alternative scenarios: (1) faster convergence in efficiency unit profiles in Low-Income region; (2) faster convergence in TFP in China; (3) faster convergence in fertility rates in Low-Income region and China; (4) faster convergence of longevity in China. By and large the effects on factor prices are not very significant under these experiments and paths of key economic variables look similar to those in the benchmark model.

8.3 Summing Up

The model of the world economy we have discussed is obviously unrealistic in many ways and the results we have obtained should be taken and interpreted with care.

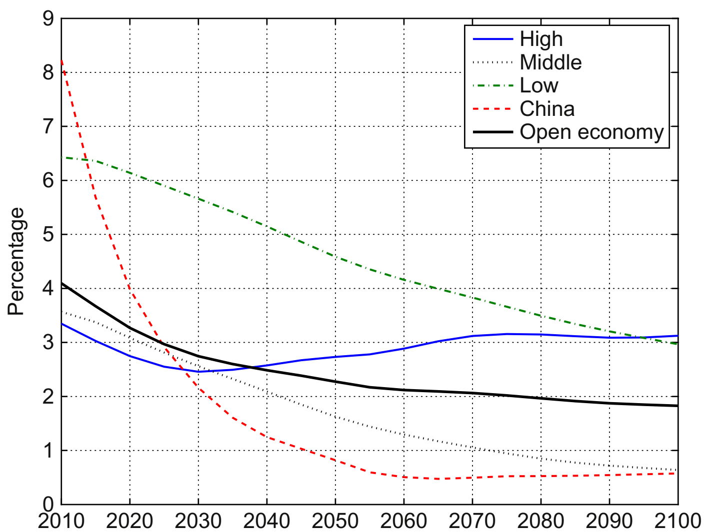

Fig. 23 Investment risk in Low-Income region: interest rates. The thick solid line represents open economy.

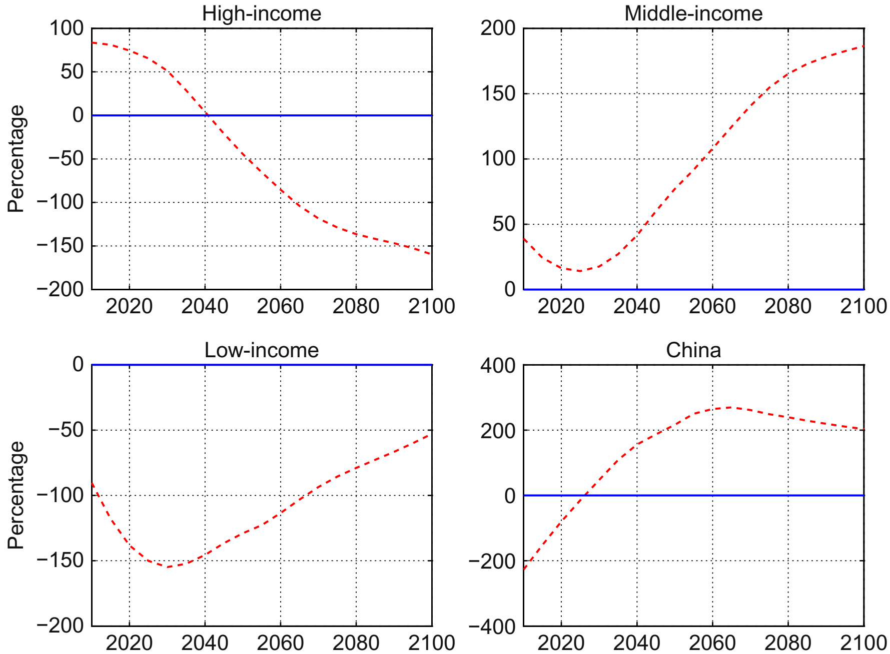

Fig. 24 Investment risk in Low-Income region: external wealth as percentage of GDP.

However, the exercise we have performed is indicative of the way in which this type of medium-scale OLG models of open economies can be developed and used. Although they abstract from many realistic feature of the real economy, they are instructive of how demographic trends put pressures on fundamental economic variables and how these effects are mediated by other factors, such as the mobility of factors of production and the nature of institutions. An understanding of these forces and effects is crucial for the design of public policies.

The main result is that the overall downward trend in real interest rates is somewhat smoothed out by factor mobility, as one would expect given the fact that the demographic trends in different regions are far from synchronized. The simulations also provide the implications for the tax rates that would be necessary to maintain a certain level of social security. In addition to a benchmark scenarios, we have also explored a variety of different alternatives that attempt to capture the high level of uncertainty about future trends in fundamental variables, such as relative productivity.

Probably the most important omission in the exercise we have performed is that of labor mobility. In our model, we have assumed that labor is completely fixed. In reality, we know that labor flow is extremely important and that there are very powerful economic incentives to migration that in some regions in recent years have been accentuated by conflicts and wars. The study of models that incorporate migration flows in a realistic fashion and develop the early contributions in this field, such as Storesletten (2000), would be extremely interesting and important.

9. CONCLUSION

In this chapter we have reviewed the recent literature on the effects of changing global demographic trends on consumption and on factor prices. We have also constructed, calibrated and simulated an OLG model of the world with four regions. Although the exercise forces upon us many strong assumptions and simplifications, it provides a useful tool to quantify the effects of important demographic trends on savings, consumption, and factor prices. We find that capital mobility can attenuate some of the negative impacts of demographic trends in the High-Income region and, in general, can lead to important welfare gains in many regions. A large difference in interest rates across regions that would prevail in the closed economy could induce significant flows of capital in the open economy, changing factor prices, tax bases, and fiscal conditions of each region. For example, we have shown that a large inflow of capital to China in early years due to its demographic transition that is unsynchronized with other regions can bring a major welfare gain, although the reversal of capital flows in later years can reduce the gains from the openness.

If we compare our model to the literature review, we notice that several questions could be addressed by extending the model in different directions. First, it remains an open question whether the very different saving behavior observed across regions is rooted in additional heterogeneity in preferences such as (long) habits. One needs to build a model in which the life-cycle decisions of households depend on their past behavior or the history of aggregate economy to address such questions. Second, the model we developed in the chapter assumes that a household acts as a unit of decision making and abstracts from the decision of household members and their interaction. By explicitly modeling female labor supply decisions, for example, the model would be able to assess whether there is a window of opportunity for Middle-Income and Low-Income countries associated with a rise in female participation rates. Third, the model assumes that capital is the only factor that moves freely across regions and labor is immobile. An interesting extension of course would be to allow for (at least some) labor mobility as well, in response to the unsynchronized transition of demographic across regions and study the impact on factor prices, consumption, and welfare. We trust that these open issues will be subject of more research in the near future.

The following is the Supplementary material related to this chapter.

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