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Demographic trends and international capital flows in an integrated world

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Demographic Trends and International Capital Flows in an Integrated World

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Abstract

This paper examines the impact of projected demographic trends on international capital flows. The analysis builds upon a ten-region overlapping generations' model of the world economy where capital is mobile across regions. Results show that, over the first half of the century, emerging regions will finance the demand of capital coming from the developed world where population aging is relatively advanced. In particular, the findings suggest that in the coming decades China will be the world's main creditor region. However, in the second half of the century, India will take over this leading position because of the predicted decline in the Chinese labor force. An additional analysis demonstrates that the economic consequences of demographic changes depend on the degree of capital market integration between regions.

Keywords: Demographic trends; capital flows; overlapping generations; general equilibrium; multi-regional model

JEL Classification: J11; F21; D91; C68

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1 Introduction

Demographic projections for the 21st century indicate that population is aging all over the world. At the same time, the pace and intensity of this demographic transition are different across countries, see the “World Population Prospects” (U.N., 2009). Population aging is extremely advanced in OECD countries, while other world regions experience lower old-age dependency ratios and their working-age population will still rise. According to life-cycle theory, a household’s age influences its saving behavior (Modigliani & Bumberg, 1954). Since a country’s current account balance is determined by its savings-investment imbalance, the age structure of the population impacts the current account balance. In a more and more globalized world, these cross-country differences in demographic dynamics can result in current account differences via capital flows from fast-aging regions to regions with high population growth.

Some authors found empirical evidence between demographics and various macroeconomic variables: savings, investments and capital flows (e.g., Higgins, 1998). However, a country’s foreign asset dynamics depends not only on its *own* demographic structure but also on those of its trading partners. A recent wave of studies rely, therefore, on multi-country or multi-region general equilibrium models to account for the impact of cross-country demographic changes. A range of studies uses demographic *projections* in this type of frameworks to quantify the consequences of *pension reforms* on the viability of the social security systems (Fehr et al., 2003; Börsch-Supan et al., 2006; Attanasio et al., 2007; Aglietta et al., 2007). Krueger & Ludwig (2007) focus on the effects of projected demographic trends on the distribution of wealth and welfare in OECD countries. By using calibrated life-cycle models several authors find that changes in demographics explain a large part of *historical* current accounts (Henriksen, 2002; Feroli, 2003; Domeij & Floden, 2006).

In contrast, the aim of this study is to explore the consequences of *future* demographic changes on international capital flows and current accounts. The methodology consists of a multi-regional general equilibrium model characterized by overlapping generations dynamics and calibrated to real data. The present approach differs in several aspects from existing models. First, the present model accounts for developed and developing regions, while most analyses in this literature rely on models calibrated to developed economies only. Exceptions are Attanasio et al. (2007), Aglietta et al. (2007) and Brooks (2003).¹ Apart from getting a step closer to reality, calibrating the demographics of developing regions matters because the “lack of synchronization in the demographic trends between North and South generates [...] major economic forces that have not been fully explored in this literature” (Attanasio et al., 2007). Attanasio et al. (2007) and Aglietta et al. (2007) deal with the impact of pension reforms. Hence, in terms of the issue addressed, this study is more

¹Aglietta et al. (2007) use the six-region model of the world economy, developed by the French INGENUE team and accounting for the population dynamics of developed and developing countries. Attanasio et al. (2007) build a two-region model, grouping developed countries in a Northern region and developing countries in a Southern region.

closely related to Brooks (2003), who also focuses on the consequences of differential demographic on current accounts. In Brooks (2003) individuals live deterministically for four periods; whereas the present model possesses, among other differences (see below), a richer life-cycle structure.

Besides, this study presents the advantage of dealing with a large number of regions. The model groups the world's countries into ten regions according to geographical criteria. As remarked by Domeij & Floden (2006), the general equilibrium analysis forces "the sum of current accounts in the world economy to balance in each period". Focusing on a small number of regions or only on developed countries may give an incorrect picture of the demographic impact on current accounts, since it excludes the possibility that all of the studied regions run current account deficits or surpluses. Attanasio et al. (2007) develop a two-region model, grouping developed countries in a Northern region and developing countries in a Southern region. Brooks (2003) builds on an eight-region model of the world economy, but with a more limited economic structure (for instance, the absence of pension systems). In this respect, the present model is closer to Aglietta et al. (2007), who exploit the first version of the world model developed by the French INGENUE team; a six-region model, accounting for the population dynamics of developed and developing countries and incorporating a public sector (see also Ingenue Team, 2002). The second version of the INGENUE model has been enlarged to ten regions, similar to the present model, which, however, differs from INGENUE in the two following aspects.

Another original feature of the present framework is that it distinguishes individuals by their educational attainment, while existing models feature agents with homogenous skills.² The present model makes a distinction between low- and high-skilled individuals and calibrates the evolution of educational levels over time. Accounting for this dimension of intra-cohort heterogeneity matters for several reasons. For instance, high- and low-skilled individuals differ in terms of their saving behavior since they perceive different labor incomes, pension benefits etc. The proportion of high-skilled individuals varies by region and affects the international allocation of capital. Finally, the skill-composition of the population drastically changes over time with people becoming more and more educated.

A last specific characteristic of the present model is that it accounts for imperfect capital markets. In most related frameworks, international capital movements are determined only by regional differences in the capital-labor ratio and in productivity. However, at least since Lucas (1990), it is well-known that capital market imperfections might hinder capital to flow from rich to poor regions (see also Alfaro et al., 2008). In this study, region-specific investment risks are based on the risk classification of the OECD (2011a).

²In most related models, individuals differ by age. The few connected frameworks, that consider intra-cohort differences, differentiate individuals by income class. For instance, in Krueger & Ludwig (2007), two classes of individuals of equal size coexist, whose wages differ in terms of deterministic and stochastic components. The present model distinguishes between two educational groups, whose size is calibrated to real data and evolves over time.

This paper examines the consequences of the demographic transition on the world economy over the 21st century. It is found that, over the first half of the century, emerging regions will finance the demand of capital coming from the developed world where population aging is relatively advanced. In fact, when their baby boomers will retire and dissave, Western Europe, Japan and North America will depend on the foreign capital coming from the Chinese, Indian and Latin American regions. In particular, the findings suggest that China will be the world's main creditor region during the next decades. However, in the second part of the century, India will take over this leading position, because the Chinese labor force will start declining as a consequence of its "one child" policy.

The above (baseline) results are obtained under the conservative assumption that exogenous variables (except demographic variables) remain unchanged after 2010. In an additional section, alternative scenarios are investigated, which allow for changes in the evolution of productivity, educational attainments, capital markets frictions and generosity of pension systems. The results obtained with the conservative baseline remain fairly robust to these alternative assumptions on the future. North America and Western Europe are the main debtor regions and China and India the major creditors during the 21st century.

Finally, a subsequent analysis aims at highlighting the importance of capital market integration. For that purpose, the implications of a very simple scenario are explored, in which there is a one-time increase in the population of a specific region. Such a demographic shock may arise as a consequence of family policies. It is found that the demographic change leads to different outcomes in terms of macroeconomic variables (wage and interest rate) and in terms of welfare (consumption profiles) whether capital is mobile or not across regions.

The paper is organized as follows. Section 2 presents the mathematical structure of the world model. The characteristics and assumptions regarding the baseline scenario are briefly defined in Section 3. Section 4 depicts the evolution of the world economy over the 21st century given the population projections in each region of the world. The scenarios considering alternative assumptions on the future are investigated in Section 5. Section 6 describes the impact of a demographic shock under various alternative model structures. Section 7 concludes.

2 The Model

This study develops a computable general equilibrium model of the world economy, with overlapping generations dynamics. The countries of the world are grouped into 10 regions. In each region x , there are three types of agents. *Households* and *firms* maximize their objectives subject to resource constraints, and a *government* levies taxes to finance spending and transfers. There is only one consumption good, and its price is the numeraire of the model. Capital markets are integrated at the world level. Individuals differ by age (8 age classes) and skills (2 skill types). Demographic

variables and education characteristics are exogenous. The model is used to map the official demographic forecasts into the predicted level of GDP per capita and other economic variables. For the time being, the regional index x is hidden for notational convenience.

2.1 Regions

Table 1 presents the models' regions. Three of them consist of developed countries: Japan (JAP), North America (NAM), which comprises the United States plus Canada; and Western Europe (WEU) with Europe-15 as the major members. The other regions comprise developing countries. In what follows, the terms "China" and "India" refer to the Chinese and Indian region, as these two countries make up most of the population of the region they belong to (see Table 7 for the list of countries).

Table 1: List of ten world regions

Region Code	Region Name	Region Code	Region Name
NAM	North America	LAC	Latin America and the Caribbean
JAP	Japan	SSA	Sub-Saharan Africa
WEU	Western Europe	RUS	The Former Soviet Union
EAS	Eastern Europe	CHI	The Chinese world
MEN	Middle East and Northern Africa	IND	The Indian world and Pacific Islands

2.2 Demographics

At each date, some individuals die and a new generation appears. Individuals live a maximum of 8 periods with age classes spanning from 15-24 to 85-94 indexed by $a = 0, 1, \dots, 7$. Households reaching age 15 (age $a = 0$ in this model's notations) at year t belong to generation t . The size of the young generation increases over time at an exogenous growth rate

$$N_{0,t} = m_{t-1}N_{0,t-1} \quad (1)$$

where $N_{0,t}$ measures the initial size of generation t and m_{t-1} is one plus the demographic growth rate, including both fertility and migration. Individuals face a cumulative survival probability decreasing with age. The size of each generation declines deterministically through time as shown by

$$N_{a,t+a} = P_{a,t+a}N_{0,t} \quad (2)$$

where $0 \leq P_{a,t+a} \leq 1$ is the fraction of generation t alive at age a (hence, at period $t+a$). Obviously, $P_{0,t} = 1$ and total population at time t amounts to $N_t = \sum_{a=0}^7 N_{a,t}$. There are high-skilled (superscript h) and low-skilled individuals (superscript l) indexed by j ($= h, l$). Their cohort sizes are given by $N_{0,t}^j = \phi_t^j N_{0,t}$, where ϕ_t^h equals ϕ_t and denotes the proportion of high-skilled individuals among the generation born in t , while ϕ_t^l equals $1 - \phi_t$ and stands for the share of low-skilled among the generation born in t . The proportion of highly educated is calibrated on the data of Barro & Lee (2010), where “high-skilled individuals” identify individuals with some post-secondary schooling (tertiary education) and “low-skilled individuals” comprise individuals with at most a high-school degree (i.e. individuals with primary and secondary education).

2.3 Preferences

As mentioned above, there is life uncertainty at the individual level since agents have a positive probability to die during each period of life. Instead of allowing for accidental bequests, the existence of an insurance mechanism à la Yaari (1965) is postulated, in which there is a perfect annuity market for every contingent consumption. In short, each time an individual dies, her/his assets will be equally distributed among individuals belonging to the same age class.

The expected utility function of high- and low-skilled individuals ($j=h,l$) is assumed to be time-separable and logarithmic as in

$$E(U_t^j) = \sum_{a=0}^7 \beta_{t+a}^a P_{a,t+a} \ln(c_{a,t+a}^j) \quad (3)$$

where $c_{a,t+a}^j$ is the consumption of age class a at time $t+a$ and β_{t+a}^a is the time preference factor.

The budget constraint of low- (l) and high-skilled (h) individuals requires equality between the expected value of expenditures and the expected value of incomes (I). It writes as follows, for $j = h, l$,

$$\sum_{a=0}^7 \frac{P_{a,t+a}}{\prod_{v=1}^a R_{t+v}^*} (1 + \tau_{t+a}^c) c_{a,t+a}^j = \sum_{a=0}^7 \frac{P_{a,t+a}}{\prod_{v=1}^a R_{t+v}^*} I_{a,t+a}^j \quad (4)$$

Incomes consist of labor income (w), pension benefits (b) and other welfare transfers (ζ) as shown by

$$I_{a,t+a}^j = \left[\lambda_{a,t+a}^j (1 - e_{t+a}^j) (1 - \tau_{t+a}^w) w_{t+a}^j + (1 - \lambda_{a,t+a}^j) b_{t+a}^j + \psi_{t+a} \zeta_a^j w_{t+a}^j \right]$$

where $\lambda_{a,t+a}^j$ is the labor participation rate for a j type individual of age class a , w_t^j is labor income of a j type worker, R_t^* is one plus the international interest rate, τ_t^c is consumption tax, τ_t^w stands for income tax, b_t^j represents (individual) pension benefits, ζ_a^j are other welfare transfers received by an individual of type j and are represented as a time-constant fraction of labor income, and, finally, ψ_t is the generosity factor, which is the factor by which these other welfare transfers are

multiplied at time t . Moreover, education is exogenous and individuals spend a fraction e_t^j of their time on education (which is only positive in their first period of life).

Individuals maximize their utility (3) subject to their intertemporal budget constraint (4) with respect to the levels of consumption. The optimal (contingent) levels of consumption for both types of households $j = h, l$ will then be

$$c_{a+1,t+a+1}^j = R_{t+a+1}^* \beta_{t+a} c_{a,t+a}^j \frac{1 + \tau_{t+a}^c}{1 + \tau_{t+a+1}^c}. \quad (5)$$

Equation (5) reveals that the optimal lifetime consumption (c_0 to c_7) of a cohort born in t can be known once its consumption level at age 0 is identified. The optimal level of consumption in the first period of life can be determined by substituting (5) in (4).

Moreover, the implicit asset holdings of each age class can be defined. It is assumed that individuals are born with no assets at time t , or, in other words, there are no bequests. At time $t + a$ with $a > 0$, assets of high- and low-skill individuals ($Z_{a,t+a}^j$) depend on their assets in the previous period ($Z_{a,t+a-1}^j$) plus an interest rate as well on current expenditures (consumption) and incomes (labor income, pension benefits and other welfare transfers). Formally, at the beginning of their first period of life (when $a = 0$), $Z_{0,t}^j = 0$ for all t . For $a > 0$, aggregated assets, for $j = h, l$, correspond to

$$Z_{a+1,t+a+1}^j = R_{t+a}^* Z_{a,t+a}^j + \phi_t^j N_{a,t+a} [I_{a,t+a}^j - (1 + \tau_{t+a}^c) c_{a,t+a}^j] \quad (6)$$

where $N_{a,t+a}$ represents the number of individuals of age class a living at time $t + a$, ϕ_t^j is the proportion of individuals of skill type j among generation t .

2.4 Firms

At each period of time and in each region, a representative firm uses efficient labor (L_t) and physical capital (K_t) to produce a composite good (Y_t). A Cobb-Douglas production function is assumed with constant returns to scale and represented by

$$Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}, \quad (7)$$

where α measures the share of capital income in the national product, and A_t is an exogenous process representing Harrod-neutral productivity. Total efficient labor force, L_t , combines the supplies of high-skilled (L_t^h) and of low-skilled labor (L_t^l) in

$$L_t = v_t L_t^h + L_t^l \quad (8)$$

where v_t measures the rate of substitutability of high- and low-skilled workers and represents also the skill premium (i.e., the ratio of high- to low-skilled wage). Labor is inelastically supplied and

wages adjust so that labor demand is equal to labor supply at the full employment level as follows

$$L_t^j = \sum_{a=0}^7 (1 - e_t^j) \lambda_{a,t}^j \phi_{t-a}^j N_{a,t}. \quad (9)$$

The profit maximization by firms requires the equality of the marginal productivity of each factor to its rate of return as in

$$w_t^j = (1 - \alpha) K_t^\alpha A_t^{1-\alpha} L_t^{-\alpha} \frac{\partial L_t}{\partial L_t^j} \quad (10)$$

$$\text{and} \quad 1 + \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} - \delta = R_t \quad (11)$$

where δ represents the depreciation rate of capital and R_t is the regional interest factor, defined in section 2.5.

2.5 International capital market

In an economy with perfect capital mobility - up to a confiscation rate on the returns to capital (see below) - the aggregate value of world assets equals the market value of the world-wide capital stock plus the sum of the debts of all regions as in

$$\sum_{x \in X} \Omega_t^x = \sum_{x \in X} K_t^x \quad (12)$$

where X is the set containing each world region. Moreover, K_t^x is the sum of the capital stock of region x at time t , Ω is the sum of the assets of all the cohorts of region x , and $d_t^x Y_t^x$ is the level of region x 's debt at time t .

An economy with capital mobility is also characterized by the arbitrage condition of the returns to capital which requires the equality between the rates of return to capital in each region. According to the neoclassical theory, if productivity is the same across regions, capital should flow from regions with a high capital-labor ratio to regions with a low capital-labor ratio until the return to investments is equalized. However, it is widely recognized that cross-border investments are refrained by international capital market imperfections or investment risks induced by a region's poor institutional quality (see Alfaro et al., 2008). Thus here, the confiscation rate or rent-seeking rate by the government captures transaction costs and various investment risks faced by international investors. A region's domestic interest factor R is equal to the international interest factor R^* up to the region's confiscation rate π

$$R_t = R_t^* (1 + \pi) \quad (13)$$

The confiscation rate in each region π is given by

$$\pi = \frac{q}{q^o} \pi^o \quad (14)$$

where q is the risk classification of a region as defined by the OECD (2011a), q^o is the highest attainable risk rating and π^o is the maximum confiscation rate. Equation (14) indicates that a region's confiscation rate increases with its risk ranking. In North America, Western Europe and Japan, the confiscation rate is zero.

2.6 Government

The government levies taxes on labor earnings (τ_t^w) and consumption expenditures (τ_t^c) to finance general public consumption (c_t^g), pension benefits (b_t^j) and other welfare transfers (c_{a+1}^j). The government surplus (S_t) can be written as follows for $j = h, l$:

$$\begin{aligned}
S_t = & \tau_t^w \sum_{j=\{h,l\}} L_t^j w_t^j + \tau_t^c \sum_{j=\{h,l\}} \sum_{a=0}^7 \phi_{t-a}^j N_{a,t} c_{a,t}^j \\
& - \sum_{j=\{h,l\}} b_t^j \sum_{a=0}^7 \phi_{t-a}^j N_{a,t} (1 - e_t^j) (1 - \lambda_{a,t}^j) \\
& - \psi_t \sum_{j=\{h,l\}} w_t^j \sum_{a=0}^7 \phi_{t-a}^j N_{a,t} (1 - e_t^j) \zeta_a^j - c_t^g Y_t
\end{aligned} \tag{15}$$

where c_t^g is a part of national income used to finance general public spending. The government's budget constraint (15) is balanced at each period via the adjustment of the wage tax rate.

Finally, in contrast to existing multi-region models, pension benefits depend on the educational level of the retirees. In general, a social security system is not only characterized by its generosity or size but also by its redistributiveness (Casamatta et al., 2000). In the following equations, the first characteristic is captured by the replacement rate χ_t and the second one by the parameter ρ . Pension benefits for low- (b_t^l) and high-skilled (b_t^h) write therefore as follows

$$b_t^l = \chi_t w_t^l, \tag{16}$$

$$b_t^h = \chi_t [\rho w_t^h + (1 - \rho) w_t^l]. \tag{17}$$

Both parameters χ_t and ρ are comprised between 0 and 1. A value for ρ close to 0 implies more redistributive pension systems, since low- and high-skilled would receive similar amounts of benefits when retired. If ρ is close to 1, then pension systems are weakly redistributive with replacement rates that are constant across income levels. The above formulation allows for (partly) Bismarckian or Beveridgian pension systems.³

³Roughly speaking, Bismarckian pension systems are highly generous and poorly redistributive while Beveridgian ones are small-sized and more redistributive (Casamatta et al., 2000).

2.7 The equilibrium of the economy

Definition (Competitive Equilibrium) *Given an initial stock of capital $\{K_t\}_{t=0}$, an initial distribution of wealth $\{Z_{a,t+a}^j\}_{a=1..7,t=0,j=h,l}$ with $\{Z_{a,t}^j = 0\}_{a=0,t \geq 0}$, an exogenous demographic structure summarized by $\{N_{a,t}\}_{a=0..7,t \geq 0}$ and an exogenous distribution of high-skilled individuals $\{\phi_{a,t-a}^j\}_{a=0..7,j=h,l,t \geq 0}$, a competitive equilibrium in an economy with (imperfect) capital mobility is*

- * a vector of individual variables $\{c_{a,t}^j\}_{a=0..7,t \geq 0,j=h,l}$ that are the optimal solutions to the households' maximization problem, i.e., equation (3) subject to (4);
- * a vector of the firm's variables $\{K_t, L_t^j\}_{t \geq 0,j=h,l}$ that maximize the firm's profit subject to technology (7);
- * a vector of income taxes $\{\tau_t^w\}$ balancing the budget of the government (15);
- * a vector of wages $\{w_t^j\}_{t \geq 0,j=h,l}$ such that labor markets are in equilibrium;
- * an interest factor $\{R_t\}_{t \geq 0}$ satisfying the no arbitrage condition of the rates of return to capital, i.e., equation (13) holds;
- * and, finally, an international interest factor R_t^* satisfying the equality between the aggregate value of world assets and the market value of the world-wide capital stock plus the sum of the debts of all regions, i.e., equation (12) holds.

The equilibrium on the goods market is achieved by Walras' law.

3 Calibration

The model economies of ten world regions are calibrated to forecast the economic consequences of an aging world population. The characterization of the baseline scenario requires the parameterization of the various parameters and exogenous variables. This calibration is achieved by fixing some constant parameters, using data for observed exogenous variables and choosing values to unobserved exogenous variables in order to match a series of characteristics.

Calibrating the model to reproduce the characteristics of a given year or period (e.g. 2010) would imply the loss of historical information on the population and educational levels per age group. The model is therefore calibrated on observations over the period 1950-2010 and the equilibrium is computed as a transition from one steady state in 1950 to another one in 2300. By starting in 1950, the model reflects the correct history of the population structure since 1950 (as well as the evolution of the skill composition of the population). The model reproduces also the evolution of regional disparities in income per capita as well as other elements, like various government expenditures and transfers.

3.1 Simulation method

The dynamic model is characterized by a set of non-linear equations of the following form:⁴

$$f(y_{t-7}^A, \dots, y_t^A, y_t^B, \dots, y_{t+7}^B, z_t) = 0 \quad (18)$$

where y_t^i denotes an endogenous variable at time t . The superscript A stands for a predetermined variable and B for a forward-looking variable. The system also depends on a vector of exogenous variables and parameters denoted by z_t and accounts for leads or lags of 7 period, which is related to the life length of an individual. Finally, initial conditions on the predetermined variables are assumed, which correspond to an initial steady state in 1950:

$$y_{-6}^A, \dots, y_0^A = y_{\text{initial}}^A.$$

Concerning the terminal conditions, baseline assumes that exogenous variables remain constant after a given date. The economy should converge to a new steady state if this latter is a saddle-point, the economy should converge to this steady state as long as the distance between the initial conditions and the initial steady state is not too large (as only local stability is granted).

Since f is non-linear, it is not possible to obtain an analytical solution of the model. The general problem consists in solving a system of finite difference equations with initial and terminal conditions. The infinite horizon of the model is approximated by a finite one, meaning that the steady state is reached at the end of the simulation limit (T). The complete system has as many equations as the number of equations at each period multiplied by the simulation horizon plus the initial and terminal conditions as the following system shows

$$(\Gamma) = \begin{cases} y_{-6}^A, \dots, y_0^A & = & y_{\text{initial}}^A \\ f(y_{-6}^A, \dots, y_1^A, y_1^B, \dots, y_8^B, z_t) & = & 0 \\ \vdots & \vdots & \vdots \\ f(y_{T-7}^A, \dots, y_T^A, y_T^B, \dots, y_{T+7}^B, z_T) & = & 0 \\ y_{T+1}^B, \dots, y_{T+7}^B & = & y_{\text{final}}^B \end{cases}$$

The simulation method solves the system (Γ) for y_t . It builds on a Newton-Raphson relaxation method put forward by Laffargue (1990) and Boucekkine (1995) for solving dynamic nonlinear models with perfect foresight. This routine is implemented with the package Dynare.⁵

⁴A more extensive description of the simulation method can be found in de la Croix et al. (2007).

⁵The Dynare pre-processor consists of a collection of MATLAB or SCILAB routines and applies a Newton-type algorithm to study the transitory dynamics of non-linear models. The details of the algorithm used in Dynare can be found in Juillard (1996) and recent developments of the program in Juillard & Oaktan (2008).

3.2 Calibration

Before turning to the description of the calibration of observed and unobserved variables, let us first observe that the parameters α , δ and β are set a priori and are assumed to be identical for all the regions. As Aglietta et al. (2007) notice, there is no reason to think that these parameters should differ across regions. The capital share in output α is set to one third, 0.33, as estimated in the growth accounting literature (see also GTAP, 2008). The annual depreciation rate of capital corresponds to 7.55% ($\delta = 0.544$) and β to $0.815 = 0.98^{10}$ in order to target, like in Attanasio et al. (2007), a capital-output ratio of 2.5 on an annual basis in 2010 in the leading region (North America).

3.2.1 Observed exogenous variables

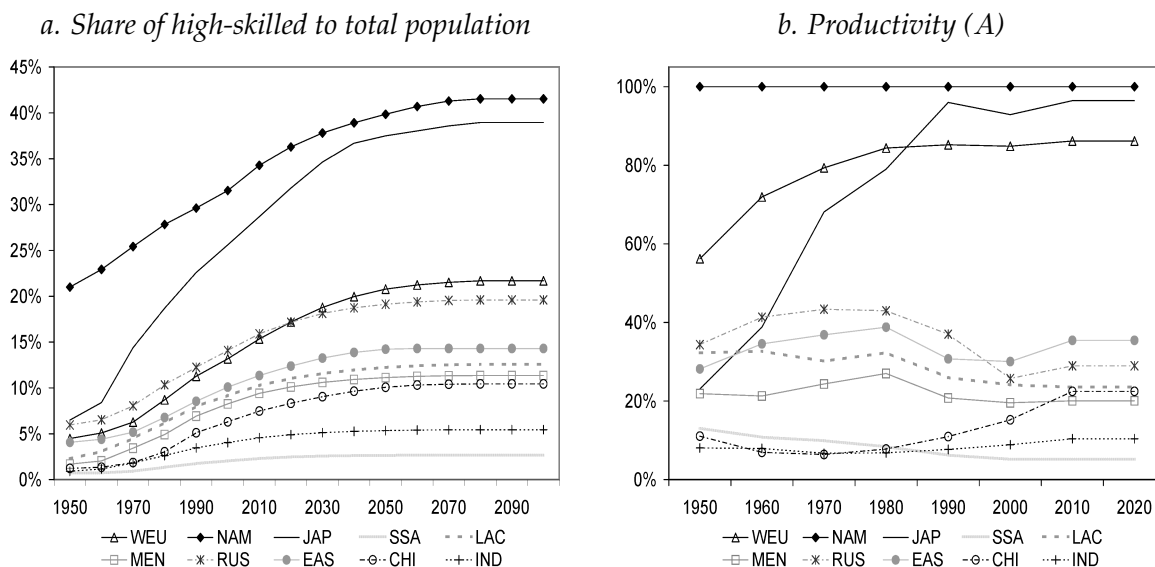
Table 3 displays the values of some observed exogenous variables.

⊙ *Demographics, m_t and $P_{a,t+a}$* . The population dynamics are calibrated by using the U.N. (2009) Population Prospects (the 2008 Revision), which provide the population by age over the period 1950 to 2050 for every country. The population structure starts from an initial steady state in 1950 (as e.g. in Attanasio et al., 2007), and reaches a final steady state after 2160. The transition is determined by the growth rate of the youngest cohort, m_t , which is used to calibrate the population size of each region at each period, and by the probability for an individual of generation t to be alive at time $t + a$, $P_{a,t+a}$, which serves to match the population structure of each region. After 2050, the probabilities to stay alive are kept constant. The growth rate of the youngest cohort, m_t , converges gradually to 1 between 2050 and 2100.

⊙ *Share of high-skilled among a generation born in t , ϕ_t* . The share of high-skilled among individuals born in t is computed using data for individuals with some tertiary education from Barro & Lee (2010, column ‘Tertiary Total’). Barro and Lee provide country-data on educational attainment of individuals aged 15+ for every 5 years over the period 1950 to 2010. Educational levels are first aggregated at the regional level (population-weighted average) and then disaggregated by age class. To do so, it is assumed that younger cohorts are more and more educated, which is not unreasonable. More specifically, the share of high-skilled among one generation corresponds to 80% of the share of high-skilled of the generation born in the following period. Given this condition, the fraction of highly educated among each new-born generation, ϕ_t , serves to reproduce the share of highly educated individuals among the total population over the period 1950-2010 as given by Barro & Lee (2010), see Figure 1.a.

⊙ *Profiles for other transfers ζ_a^j* . The profiles for other transfers (than public pensions) are specific to each educational group and are assumed to be stable over time. The data for these transfer profiles (ζ_a^j) come from US and European generational accounting studies. North American profiles are based on US profiles from Chojnicki & Docquier (2007), who disaggregate the profiles from Gokhale et al. (2000) by individuals’ educational level. These profiles comprise eight types

Figure 1: Share of high-skilled and Productivity



of transfers: old age security, disability insurance, medicare and medicaid, unemployment insurance, general welfare, aid to families with dependent children, food stamps and, finally, educational transfers. European data are employed for Western Europe based on de la Croix & Docquier (2007). For the developing regions, data is hardly available. The profiles in developing regions are set equal to the North American one, as transfers are believed to be less generous in these regions than in Western Europe (see Table 2).

Table 2: Time-constant transfer profiles (ζ)

Age groups	15-24	25-64	65-74	75+
<i>Western Europe</i>				
High-skilled	3%	6%	10%	15%
Low-skilled	10%	18%	20%	22%
<i>North America</i>				
High-skilled	0.5%	1%	6%	12%
Low-skilled	7%	12%	20%	25%

Source: Chojnicki & Docquier (2007) and de la Croix & Docquier (2007).

⊙ *General public spending, c_t^g* . The share of general public spending to GDP is computed from the data on general government final consumption expenditure of the World Development Indicators (WDI, 2010). Regional values are obtained by calculating GDP-weighted, 5-year averages (1960-62 for 1960, 1968-1972 for 1970,... and 2005-2009 for 2010).

Table 3: Values for observed exogenous variables (in 2010)

Region	WEU	NAM	JAP	EAS	MEN	LAC	SSA	RUS	CHI	IND
ϕ_{2010} (in %)	21.68	41.53	38.95	14.30	11.35	12.56	2.67	19.60	10.44	5.44
π_{2010}	0	0	0	2.15	4.04	3.97	5.37	2.60	2.01	3.35
τ_{2010}^c (in %)	15.25	5.00	5.48	19.30	14.85	10.37	12.50	11.72	10.73	8.12
c_{2010}^g (in %)	20.91	16.53	18.41	18.63	15.42	14.57	15.28	17.01	13.39	10.51
v	1.60	1.87	1.33	1.44	2.30	2.74	2.27	1.28	2.17	1.89

Source: OECD (2011a,b), WDI (2010), Barro & Lee (2010) and own computations.

⊙ *Region specific risk category, q .* A region's risk category, q , is based on the KNAEPEN package data of the OECD (2011a), which measures country credit risk, i.e. the likelihood that a country will service its external debt. The Knaepen Package is a system for assessing country credit risk, which exists since 1999 and classifies countries into eight country risk categories (0 - 7) from no risk (0) to high risk (7). The risk classification per region is calculated by taking GDP-weighted averages of country ratings issued on *January 24th, 2000* for the period 2000 and the most recent one released on *January 28th, 2011* for the period 2010. For Western Europe, North America and Japan the risk is nil. As few countries change category between the first ranking and the most recent one, the risk categories of the various regions for the periods 1950-1990 are kept similar to the ones in 2000. These values combined to $\pi^o = 0.5$ produce regional accounts that match relatively well the *evolution* of observed regional current account balances over the period 1980-2010 (GDP-weighted, calculated from the WDI (2010) data).

3.2.2 Unobserved exogenous variables

⊙ *Harrod-neutral productivity, A_t .* A region's productivity relative to North America (A_t/A_t^{NAM}) serves to reproduce the economic disparities between regions, i.e. the ratio of a region's per capita GDP to the leader's one (y_t/y_t^{NAM}) over the period 1950-2010. GDP per capita differences of each region to North America are computed by employing data from Maddison (2010). GDP per capita for each region is based on population-weighted averages and the 5-year average value of 1948-1952 for the period 1950, 1958-1962 for 1960, ... and 2005-2009 for 2010. A back-solving identification method like in de la Croix et al. (2007) is applied to calibrate productivity. This procedure consists in swapping the exogenous variable A_t/A_t^{NAM} for the endogenous variable y_t/y_t^{NAM} and solving the identification step with the Dynare algorithm. In other words, the model is first solved by letting productivity differences adjust so as to match an imposed path of GDP per capita differences. This procedure offers a series of productivity differences used for baseline simulations of the world model (see Figure 1.b and Table 4 for 2010 values).

Table 4: Target values and exogenous variables (period 2010)

Region	NAM	JAP	WEU	EAS	RUS	LAC	CHI	MEN	IND	SSA
Targets (in %)										
Ratio of GDP per capita (y/y^{NAM})	100	74.48	70.47	27.67	23.09	21.49	20.34	18.19	9.06	4.32
Public pension expenditures to GDP	6.39	8.88	10.64	8.40	7.00	3.61	3.38	2.97	1.20	0.71
Public health expenditures to GDP	7.01	6.61	7.27	4.89	3.23	3.48	1.95	2.98	1.09	2.62
Exogenous variables										
A/A^{NAM}	1	0.96	0.86	0.35	0.29	0.24	0.22	0.20	0.10	0.05
χ	0.37	0.28	0.41	0.39	0.41	0.35	0.28	0.40	0.14	0.11
ψ	0.98	0.45	0.50	4.62	3.42	4.12	2.32	3.58	1.35	4.79

Source: Maddison (2010), WDI (2010), Palacios (1996), OECD (2011b) and own computations

⊙ *Replacement rate, χ_t* . The replacement rate is set by the same back-solving method as for productivity (A) and is used to match the share of public pension spending in GDP (see Table 4). Comparable data is hardly available for every country of the different regions, except for the year 1990, for which public pension spending to GDP is computed from a common source, Palacios (1996, Table A.5), for every region. This share of public spending evolves then for the years 2000 and 2010 according to the data of the OECD (2011b), which offers data on public pension spending over the period 1990-2005 for different countries of every world region. For the years before 1950, 1960, 1970 and 1980, it is assumed that public pension spending to GDP corresponds to 20%, 45%, 65% and 85% of the level in 1990 (see Table 4 for 2010 values).

⊙ *Generosity factor of the other transfers, ψ_t* . The generosity factor is also obtained via the back-solving method and targets the share of public health expenditure to GDP. The data for this latter indicator is computed from the WDI (2010) for the periods 2000 and 2010 (GDP-weighted region averages for 2003-2004 for 2000 and 2005-2007 for 2010). The periods 1950, 1960, 1970, 1980 and 1990 correspond to 40%, 55%, 70%, 90% and 100% of the level in 2000 (see Table 4 for 2010 values).

⊙ *Growth in the leader's Harrod-neutral productivity, g_t* . Based on observations, productivity growth in North America ($g_t = A_{t+1}^{NAM}/A_t^{NAM}$) is set to 1.2 (i.e., the annual growth rate equals 1.84%).

⊙ *Skill premium, v_t* . The ratio of high- to low-skilled wage, v , is constant and computed from the *General Industrial Statistics* of the United Nations and corresponds to the skill premium in the manufacturing sector for the year 2000 (see Zhu, 2005).

⊙ *Pension scheme parameter, ρ* . The pension scheme parameter, ρ , captures the redistributiveness of the pension system. It is time-invariant and specific to each region. Combining equations (16) and (17) yields $\rho = (\epsilon v - 1)/(v - 1)$, where v is the skill premium as defined above and ϵ is the ratio of gross replacement rates of individuals with earnings level 1.5 (multiple of mean income) and individuals with earnings level 0.5. This latter value is computed from the "Gross pension replacement rates by earnings" data of the OECD (2011b).

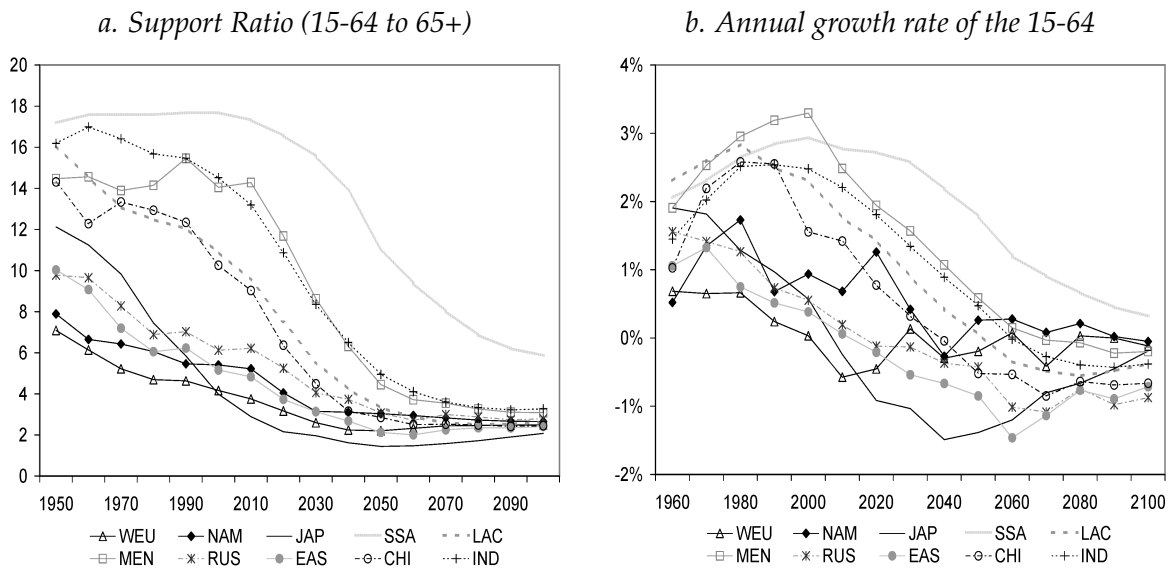
⊙ *Labor participation, $\lambda_{a,t}^j$* . The labor participation rates of high- and low-skilled individuals (respectively $\lambda_{a,t}^h$ and $\lambda_{a,t}^l$) are set to 1 for the age groups 15-24, 25-34, 35-44 and 45-54. Individuals work until 60 in all the regions, i.e., participation rates for individuals aged 55-64 ($\lambda_{5,t}^j = 0.5$) except high-skilled individuals in North America, Japan and Western Europe who work until 62 ($\lambda_{5,t}^h = 0.7$). The participation rate for the three last age groups equals 0 in all the regions.

⊙ *Time spent in education, e^h and e^l* . Time spent in education is set to 0.6 for high-skilled individuals, meaning that they obtain a secondary school diploma (or above) and start working at the age of 21. Low-skilled individuals enter the labor force at 17 in North America, Japan and Western Europe ($e^l = 0.2$) and at 15 in developing regions ($e^l = 0$).

3.3 Assumptions on the future

The model is calibrated to real data until 2010. The baseline scenario is conservative as all exogenous variables (except demographic variables, m_t and $P_{a,t+a}$) are held constant from 2010 onwards. Section 6 analyzes additional scenarios based on alternative assumptions on the future evolution of various exogenous variables.

Figure 2: Support Ratio and Working Age Population (15-64)



Demographic trends, characterized by m_t and $P_{a,t+a}$, are computed from the United Nations Population Projections. The support ratio, defined as the number of individuals of working age for one pensioner, as well as the annual *growth rate* in the working age population decrease for all the regions over the period 1950-2050 (Figures 2.a and 2.b). However, the aging process is not synchronous and the evolution of these indicators differs for each region. The Russian World,

the Eastern Countries and the three developed regions (i.e., North America, Western Europe and Japan) reached a low support ratio by the end of the 20th century with less than 8 people of working age for one pensioner in 1980. Due to a huge decline in fertility after World War II, Japan is the fastest aging region and has the lowest number of working aged relative to elderly from 2000 onwards. The other regions start the 21st century with more than 11 individuals of working age for one pensioner. However, they have to cope with a very strong fall in their support ratios during the 21st century, which makes them slowly converge to the levels of the first group. Sub-Saharan Africa is characterized by the highest support ratio and a continuously increasing working age population all along the 21st century. China ages most rapidly as a consequence of its “one child” policy. The growth rate of the Chinese working age population rises since the mid-20th century and is among the highest in the world in 1990, but afterwards it declines and becomes even negative in 2040. The working force growth rate of LAC, IND and MEN feature a similar pattern by with a delay of several decades.

Finally, the proportion of high-skilled individuals among each new generation is held constant from 2010 onwards. However, the share of high-skilled in the total population continues to rise during the 21st century until the cohorts born before 2010, who are less educated than those born in 2010 and after, pass away (see Figure 1.a).

4 The world economy under the baseline scenario

The calibration of the model delivers a dynamic equilibrium path of the world economy. The Population Projections of the United Nations for the period 1950-2050 generate population dynamics even in the following decades until the structure and size of the population in each region become stationary in 2170 (as explained above). The following paragraphs depict the evolution of the world interest rate and GDP growth rate under the baseline scenario. Next, the focus is turned on the determinants of current accounts and on capital flows themselves. The aim of the study is to investigate the role of future demographic changes on capital flows. Hence, results are presented from 2010 onwards with a particular interest for the first half of the 21st century.

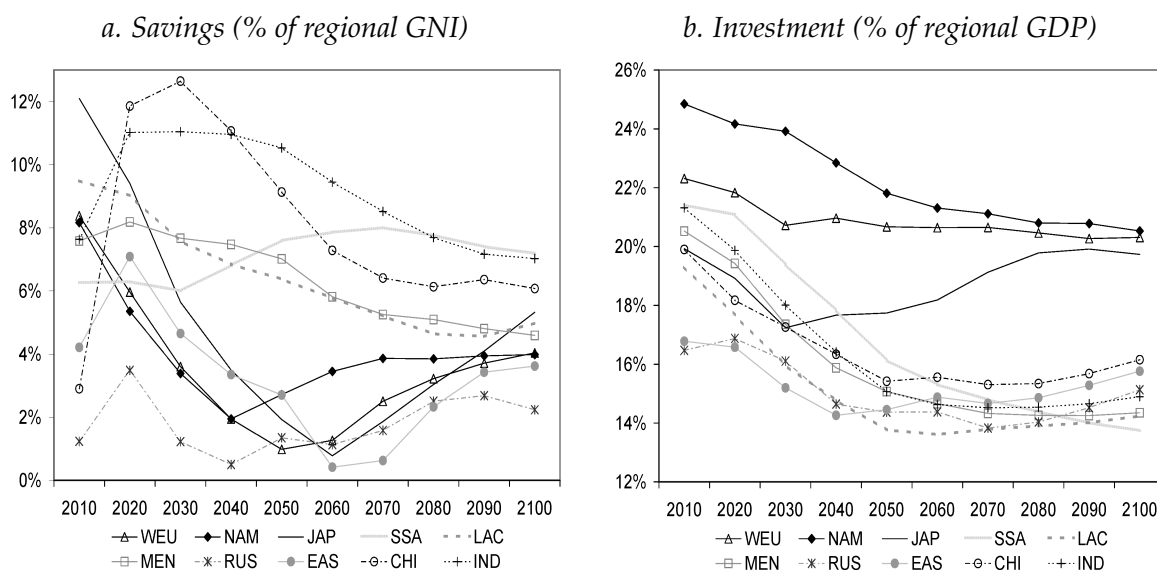
⊙ **World interest and growth rates.** The world interest rate is determined on the world capital market by equating the world demand and the world supply of capital. In a context of global aging, the world economy experiences a decline in the growth rate of its working age population (potential labor force) and a rise in the capital to efficient labor ratio. This is translated by an increase in the marginal productivity of labor whereas the marginal productivity of capital decreases. The world interest rate falls and reaches a low in 2040 (see Figure 3.a). From 2050 onwards, the interest rate slightly augments with the recovering and stabilization of the world support ratio. The dynamics of the working age population are also the driving force behind the decrease in the

Figure 3: Evolution of the world interest rate and of the GDP growth rate



GDP growth rate.⁶ The growth rate of the world GDP follows a similar evolution as the world interest rate (see Figure 3.b): it goes through a huge decline at the beginning of the 21st century due to the pronounced aging of the population and stabilizes after 2060 around an (exogenously imposed) 1.84% annual growth rate.

Figure 4: Savings and Investment rates



⊙ **Savings and investment rates.** On the supply side of capital, the evolution of the net savings rate, i.e., the ratio of aggregate savings of all cohorts to GNI, is determined by demographic trends

⁶The general rise in educational attainment slightly mitigates the downward trend in the annual GDP growth rate. It would be as much as 0.15% smaller if the educational attainment is fixed at its 1950 level in each region.

(Figure 4.a). Regions facing serious aging of their population see their saving rates decline sharply during the first half of the 21st century. This is the case for North America, Western Europe, Japan, the Eastern Countries and the Russian World. In these regions, the rise in life expectancy has stimulated savings of the baby boom generations during the second half of the 20st (not shown). Thereafter, i.e. at the beginning of the 21st century, these generations retire and start dissaving. A similar rise and bust of the savings rate occurs in the other five regions, but with a delay of several decades. The savings rate remains relatively high levels in the first decades of the 21st century because of high life expectancy and fertility rates. It decreases significantly at mid-century with the reduction in fertility (as indicated by the fall in the labor force growth rate in Figure 2.b). The regions of Latin America, India and the Middle East and North Africa have a comparable aging pattern and experience a quite parallel trajectory in their savings rate. China is the region with the most important savings rate at the beginning of the 21st century, thanks to the rise in its labor force and a high support ratio at the end of the 20th century. Afterwards, the growth in its labor force slows down and its support ratio drops, leading to a fall in its savings rate. After 2030, India becomes the region with the highest savings rate, thanks to a relatively fast-growing labor force (compared to China). Finally, Sub-Saharan Africa, characterized by a favorable demographic evolution, sees its savings rate rise until 2070.⁷

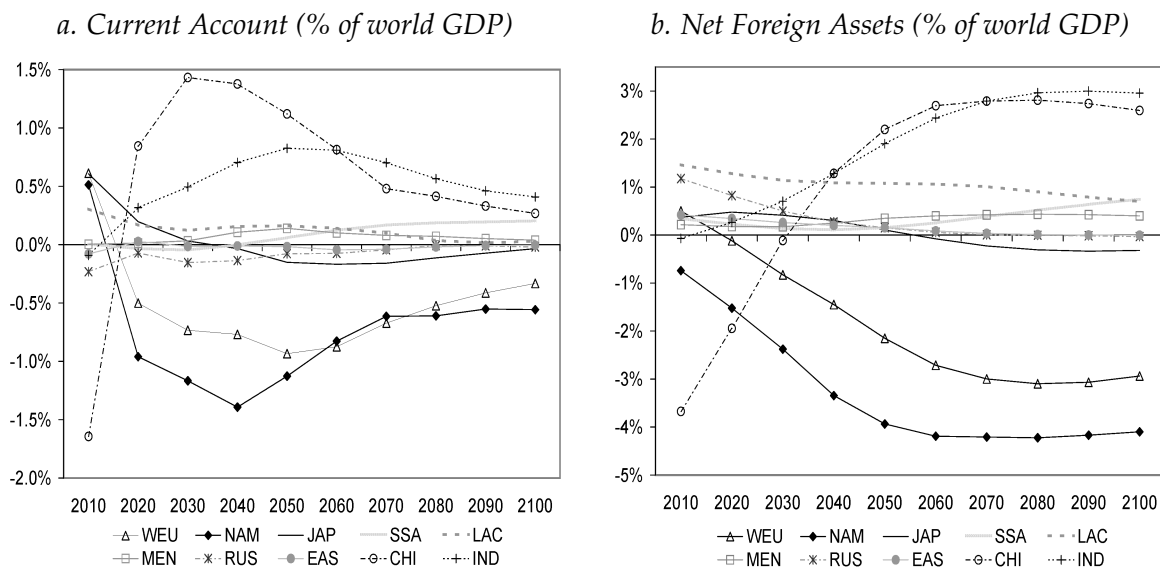
The demand side of capital is represented by the investment rate, i.e. the ratio of gross investment to GDP. It is characterized by a slightly decreasing trend over the century (Figure 4.b), which is, however, less pronounced than the one in the savings rate. Thus, as in Aglietta et al. (2007), the world interest rate is mostly driven by the movement on the supply side of capital. The reason is that, on the demand side of capital, the negative effect of a declining labor force on capital accumulation can be partly offset by increases in capital intensity. In fact, gross investment is defined as $I_t = K_{t+1} - (1 - \delta)K_t$ and depends thus on net capital accumulation and capital replacement. In turn, the capital stock rises with employment and with capital intensity, which is increasing in technology and decreasing in the return to capital and in the confiscation rate.⁸

⊙ **Capital flows.** In an open economy, international trade is determined by the equality between net exports and net capital outflows. In the present model, every region produces one consumption good and these goods are perfectly substitutable. Thus, we are in presence of a supply-side

⁷The savings rates of EAS and RUS peak slightly in the first decades of the 21st century due to the economic recovery after the fall of the Soviet Union. The Chinese savings rate rises pronouncedly because of the rapid growth of its economy in the last years and because its savings rate starts from a low level (during the period 1950-1990). Overall however, the rise and bust of the savings rate is substantially due to demographic changes. In fact, similar patterns for the savings rate are obtained in an alternative experiment, where productivity is time-invariant and set at its 2010 level in all the regions. In that case, the savings rate of CHI increases more moderately between 2010 and 2020 (as it starts from higher levels during the period 1950-2000) and no pike appears in 2020 for the savings rate of EAS and RUS.

⁸Capital intensity can be written as $\frac{K}{L} = \left[\frac{A}{R(1+\pi)} \right]^{\frac{1}{1-\alpha}}$.

Figure 5: Current Account and Net Foreign Assets



view of international trade, i.e., trade is driven by net capital outflows.⁹ Current account balances are computed as the change in net foreign assets (NFA), $CA_t = NFA_{t+1} - NFA_t$, which are themselves defined as total assets minus the sum of capital $NFA_t = \Omega_t - K_t$. Current account deficits or surpluses arise from differences between domestic saving and domestic investment. Figure 5.a plots the evolution of the current account balances as a share of world GDP. Two main findings can be highlighted. First, developed regions, and in particular North America and Western Europe, start running current account deficits in the beginning of the 21st century (Figure 5.b), which turn them into the main debtor regions (Figure 5.b). Second, their needs for capital are financed by emerging regions: China is the major creditor region during the first half of the century and this position is taken over by India in the second half of the century. These results are explained below, in relation to the literature.

⊙ **Related Studies.** Current accounts dynamics are in line with the literature. The Japanese current account is positive at the beginning of the 21st century and turns into a deficit after 2030, which is compatible with Brooks (2003) and Domeij & Floden (2006). Moreover, as in Brooks (2003), the decreasing current accounts of North America and Western Europe indicate that both regions will depend on foreign capital in the 21st century. The reason is the large number of baby boomers who enter retirement and start to dissave. The demands for capital of both regions are largely financed by China. Moreover, the behavior of the current account of Sub-Saharan Africa is also similar to

⁹This is a standard feature of the literature dealing with international capital flows within a large-scale multi-region models.

Brooks (2003) and to the 'J2' region of Aglietta et al. (2007), which groups high fertility regions and comprises the African continent. As in Brooks (2003), Sub-Saharan Africa is projected to import capital until 2030. Its current account turns positive after 2040.

Net foreign assets positions indicate that North America and Western Europe are net debtors (see Figure 5.b) as they accumulate current account deficits over almost the whole 21st century. Japan is a net creditor at the beginning of the century but becomes a net debtor starting from mid-century when its current account balance goes into deficit. This is comparable to the findings in Brooks (2003) and, to a lesser extent, to the slowly decreasing pattern in the Japanese current account in Aglietta et al. (2007). China's external position goes the opposite direction than the aforementioned regions. The large current account surpluses at the beginning of the 21st century (starting from 2020) turn China into the main creditor region until mid-century. Afterwards, as its current account balance decreases, India takes over and becomes the main creditor region.

⊙ **Discussion.** Finally, two remarks can be added here. First, the strong rise of the Chinese current account is due to rapid economic growth in the last decades of the 20th century. The increase would indeed be less pronounced in a scenario where productivity is held constant in all regions since 1950 (see Appendix C, Figure 14). However, in such a variant, demographic trends continue to play an important role and the main results on capital flows between regions hold nonetheless. In fact, North America and Western Europe still depend nevertheless on foreign capital (and even more markedly), while China is still conferred the main creditor position over the first half of the century (in an even more clear-cut manner) and India in the second half of the century.

Second, baseline findings suggest that capital flows from the South (the seven developing regions) to the North (the three developed regions) after 2010. In fact, the aggregate current account of NAM, WEU and JAP (as a percentage of world GDP) is positive in 2010 and runs into deficit in 2020. It further decreases thereafter before recovering after mid-century. Moreover, the Northern net foreign assets position (as a % of world GDP) is positive in 2010 but negative afterwards (see Appendix C, Figure 15.b), which indicates that the South owns capital of the North after 2010. In the two-region model of Attanasio et al. (2007), the Northern current account (which comprises for the same countries as in NAM, WEU and JAP) runs into deficit in 2020 with increasing negative values from 2020 to 2060 and recovers after 2060, while the South starts owning Northern capital only after 2040 (Attanasio et al., 2007, Figure 7 and top panel of Figure 6, respectively). Hence, the baseline findings are compatible with Attanasio et al., except that the reversal in capital ownership between the North and the South occurs several periods later in their study.¹⁰

¹⁰The benchmark model of the present study differs in several ways from Attanasio et al. (2007). For instance, it incorporates "other welfare transfers" and "capital market frictions". First, the absence of other welfare transfers induces households to save more. In particular, Northern households save proportionally more than Southern ones as other welfare transfers represent a larger (as a share of GDP) in the North than in the South. In such a variant, the North depends less on foreign capital and its current account and

5 Alternative assumptions on the future

The baseline is conservative because it assumes that exogenous variables do not change from 2010 onwards (except demographic variables). This section considers alternative assumptions on the future and analyzes their impact on capital flows. Four types of scenarios are envisaged, accounting for changes in productivity, educational attainment, capital market frictions and pension systems. They are summarized in Table 5 and explained in the following paragraphs.

5.1 Scenario description

Productivity

The recent literature on economic growth argues that cross-country differences in income per capita result largely from differences in total factor productivity (e.g. Prescott, 1998; Hall & Jones, 1999). Moreover, according to modern growth theory, human capital exerts a strong positive externality on economic growth via its effect on productivity (Lucas, 1988; Romer, 1990). At the micro level, many empirical studies find a positive relationship between workers' education and labor earnings/productivity. At the macro level, the evidence is rather mixed. Some studies find that more education does not lead to more growth (e.g. Pritchett, 2001). Other authors stress that schooling and growth are positively associated and that results pretty much depend on the quality of the education data (Krueger & Lindahl, 2001; Cohen & Soto, 2007). The aim here is not to enter in such a debate, but rather to propose an illustrative example of the implications of a positive externality of human capital on capital flows.

Scenario A0 incorporates an externality à la Lucas (1988), i.e. an externality on productivity (A) exerted by the workforce educational attainment, in which the Harrod-neutral productivity term A_t in equation (7) takes on the following form, for $t \geq 2010$:

$$A_t = \bar{A}_t \left(\frac{H_t}{H_{2010}} \right)^{\gamma/(1-\alpha)}, \quad (19)$$

where \bar{A}_t is the productivity sequence of the baseline, H_t is the share of high-skilled in the population aged 15-64, γ (>0) is an externality parameter set at 0.1 as in Bouzahzah et al. (2002), and the term H_{2010} deducts the externality component already implicitly accounted for in the 2010 productivity value.¹¹

foreign assets position are higher than in the benchmark (Figure 15, comparing 'benchmark' with the variant ' $\chi = 0$ '). Second, the removal of capital market frictions favors investment in the South (Figure 15, variant ' $\pi^0 = 0$ '). Combining these two elements (variant ' $\chi = \pi^0 = 0$ ') implies that the Northern foreign assets position turns negative only in 2030, which is closer to the benchmark findings of Attanasio et al. (2007).

¹¹Baseline productivity values are calculated to reproduce observed GDP per capita differences over the period 1950-2010 and incorporate therefore implicitly an eventual externality of human capital. Hence, in

In past years, developing countries like China and India experienced sustained economic growth, as indicated by a reduction in their productivity distance to the leader (Figure 1.b). Other developing regions also show improvements in economic performance, e.g. the EAS region, of which many countries recently accessed the European Union. Given the numerous “economic miracles” witnessed during 20th century, it is not unreasonable to think that the economic growth of these economies may hold on in the future.¹² According to many authors, improvements in economic performance may result from better institutions, which translate into enhanced productivity (North, 1990; Acemoglu & Johnson, 2005). Scenarios A1 and A2 envisage therefore a catch-up of developing regions with the three developed ones. In particular, productivity in the seven developing regions increases linearly over the period 2010-2050, being 50% (scenario A1) and 100% (scenario A2) higher in 2050 than in 2010.

Scenario A0 assumes that human capital, proxied by the level of education, has a positive impact on productivity. However, schooling is not the only determinant of human capital. The demographic structure of the workforce can affect aggregate human capital in the form of experience and, thereby, influence productivity. Several studies find that demographic variables, measured for instance by the youth dependency ratio (Kögel, 2005) or the age structure of the workforce (Feyrer, 2007), influence total factor productivity. Scenarios A3 and A4 account for a link between demographics and productivity based on the estimates of Feyrer (2007), who regresses the change in the logarithm of Harrod-neutral productivity ($\Delta \log(A)$) on the dependency ratio and the change in proportion of the workforce by age group. Over the period $t \geq 2020$, productivity in t depends on productivity in the previous period and on the effect of demographics on productivity:

$$\log(A_t) = \log(A_{t-1}) + \eta \cdot f(\Delta DR_t, \Delta W_{a,t}), \quad (20)$$

where Δ is the first difference operator and $f()$ is a function based on Feyrer’s regression. It gives scenario A0, A_t is equal to \bar{A}_t over the period 1950-2010 and follows the dynamics imposed by equation (19) after 2010. Recall also that the baseline assumes that \bar{A}_t and the share of high-skilled among each new-born generation (ϕ) are fixed after 2010, which implies that $\bar{A}_t = \bar{A}_{2010}$ for $t \geq 2010$ in equation (19) and that H_t is stabilized after 2050. Moreover, Bouzahzah et al. (2002) remark that there is no consensus on the value for γ , but the experiments of this section remain qualitatively similar for other choices of γ . Finally, a more complex link between human capital and productivity can be envisaged. For instance in Vandebussche et al. (2006), human capital may either harm or stimulate productivity depending whether it serves for adoption or imitation (which is determined by a country’s distance to the leader economy).

¹²There exists numerous historical examples. For instance, at the end of the World War II, West Germany had a GDP per capita of 24% of the US American one. Sustained economic growth from 1946 to 1960 raised its GDP per capita to its pre-World War II level (i.e., 70% of the American one). Since then, its GDP per capita grew but remained stable relative to the American one. Japan experienced also rapid economic growth from 1946 to 1991. GDP per capita relative to the US reached its pre-World War II level in 1963 (40%), rose until 1991 (85%) and stabilized since then at 73% (IMF, 2010b, and own computations). Finally, South-Korea’s GDP per capita gap with the US shrunk since the end of the 1960’s and is considered today as a “high-income country” by the World Bank.

the change in log productivity over the period $t-10$ to t as a function of changes in the dependency ratio (ΔDR_t) and in the proportion of the workforce by age group ($\Delta W_{a,t}$). Parameter η ($\in [0, 1]$) measures the importance of demographic changes in determining future productivity. As Feyrer's regressions yield R^2 values varying between 0.29 and 0.55, it can be supposed that the "true" effect of demographic components is comprised between values for η of 0.1 (scenario A3) and 1 (scenario A4).¹³

Table 5: Alternative assumptions on the future

Scenario	Description	Concerned Regions	Period
Assumptions on Harrod-neutral productivity (A)			
A0	Lucas externality, $\gamma = 0.1$ (High-skilled workforce affects A)	Every region	2010-2050
A1	A augments gradually by 50%	Southern regions	id.
A2	A augments gradually by 100%	id.	id.
A3	A affected by a weak demographic externality ($\eta = 0.1$)	Every region	2010-2100
A4	A affected by a strong demographic externality ($\eta = 1$)	id.	id.
Assumptions on the educational attainment of a new-born generation (ϕ)			
B1	ϕ augments gradually by 100%	Southern regions	2010-2050
B2	ϕ converges gradually to NAM levels	Every region	id.
B3	B1 + Lucas externality	id.	id.
B4	B2 + Lucas externality	id.	id.
Assumptions on capital markets imperfections (risk category, q)			
C1	π decreases gradually by 50%	Southern regions	2010-2050
C2	π decreases gradually by 100%	id.	id.
Assumptions on pension systems (replacement rate, χ)			
D1	χ decreases gradually by 50%	Northern regions	2010-2050
D2	χ decreases gradually by 100%	id.	id.

Human capital

A second set of scenarios deals with assumptions on the evolution of educational attainment. According to some reports, educational levels are expected in developing economies are expected to rise more substantially than in developed countries over the next years (Bergheim, 2005, see also

¹³Equation (20) is based on estimates of regression 3 in Table 2 of Feyrer (2007), which rely on ten-year unimputed workforce numbers. Feyrer (2007) includes the age groups 10-19, 20-29, ... approximated here by age groups 15-24, 25-34, ... Moreover, Feyrer excludes the age group 40-49 as a regressor (since the proportions of age groups sum to one) and coefficients have to be interpreted, therefore, with respect to this age group. In fact, the share of 40-49 year olds has the largest coefficient on productivity, followed by the age groups 50-59 and 60+. Thus, approximating the share of 40-49 by the share of 45-54 is not completely mistaken. Finally, Feyrer's regressions include also country and time dummies.

OECD (2010)): the average years of education is projected to increase by more than 40% in India and by 30% in China, South Africa and Thailand over the period 2005-2020, but more moderately in Europe (15% in France) and even less in the US (see also Day & Bauman, 2000, for US educational projections). Based on these insights, two scenarios of increased educational attainment are proposed. In scenario B1, all developing regions will have doubled their share of high-skilled among their new-born generations over the period 2010-2050, while a more extreme case is considered with scenario B2, where all regions will have caught up with the leader (NAM) in terms of the educational attainment of the youngest cohort by 2050 ($\phi = 0.4153$ in 2050 in all the regions). In the scenarios B3 and B4, human capital affects productivity as in scenario A0. In particular, scenarios B3 and B4 assume the same evolution for educational attainment as scenarios B1 and B2, respectively, but account for the Lucas-type externality represented in equation (19).

Capital market imperfections

Frictions in the capital market are based on a region's risk category, q , defined by the KNAEPEN package of the OECD (2011a). It can be observed that the regions improved their risk category over time. EAS, MEN, LAC, SSA, RUS and IND experienced reductions in their risk value of -1.15, -0.80, -1.01, -0.72, -0.95, and -0.62, respectively, over the period 2000-2010. Only the risk category (q) of CHI slightly increased between 2000 and 2010 (by 0.19), because the country China has a larger q than the other countries in region CHI and its GDP increased proportionally more than its neighbors over the period 2000-2010.¹⁴ Scenarios C1 and C2 simulate therefore a gradual reduction in capital market imperfections of 50% and 100% between 2010 and 2050, as an improvement in a region's category is more frequent than a deterioration.

Pension systems

Population aging is expected to lead to substantial increases in public pension spending in advanced countries. Many developed countries have therefore set forth significant reforms of their pay-as-you-go pension systems in order dampen the rise in pension expenditures (see IMF, 2010a, Appendix IV). In developing regions, pension expenditures are also expected to rise in future decades and in some regions, like LAC or EAS, pension reforms are introduced. However, in some regions, like MENA countries, comparable pension reforms as in developed countries are not planned (Robalino et al., 2005). In general, pension expenditures are lower in developing regions. Therefore, like in Attanasio et al. (2007), scenarios D1 and D2 consider a reduction in the

¹⁴Only few countries experience a change in their category from one ranking to another (new rankings appear every 3 to 6 months). Over a longer period, i.e. between the first ranking (1 Jan 1999) and the most recent one (28 Jan 2011), 54% of the 155 countries listed appear with the same risk category, while 36% experienced an improvement (most of them only by 1 category) and 10% slipped in the risk ranking (author's computations).

replacement rate only in the Northern regions between 2010 and 2050 of 50% and 100%, respectively.

5.2 Scenario Results

Figures 6.a, 6.c and 6.d display the results in terms of net foreign assets of the North (North America, Western Europe and Japan) as a percentage of world GDP. As the South comprises the other 7 regions, the sum of net foreign assets of the North and the South amount to 0 (in each period). A negative value means that the seven developing regions (“South”) own capital of the three developed ones. Educational levels increase in all regions and induce a positive externality in productivity under scenario A0. Productivity rises relatively more in the North where the rise in educational attainment is larger than in the South (in absolute terms). As a consequence capital flows from the South to the North and net foreign assets of the North are slightly more negative in Scenario A0 than in the baseline. Institutional improvements in the South enhance productivity, which raises the marginal productivity of capital and attracts capital from the North (scenarios A1 and A2). As a consequence, the reversal in the net foreign assets position (of the North) is delayed by several decades. A similar result is obtained when considering the link between demographics and productivity. The share of 45-54 year olds in the labor force, which is the age group with the highest “experience capital” and largest impact on productivity according to Feyrer’s estimates, is expected to fall in the North and rise in the South (absolute change between 2010 and 2050 is -0.92 and 3.07 percentage points, respectively).¹⁵ Figure 13 in Appendix C shows the high correlation between the share of 45-54 year olds and productivity. Increased educational levels in the South (scenarios B1 and B2, Figure 6.c) raise the demand for capital and reduce capital flows to the North (net foreign assets position of the North is -4.73% in scenario B2 in 2050 compared to -5.98% in the baseline). This effect is stronger when improvements in educational attainments have a positive externality on productivity (scenarios B2 and B4). Although no reversal in capital ownership occurs between the North and South, the impact of educational levels on net foreign assets position is not insignificant (by mid-century, the net foreign assets position of the North is around 50% larger in scenario B4 compared to the baseline).

A gradual improvement of the risk ranking in Southern regions (scenarios C1 and C2, Figure 6.d) makes investment less unattractive in these regions and dampens capital outflows from the South.¹⁶ A reduction in pension benefits (scenarios D1 and D2) stimulates aggregate savings in the

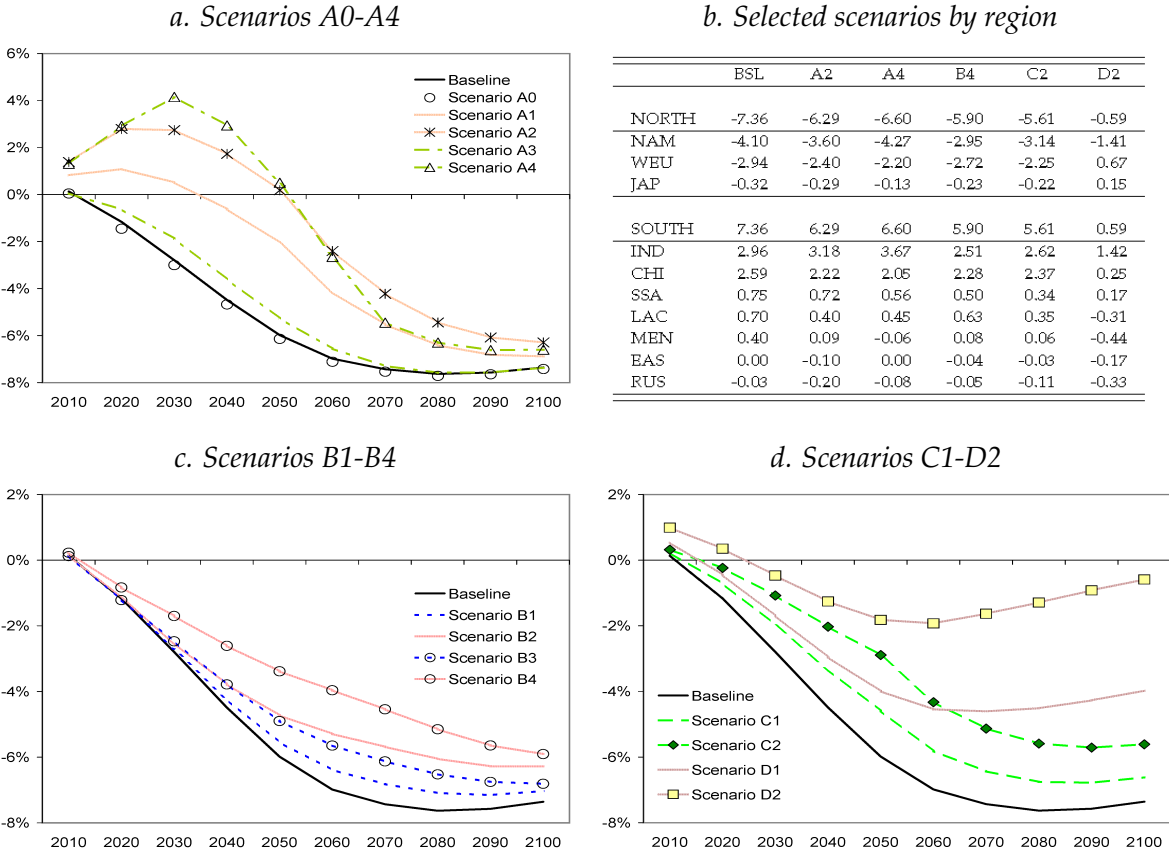
¹⁵This share shrinks in North America, Western Europe and Japan (between 2010 and 2050, the absolute change is -1.09, -0.43 and -1.85 percentage points, respectively) and rise significantly in MEN, LAC, SSA, CHI and IND (change between 2010 and 2050 is 4.64, 5.02, 3.50, 1.73 and 5.18 pp, respectively). In EAS and RUS, the share of 45-54 aged rises from 2010 to 2040 but is decreased in 2050 relative to 2010 (-2.30 and -1.05 pp, respectively).

¹⁶A different way of introducing capital market imperfections is provided in a sensitivity exercise by

North and domestic supply of capital is closer to investment needs. Capital deepening is important enough to induce a small reversal in capital flows (current accounts) when the PAYG is completely removed (after 2050, scenario D2), like in Attanasio et al. (2007, p. 179).

Finally, the two largest debtor regions remain NAM and WEU and the two largest creditor regions CHI and IND across the various scenarios, see Figure 6.b (for selected scenarios). The exception is for Western Europe in scenarios A2 and A4, where its net foreign assets position is positive until 2050, but turn negative thereafter, and scenario D2, where Western Europe is a net creditor all over the century. In fact, dismantling the large WEU public pension systems raises savings above investment levels.¹⁷

Figure 6: Net Foreign Assets of the North (% world GDP)



Attanasio et al. (2007, p. 186), where frictions appear only when the North has positive external wealth.

¹⁷Table 8 in Appendix displays the net foreign assets of each region (as a % of world GDP) in the various scenarios for the years 2050 (top panel) and 2100 (bottom panel).

6 Demographic shock in Western Europe

This section aims at demonstrating the importance of endogenizing capital mobility. To do so, it is proposed to investigate the implications of a very simple scenario, describing the effects of a *fertility boom* in Western Europe in 2010. To highlight the effects of capital mobility, the consequences of this scenario are analyzed in a framework where the regions are fully financially integrated and, in a closed economy environment, where the regions are completely independent of each other. In addition, this section offers further experiments to examine whether general equilibrium effects are significant and whether the demographic shock has similar consequences if it arises in other regions. The next paragraphs describe first the characteristics of the demographic shock before explaining its implications.

6.1 Describing the demographic shock

Various factors can bring about an increase in population. First, family policies decided at the regional level might stimulate fertility. Several such policies exist at the European level, as, for instance, the parental-leave directive or the recommendation to provide childcare to a certain number of children.¹⁸ While these policies have the objective to increase female labor force participation, they also coincide with the concerns about declining fertility and the viability of the welfare-state systems (Neyer, 2006). Second, increased immigration could also lead to a demographic boom. Opening the borders to more migrants could result from the idea that immigration is necessary to sustain the welfare state, despite the large debate on whether immigration leads to fiscal gains (Rowthorn, 2008).

The effectiveness of family policies at increasing fertility might be questioned (Gauthier, 2007) as well as the political feasibility of increased immigration, but the aim here is to highlight the mechanisms at work in a model with integrated capital markets. The demographic shock occurs, for simplicity, via increase in fertility, because increased immigration would imply a reduction in another region's population. The considered scenario assumes that 100 million *additional* individuals are born in 2020 in Western Europe. Compared to the baseline, this corresponds to an extra 10 million people born every year during the decade 2011-2020. This fertility boom implies that the number of children per woman rises from 2.03 in the baseline in 2020 to 5.27 and induces a 160% increase in the number of 15 to 24 year olds in Western Europe in 2020.¹⁹ These additional individ-

¹⁸For the directive, see Council Directive 96/34/EC of 3 June 1996 on the framework agreement on parental leave concluded by UNICE, CEEP and ETUC (OJL 145, June 19, 1996, 4-9), and, for the recommendation, see European Council (2002) Presidency Conclusions. Barcelona European Council 15 and 16 March 2002.

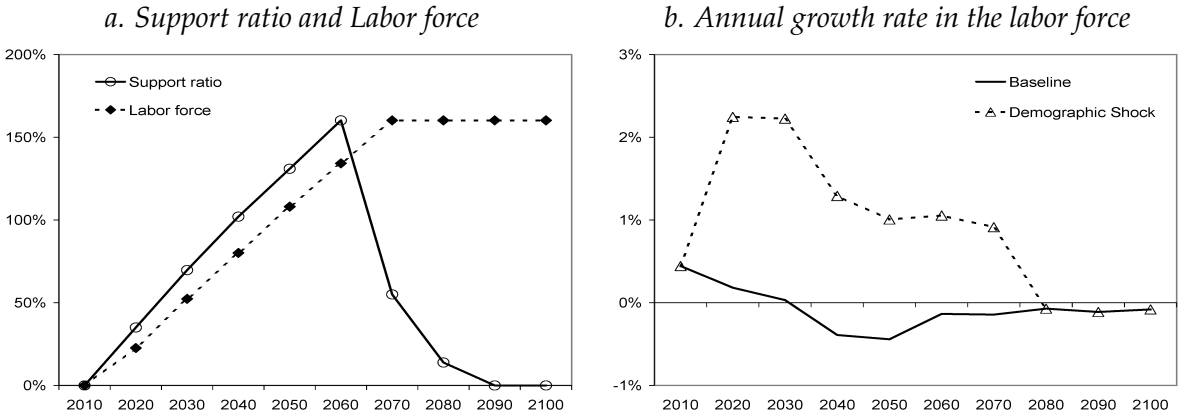
¹⁹The number of children per woman is roughly computed as the ratio of the cohort aged 15-29 in 2020 to half of the cohort aged 15-29 in 2010.

uals have the same reproduction rate and probabilities to be alive than similar aged individuals living in Western Europe. The population in Western Europe augments, compared to the baseline, by 27% in 2020 and by 160% in the long run (Table 6). At the world level, the population increases by 2% in 2020 and by 8% in the long run. In fact, the additional 100 million persons born in 2020 will augment the population even in successive periods as they procreate.

Table 6: Population change due to the demographic shock (% change from the baseline)

	2020	2040	2060	2080	2100
Western Europe	26.6%	70.5%	112.0%	151.0%	160.2%
World	1.8%	3.9%	5.6%	7.4%	8.0%

Figure 7: Impact on the support ratio and the labor force (% change from the baseline)



The enlargement in the 15-24 age group in 2020 relieves, therefore, the demographic pressure of aging even in later periods, as shown by the improvement in the support ratio (persons of working age/pensioners) over a longer time period (see Figure 7.a). After 2050, the newly-born individuals retire and the support ratio comes back to its baseline value. Moreover, the demographic change translates into a progressive increase in the labor force (see Figure 7.a) and into a positive growth rate in the workforce (Figure 7.b).

6.2 Capital mobility versus capital immobility

In the following analysis, “open economy” framework is considered, where capital is mobile across regions, and a “closed economy” framework, where capital is immobile.

Effects on macroeconomic variables

Figure 8 shows that the increased population scenario yields distinct outcomes whether performed in the open economy (*solid line*) or closed economy setting (*dashed line*). The boost in the labor force, depicted in Figure 7.b, will reduce the capital to labor ratio and raise the marginal productivity of capital. The Western European interest rate will increase in both frameworks and the wage rate decrease (Figure 8.c). When the growth in the labor force slows down (after 2030) and when the additional individuals retire (after 2060), the rise in the interest rate decelerates. When the population structure stabilizes, the interest rate goes back to its baseline value.

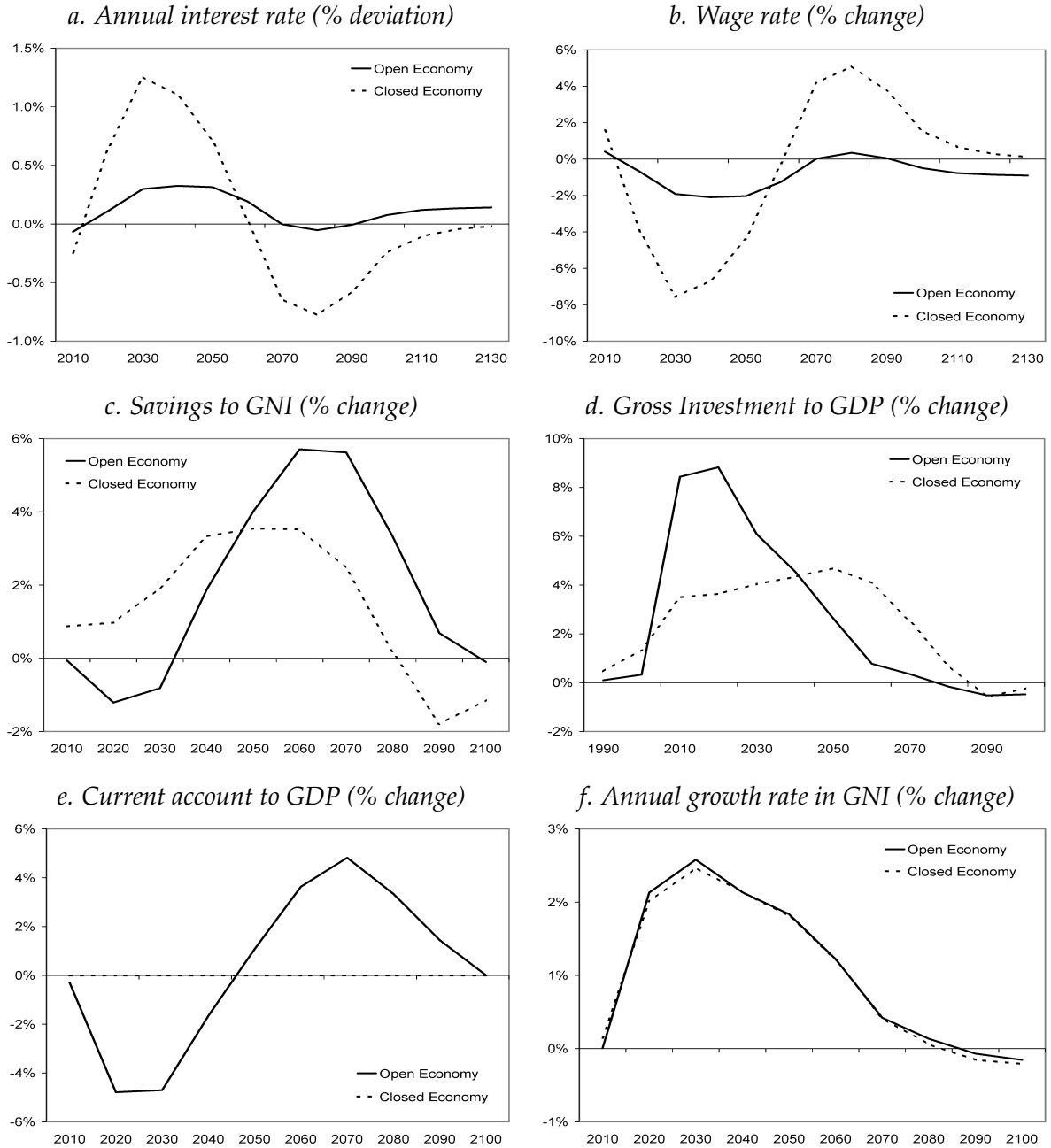
There are quantitative differences between the open and closed economy settings. In the open economy framework, capital markets are fully integrated and the Western European interest rate is equal to the world interest rate. The effects of an increased labor force are diluted on the international capital market and the interest rate reacts less than in the closed economy framework. In the open economy, regions are interdependent and the demographic shock has a long term impact on the interest rate. In fact, regions differ in terms of demographics, productivity, pension systems, educational levels etc.²⁰ In the closed economy, the response of the interest rate is larger because the effects of a rising labor force are totally absorbed by the regional capital market. However, there is no long run change in the interest rate and the increased population scenario leads simply to a rescaling of the Western European economy.

In the fully integrated world, changes in the savings and investment rates are asymmetric (Figures 8.c and 8.d). In the first decades following the shock, the savings rate is depressed as the new-born individuals (compared to the baseline) belong to age classes with negative savings rates. At the same time, the rise in the Western European labor force creates a demand for capital. The pronounced increase in the investment rate is financed by capital inflows, as indicated by the reduction in the current account balance compared to the baseline (Figure 8.e). Several decades later, the additional individuals have grown older and become high savers. The aggregate savings rate increases and the demand for capital is reduced as these individuals retire. Western Europe exports capital and its current account is positive. In a closed economy framework, changes in the savings and investment rates are asymmetric. In fact, the higher investment needs created by the rise in the labor force until 2080 are satisfied by domestic savings.

Finally, the impact on the GNI growth rate is similar in both frameworks (see Figure 8.f). The reason is that changes in the prices of each input compensate each other. In fact, in the closed economy, the rise in the labor force leads to a larger response in the interest rate than in the open economy setting but also to a higher decrease in wages.

²⁰A higher long term interest rate is established because the labor force increases in a highly productive region. The long term impact on the interest rate can be negative if the demographic shock arises in a relatively less productive region. This would be the case if the shock arises in sub-Saharan Africa (see Appendix).

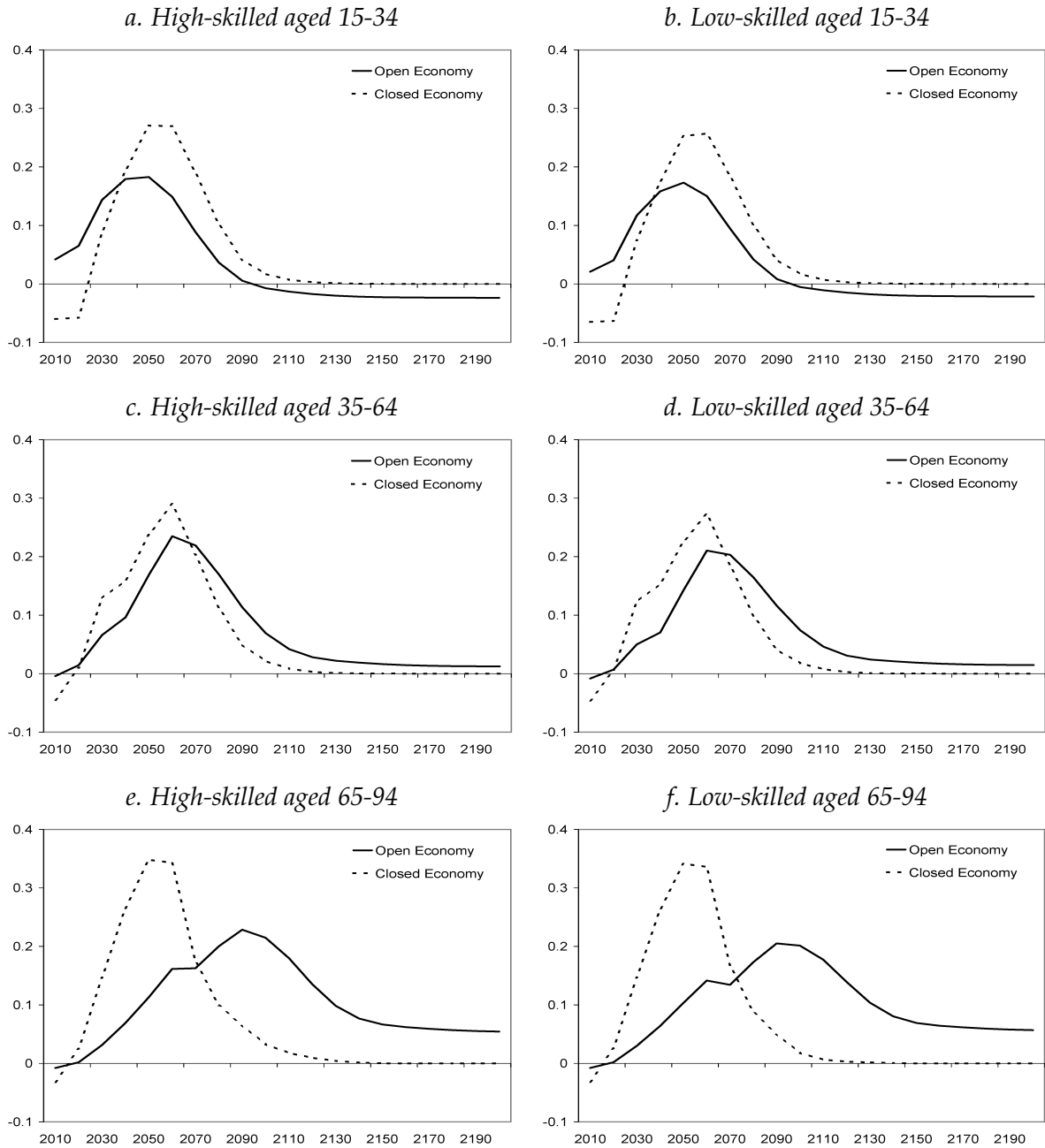
Figure 8: Impact of the demographic shock on aggregate variables



Welfare effects

However, the consumption profiles of the various age groups are affected in a distinct way in both frameworks, because of the differences in the response of input prices (Figure 9). Let us first notice that, in general, average consumption in Western Europe is increased for every cohort.

Figure 9: Impact on consumption profiles in Western Europe (% change from baseline)



In the open economy setting (*solid line*), the maximal change in the average consumption of the different age groups arises at different moments in time: the highest increases in consumption occur in 2040 for the 15-34 year olds, in 2060 for the 35-64 year olds and in 2090 for the 65+ year olds. This means that the individuals benefiting most from the population increase belong to the

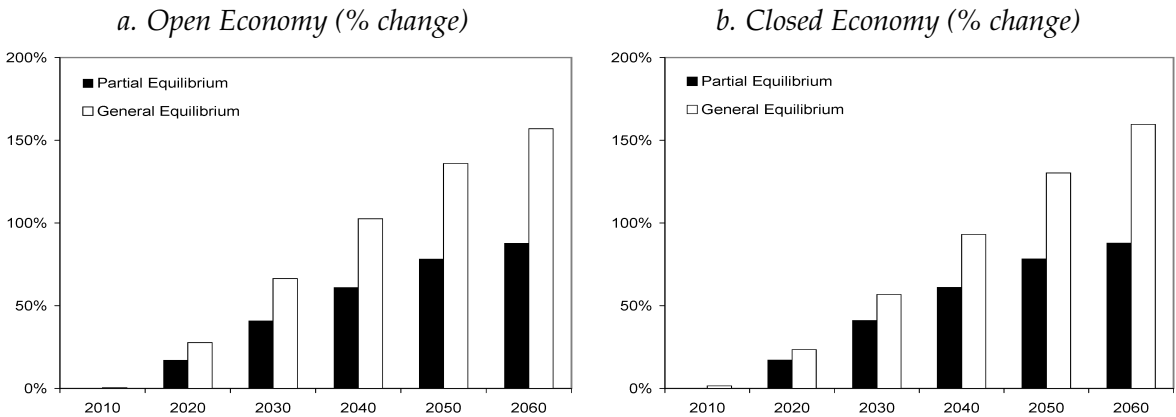
same cohort, i.e., the one born around 2040. This corresponds to the period where the fiscal effect is largest: the number of contributors is considerably enhanced while the number of pensioners is constant compared to the baseline level. In a fully integrated world, the fiscal effect explains most of the changes in consumption profiles, because changes in the returns to production inputs are small. Moreover, the cohort born at the time of the “arrival” of the 100 million individuals in 2020 witnesses a (slight) downward peak in consumption compared to other cohorts. This can be explained by the lower wage rate of this cohort, which leads to lower asset accumulation than the cohorts born before or after 2020.

In the closed economy framework (*dashed line*), average consumption of the different age groups is enhanced with a maximum in 2050-2060. The consumption of the youngest cohorts (i.e., the 15-34 year olds) is, however, decreased in 2020 (Figures 9.a and 9.b). These individuals have few assets and do not benefit from the higher interest rate and rather suffer from the drop in the wage rate. This also explains the downward peak in the consumption increment of 35-64 year olds individuals in 2040 since these are the individuals aged 15-34 in 2020 (Figures 9.c and 9.d). The pensioners are the individuals benefiting most from the 100 million additional individuals “born” in 2020, because their wealth is enhanced by the higher interest rate (Figures 9.e and 9.f).

6.3 Further experiments

The following analysis shows that taking a general equilibrium approach is necessary for an exact quantification of demographic consequences. Besides, the geographic location of a shock matters since regions differ in many aspects, e.g., demographics, productivity, welfare state and educational levels.

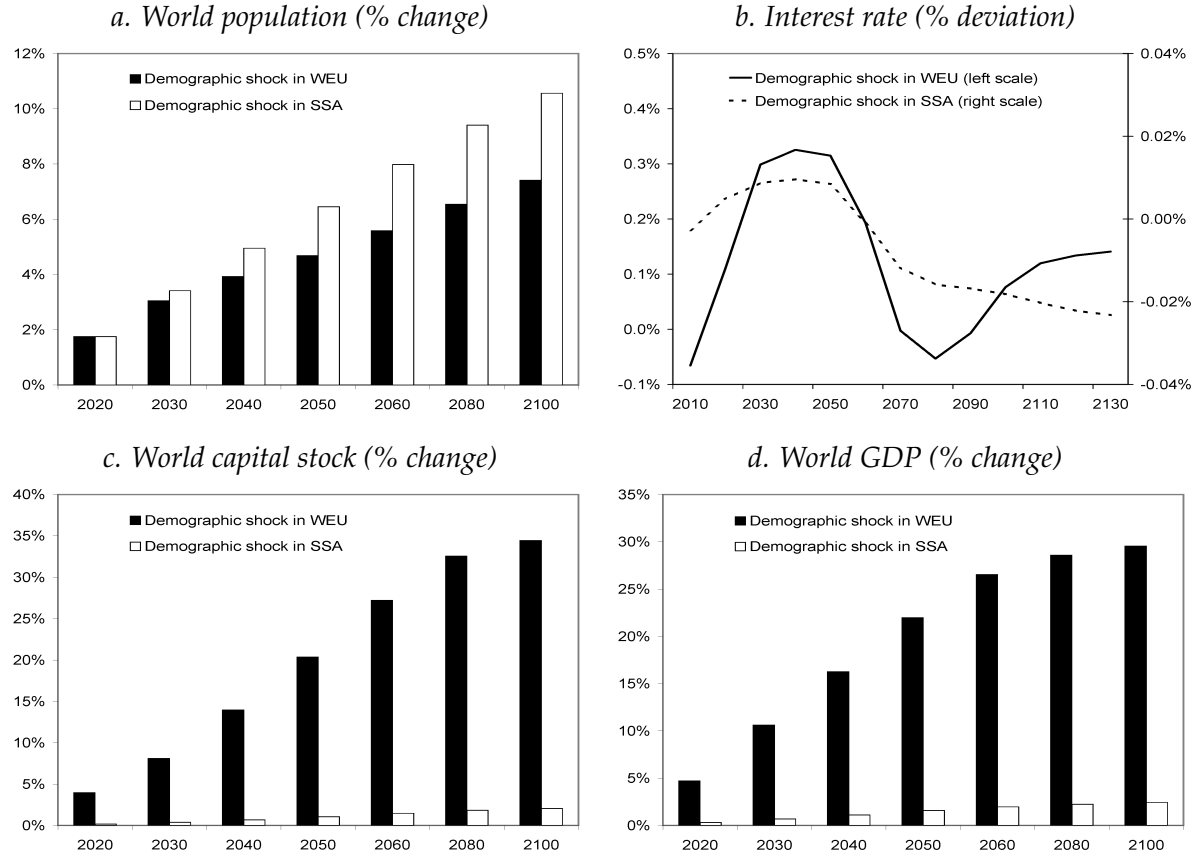
Figure 10: GDP in Western Europe under a partial and general equilibrium



Under a partial equilibrium analysis, the capital stock is kept at its baseline level, and an augmentation by 100 million individuals in the population arising in Western Europe leads to a 16%

increase in its GDP in 2010 (Figure 10.a). In the general equilibrium analysis, the response of the GDP differs, and output rises by 24% because the decisions of households and firms matter in terms of capital accumulation. In 2060, output is increased by 98% in a partial equilibrium setting and by 176% when general equilibrium effects are taken into account. The difference in output responses between a partial and general equilibrium analysis is not only due to the full integration of the capital markets. In fact, the difference would still subsist within a closed economy framework, showing that domestic supply and demand of capital are important (Figure 10.b): output is raised by 16% (partial equilibrium) and by 20% (general equilibrium) in 2010.

Figure 11: Demographic shock in Western Europe (WEU) and Sub-Saharan Africa (SSA)



The consequences of a population increase on aggregate world variables depend also on the region in which such a shock arises. Let us compare the consequences of a demographic shock in Western Europe and Sub-Saharan Africa. Figure 11.a shows that, except in 2010, a similar demographic shock affects the world population in a different way because reproduction rates differ across regions. An increase by 100 million individuals of the youngest cohort in Western Europe, respectively, in Sub-Saharan Africa in 2010 raises the world population by 8.6% and by 13.5%, re-

spectively, in 2100. The annual world interest rate will increase in 2020 by 0.38 percentage points compared to the baseline if population increases in Western Europe but only by 0.01 percentage points if the demographic shock arises in Sub-Saharan Africa (Figure 11.b). Since labor is relatively less productive in Sub-Saharan Africa than in Western Europe, the demand for capital will be lower, explaining the smaller magnitude in the response of the world interest rate to a population boom in Sub-Saharan Africa.

Moreover, in the long run, the world interest rate is enhanced (by 0.15 pp) if population rises in Western Europe and slightly depressed (by 0.02 pp) if Sub-Saharan Africa experiences the demographic shock. The “arrival” of 100 million additional individuals in a region increases its population in the long run and gives a higher weight to this region in the international capital market. When population rises in Sub-Saharan Africa, the world demand for capital is relatively less stimulated, and the interest rate is negatively impacted in the long run. It matters, thus, where the fertility boom occurs. Furthermore, the impact on the world aggregate capital stock and GDP will also differ. The world capital stock is raised by 31.8% (2.3%) in 2100 when Western Europe (Sub-Saharan Africa) witnesses a demographic shock. The world GDP rises by 39.2% when the fertility boom occurs in Western Europe and only by 2.7% when it occurs in Sub-Saharan Africa (Figure 11.d). Geographic differences also play a role even when the demographic shock leads to a similar change in the world population. In 2020, the world population increases by 1.8% when Western Europe or Sub-Saharan Africa see their youngest cohort enlarged by 100 million individuals, but the impact on the world GDP is still different: it rises by 4.7% when the demographic shock arises in Western Europe compared to 0.3% when the demographic shock happens in Sub-Saharan Africa.

7 Conclusion

This paper explores the implications of projected demographic trends on international capital flows. A calibrated overlapping generations’ model of the world economy is developed, in which the population of each region is calibrated on official population projections. Driven by these projections, the model forecasts a path of the world economy over the 21st century in which capital is internationally mobile. It is found that, over the first half of the century, emerging regions will finance the demand of capital coming from the developed world where population aging is relatively advanced. In fact, when their baby boomers will retire and dissave, Western Europe, Japan and North America will depend on the foreign capital coming from the Chinese, Indian and Latin American regions. In particular, findings suggest that China will be the world’s main creditor region during the next decades. In the second part of the century, India will take over this leading position, because the Chinese labor force will start declining as a consequence of its “one child” policy. These results are robust under various alternative assumptions on the future evolution of

productivity, educational attainments, capital market frictions and pension systems. This paper also highlights that policies affecting the demographic structure of a country, like family or immigration policies, need to account for the degree of capital market integration. In fact, the economic consequences of demographic changes differ when capital is mobile or immobile between regions.

The analysis can be improved in many ways. First, while capital can move freely across regions (up to some region-specific risks), labor is immobile. An extension of the model would be to endogenize labor movements and study the consequences of skill-specific labor movements. Moreover, like existing models, the analysis assumes that each region produces the same good. The introduction of region-specific goods, which differ for instance in their skill-intensity, would allow to study the terms of trade between the various regions.²¹ These issues are left for future research.

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²¹Attempts in those directions have been made within the INGENUE world model, by the Ingenue Team (2005), who incorporate regional-specific intermediate goods to study the evolution of real exchange rates between regions, and by Borgy et al. (2010), who analyze the implications of endogenous migration flows. The INGENUE model does, however, not distinguish individuals by their educational level.

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Appendix A: Further information on the calibration

Table 7 lists the various countries comprised in the different regions. Figure 12 provides an idea of the general fit of the model to the data in terms of demographics and educational levels for the North (aggregate of NAM, WEU and JAP) and the South (aggregate for EAS, MEN, LAC, SSA, RUS, CHI and IND).

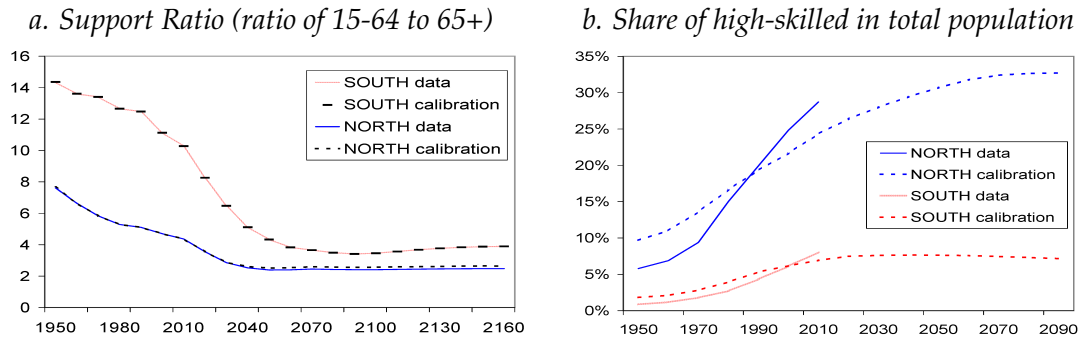
Table 7: List of countries

Region Code	Region Name	Country List
NAM	North America	United States and Canada.
WEU	Western Europe	Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.
JAP	Japan	Japan.
EAS	Eastern Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Poland, Romania, Serbia, Montenegro, Slovakia and Slovenia.
MEN	Middle East and North Africa	Algeria, Bahrain, Cyprus, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Malta, Morocco, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates and Yemen.
LAC	Latin America and Caribbean	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela.
SSA	Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Congo Democratic Republic, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Ivory Coast, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.
RUS	Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.
CHI	Chinese World	Brunei, Cambodia, China, Democratic People's Republic of Korea, Hong Kong, Lao People's Democratic Republic, Macau, Mongolia, Myanmar, Philippines, Republic of Korea, Singapore, Thailand, Timor-Leste and Vietnam.
IND	Indian World and Pacific Islands	Afghanistan, Bangladesh, Bhutan, Federated States of Micronesia, Fiji, India, Indonesia, Malaysia, Maldives, Nepal, Pakistan, Papua New Guinea, Samoa, Solomon Islands, Sri Lanka, Tonga and Vanuatu.

Appendix B: The demographics-productivity link

Figure 13 displays the evolution of the proportion of 45-54 year olds in the population aged 15-74, "45-54" (solid line with squares, right scale) as well as the evolution of productivity (A) in the baseline (solid line, left scale) and in scenario A3, when A is affected by a demographic externality with $\eta = 0.1$ (dashed line, left scale). The latter variable is computed from Feyrer (2007)'s estimates

Figure 12: Support ratio and Proportion of high-skilled



and is a function of the dependency ratio and the age groups 15-24 to 65-74 (excluding the 45-54 group). The so obtained productivity values are rescaled for every region in terms of the North American productivity (such that productivity in NAM remains equal to 1). According to Feyrer, the age group 45-54 is the one with highest “experience capital”. (Actually, Feyrer considers age classes 10-19, 20-29, ... which are approximated by the age classes 15-24, 25-34 ..., respectively, in the present study.) Figure 13 shows indeed that productivity computed from Feyrer’s estimates and the proportion of 45-54 years follow a similar pattern. Productivity in scenario A4 ($\eta = 1$) is not shown (because productivity in scenario A4 yields larger variations a third scale would be needed in Figure 13), but a comparable relationship with the age group 45-54 is obtained.

Appendix C: Further Robustness

Figure 14 displays the evolution of current accounts and net foreign assets (as a % of world GDP) in the case where productivity (A) is time-invariant and fixed at 2010 level in all regions since 1950. The current account and net foreign assets of the North (aggregate of NAM, WEU and JAP) is shown in Figure 15 in the baseline and in variants that exclude capital market frictions ($\pi = 0$), “other welfare” transfers ($\psi = 0$) or both ($\pi = \psi = 0$).

Figure 13: The demographics-productivity link in the various regions

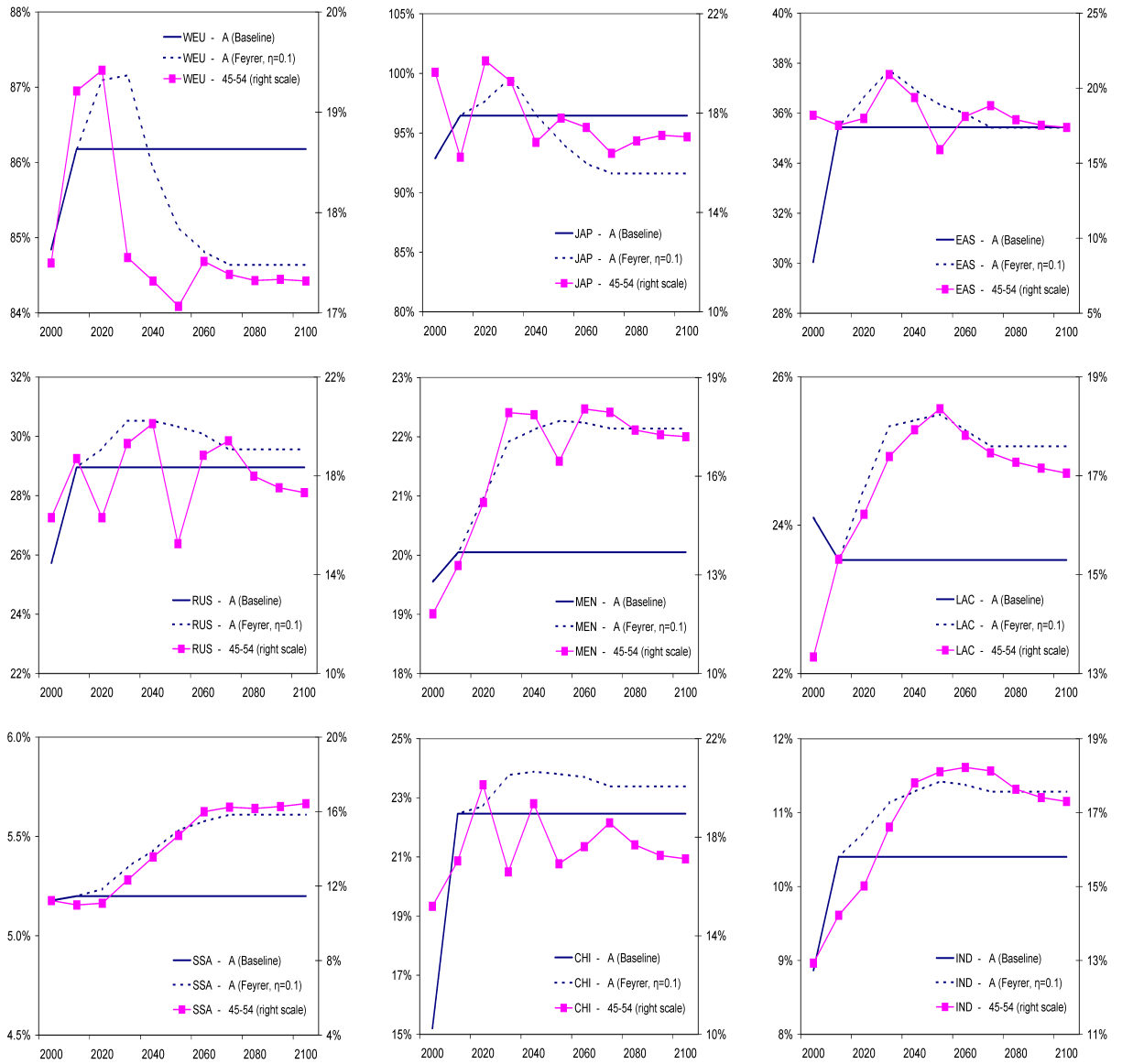
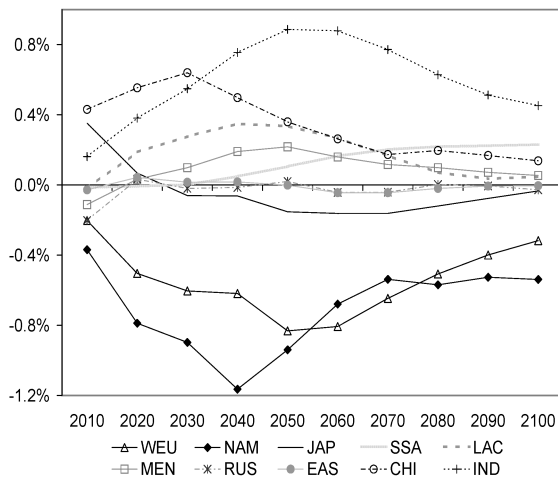


Figure 14: Current Account and Net Foreign Assets (constant productivity)

a. Current Account (% of world GDP)



b. Net Foreign Assets (% of world GDP)

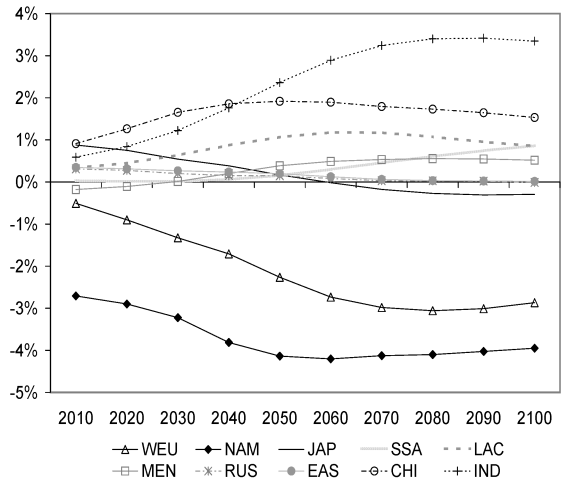
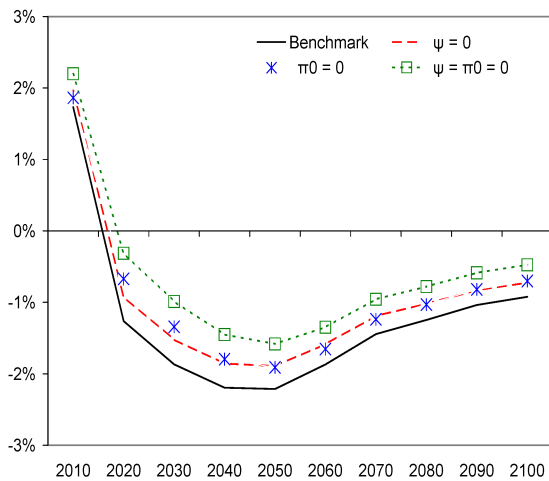


Figure 15: Current Account and Net Foreign Assets in the North

a. Current Account (% of world GDP)



b. Net Foreign Assets (% of world GDP)

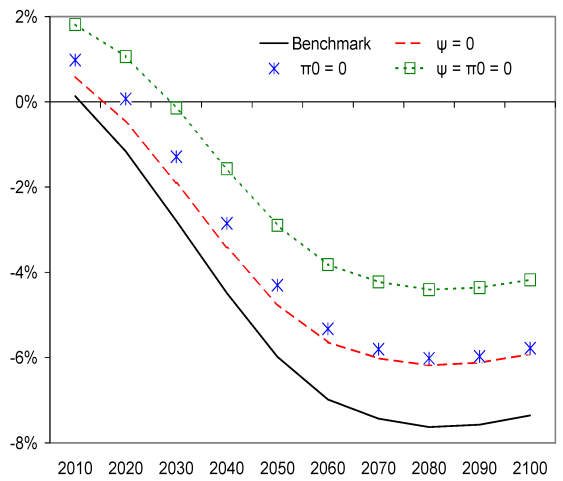


Table 8: Alternative Assumptions: Net Foreign Assets in 2050 & 2100 (% of world GDP)

2050	BSL	A0	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	D1	D2
NORTH	-5.98	-6.14	-2.05	0.18	-5.27	0.50	-5.55	-4.73	-4.90	-3.38	-4.59	-2.89	-3.99	-1.82
NAM	-3.94	-4.00	-1.80	-0.58	-3.70	-1.41	-3.69	-3.08	-3.32	-2.05	-3.20	-2.30	-3.21	-2.40
WEU	-2.15	-2.25	-0.62	0.25	-1.79	0.93	-1.99	-1.85	-1.77	-1.66	-1.61	-0.95	-1.07	0.11
JAP	0.10	0.10	0.37	0.51	0.23	0.99	0.13	0.20	0.19	0.33	0.22	0.36	0.28	0.47
SOUTH	5.98	6.14	2.05	-0.18	5.27	-0.50	5.55	4.73	4.90	3.38	4.59	2.89	3.99	1.82
CHI	2.20	2.15	0.69	-0.16	2.04	0.89	2.02	1.78	1.66	1.23	1.95	1.76	1.44	0.61
IND	1.90	1.91	1.15	0.73	1.72	-0.38	1.86	1.56	1.72	1.09	1.54	1.10	1.50	1.07
LAC	1.08	1.08	0.44	0.07	0.99	0.17	0.95	0.86	0.82	0.71	0.78	0.39	0.75	0.40
SSA	0.15	0.16	-0.04	-0.14	0.09	-0.40	0.15	-0.01	0.11	-0.22	-0.03	-0.31	0.06	-0.04
MEN	0.35	0.35	-0.08	-0.33	0.23	-1.13	0.28	0.21	0.18	0.09	0.13	-0.18	0.13	-0.10
RUS	0.15	0.34	-0.12	-0.27	0.03	0.03	0.14	0.18	0.29	0.35	0.09	0.02	0.03	-0.11
EAS	0.15	0.15	0.00	-0.08	0.17	0.32	0.15	0.16	0.12	0.14	0.13	0.11	0.08	0.00

2100	BSL	A0	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	D1	D2
NORTH	-7.36	-7.42	-6.88	-6.29	-7.37	-6.60	-7.03	-6.28	-6.81	-5.90	-6.62	-5.61	-3.98	-0.59
NAM	-4.10	-4.12	-3.90	-3.60	-4.18	-4.27	-3.92	-3.36	-3.80	-2.95	-3.69	-3.14	-2.77	-1.41
WEU	-2.94	-2.98	-2.67	-2.40	-2.89	-2.20	-2.80	-2.67	-2.72	-2.72	-2.65	-2.25	-1.13	0.67
JAP	-0.32	-0.32	-0.31	-0.29	-0.30	-0.13	-0.30	-0.26	-0.29	-0.23	-0.28	-0.22	-0.08	0.15
SOUTH	7.36	7.42	6.88	6.29	7.37	6.60	7.03	6.28	6.81	5.90	6.62	5.61	3.98	0.59
CHI	2.59	2.64	2.42	2.22	2.56	2.05	2.56	2.50	2.48	2.28	2.47	2.37	1.42	0.25
IND	2.96	2.96	3.13	3.18	3.05	3.67	2.83	2.43	2.83	2.51	2.82	2.62	2.18	1.42
LAC	0.70	0.70	0.54	0.40	0.69	0.45	0.72	0.76	0.66	0.63	0.56	0.35	0.20	-0.31
SSA	0.75	0.74	0.74	0.72	0.74	0.56	0.71	0.48	0.70	0.50	0.60	0.34	0.46	0.17
MEN	0.40	0.40	0.23	0.09	0.38	-0.06	0.31	0.19	0.24	0.08	0.26	0.06	-0.02	-0.44
RUS	-0.03	-0.01	-0.13	-0.20	-0.04	-0.08	-0.08	-0.06	-0.07	-0.05	-0.07	-0.11	-0.18	-0.33
EAS	0.00	0.00	-0.06	-0.10	0.00	0.00	-0.02	-0.02	-0.04	-0.04	-0.02	-0.03	-0.08	-0.17