Pension Reforms in Europe : an Investigation with a Computable OLG World Model.

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Abstract

This paper presents and briefly discusses the new and second version of the INGENUE model. This applied, international, overlapping-generations, general-equilibrium model of the world economy has been built mainly to analyze the interplay of pensions schemes and reforms with domestic capital accumulation in the various countries and with international capital flows, in a world of global finance. After a short description of the major features of the baseline scenario of the model for the world economy over the next 50 years, we systematically explore the domestic and international macroeconomic consequences of three scenarios of pension reforms in Europe, as well as their welfare and intergenerational distributional effects.

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1. INTRODUCTION

1.1. Ageing and Capital Flows

Demographic transition and the consequent population aging are putting the pay-as-you pension systems of OECD countries under stress and fostering various reforms whose economic consequences are likely to be important and far-reaching, both in the domestic economies of the countries implementing them and in the world economy, given the current and foreseeable degree of international economic and financial integration. Current population structures and

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demographic projections for the various regions of the world show that the aging process is not synchronous: over the next decades, while OECD countries – and most notably Europe and Japan – will experience large increases in their old-age dependency ratios, other regions of the world will be facing relatively low ratios and still rising working-age populations. This difference in time profiles of demographic changes suggests that inter-temporal trade, in the form of international capital flows, would be mutually advantageous and might improve the economic outcomes of aging compared to a situation of economic and financial autarky.
While populations in OECD countries have been aging for a long time now, raising living standards in other parts of the world are also bringing longer life expectancy and falling fertility rates in developing countries: the so-called demographic transition pattern is progressively spreading over the entire world; thus, the world population is aging, but at a different pace in the various regions of the world. Whereas various economic and social consequences of aging have been investigated in OECD countries, very few analyses have explicitly taken the worldwide aspect of the problem into account. Indeed, this generalized but differentiated aging process is occurring in a world of increasing capital mobility and financial globalization, which suggests that it may give rise to new opportunities for profitable exchanges amongst regions, a situation of mutually beneficial gains from inter-temporal trade through international financial transactions. The purpose of this analysis is therefore to evaluate the potential magnitude of such capital flows: if they are found very large compared to what has been observed in the past (end of the XIX century up to World-War-I) or in more recent years, such a prospect raise the issue of international financial instability and of the institutions and regulations that would have to be set up to make such large capital flows between developed and aging countries and developing countries with younger populations sustainable.

This paper presents, and makes use of, an applied, international, overlapping-generations, general-equilibrium (OGGE) model of the world economy built upon the 2000 UN demographic projections to study the prospects of asset accumulation and investment in the various regions of the world and of international capital flows over the next few decades.
The first section of the paper presents the model, and discusses a number of aspects of the calibration process. The steady state and transition path of the baseline scenario are described and briefly commented in Section 2. Section 3 explores the aggregate consequences, on the world economy and on regions, of three contrasted pension reform scenarios in Europe: a more generous indexation rule; a constant contribution rule; and a postponement of retirement.

1.2. A brief report on the Ingenue project

The first version of the INGENUE model describe a multi-region, world model, in the spirit of those developed by Obstfeld and Rogoff [1996, chap. 3], in

which the structure of each regional economy is similar to that of other applied, OGGE models, such as Auerbach and Kotlikoff [1987], except that labor supply is exogenous.
The world was divided into six regions, each of which is made of three categories of economic agents: the households, the firms, and a PAYG retirement pension system. There was only one good, and only one financial asset, which is an ownership stake in the firms' productive capital ; both of them are freely traded on perfectly competitive world markets. There was no money and hence only two relative prices in each region: the (real) wage rate accruing to local, internationally immobile, workers; and the single (real) price of financial assets, both expressed in terms of goods, which may be chosen as *numéraire*. Hence, the various regions of the world were economically and financially perfectly integrated and there is only one world market for goods and one for financial assets.
We have performed various work with this first model (among them Ingenue [2001], Ingenue [2002a], Ingenue [2002b]) but the model soon appeared to be unrealistic in some of its outcome because of some irrelevant elements in its theoretical structure. So we decided to built a new version of this model and also to improve the calibration data and procedure.

Ingenue 2 v.s. Ingenue1 : what is new?

1. Demographics : the World is now divided in 10 regions. In order to make autonomous own demographic projections we have built a population projection model based upon UN coefficient methods.

2. We now assume uncertainty in lifetime expectancy at individual level. At the macroeconomic level there is still no uncertainties about it.

3. International trade of commodities : In order to deal with relative price movements of foreign and domestic goods we assume that the different countries produce, different imperfectly substitutable intermediate goods as in Backus, Kehoe and Kydland [1995]. This will imply the existence of real effective exchange rates between the different regions. Here the main determinants of exchange rates are the relative productivity in the two productive sectors as in the standard view developed since Obstfeld and Rogoff works (i.e. the famous *Balassa-Samuelson effect* that is predominant in long run explanations of difference in real exchange rates).

4. We model region-specific interest rates to debtor that differ from the unique world interest rate to creditor by imposing an *ad hoc* convex function of the region own ownership ratio.

5. Calibration improvements : introduction of inheritances based upon a bequest motive, age-specific labor participation rates (exogenous), age-specific human capital (exogenous), labor income of children in some parts of the world ...

2. An international, inter-temporal model of the world economy with realistic demographics

The INGENUE model is a multi-region, world model. The world is divided into ten regions, each of which is made of four categories of economic agents : the households, the firms, a fictive world producer of a world intermediate good, and a PAYG retirement pension system. So lets begin by describing the different regions and the households then we will discuss about the firms and the social security and at last we will study the general equilibrium of the model.

2.1. DEMOGRAPHICS

2.1.1. Regions

The World is divided in 10 regions according to geographical criteria in the following way :

1. **"Western Europe" :** 'Channel Islands', 'Denmark', 'Finland', 'Iceland', 'Ireland', 'Norway', 'Sweden', 'United Kingdom', 'Greece', 'Italy', 'Malta', 'Portugal', 'Spain', 'Austria', 'Belgium', 'France', 'Germany' (East + West), 'Luxembourg', 'Netherlands', 'Switzerland'.

2. **"Eastern Europe" :** 'Estonia', 'Latvia', Lithuania', 'Bulgaria', 'Czech Republic', 'Hungary', 'Poland' 'Romania', 'Slovakia', 'Slovenia', 'Albania', 'Bosnia and Herzegovina', 'Croatia', 'TFYR Macedonia', 'Yugoslavia'.

3. **"North America" :** 'Canada', 'United States of America', 'Australia', 'New Zealand', 'Melanesia', 'Fiji', 'New Caledonia', 'Papua New Guinea', Solomon Islands', 'Vanuatu', 'Micronesia', 'Guam', 'Polynesia', 'French Polynesia', 'Samoa'.

4. **"South America" :** 'Argentina', 'Bolivia', 'Brazil', 'Chile', 'Colombia', 'Ecuador', 'French Guiana', 'Guyana', 'Paraguay', 'Peru', 'Suriname', 'Uruguay', 'Venezuela', 'Belize', 'Costa Rica', 'El Salvador', 'Guatemala', 'Honduras', 'Mexico', 'Nicaragua', 'Panama', 'Bahamas', 'Barbados', 'Cuba', 'Dominican Republic', 'Guadeloupe', 'Haiti', 'Jamaica', 'Martinique', 'Netherlands Antilles', 'Puerto Rico', 'Saint Lucia', 'Trinidad and Tobago'.

5. **Japan**

6. **"Mediterranean World" :** 'Algeria', 'Egypt', 'Libyan Arab Jamahiriya', 'Morocco', , 'Tunisia', 'Western Sahara', 'Armenia', 'Azerbaijan', 'Bahrain', 'Cyprus', 'Georgia', 'Iraq', 'Iran', 'Israel', 'Jordan', 'Kuwait', 'Lebanon', 'Occupied Palestinian Territory', 'Oman', 'Qatar', 'Saudi Arabia', 'Syrian Arab Republic', 'Turkey', 'United Arab Emirates', 'Yemen'. 'Turkmenistan', 'Uzbekistan' 'Kyrgyzstan'

7. **“Chinese World” :** ’China’, ’Democratic People’s Republic of Korea’, ’Mongolia’, ’Republic of Korea’, ’Brunei Darussalam’, ’Cambodia’, ’East Timor’, ’Lao People’s Democratic Republic’, ’Myanmar’, ’Philippines’, ’Singapore’, ’Thailand’, ’Viet Nam’.

8. **“Africa” :** ’Burundi’, ’Comoros’, ’Djibouti’, ’Eritrea’, ’Ethiopia’, ’Kenya’, ’Madagascar’, ’Malawi’, ’Mauritius’, ’Mozambique’, ’Réunion’, ’Rwanda’, ’Somalia’, ’Uganda’, ’Tanzania’, ’Zambia’, ’Zimbabwe’, ’Angola’, ’Cameroon’, ’Central African Republic’, ’Chad’, ’Congo’, ’Democratic Republic of the Congo’, ’Equatorial Guinea’, ’Gabon’, ’Botswana’, ’Lesotho’, ’Namibia’, ’South Africa’, ’Swaziland’, ’Benin’, ’Burkina Faso’, ’Cape Verde’, ’Côte d’Ivoire’, ’Gambia’, ’Ghana’, ’Guinea’, ’Guinea-Bissau’, ’Liberia’, ’Mali’, ’Mauritania’, ’Niger’, ’Nigeria’, ’Senegal’, ’Sierra Leone’, ’Togo’. ’Sudan’

9. **“Russian World” :** ’Belarus’, ’Russian Federation’, ’Ukraine’. ’Kazakhstan’, ’Republic of Moldova’,

10. **“Indian World” :** ’India’, ’Afghanistan’, ’Bangladesh’, ’Bhutan’, ’Maldives’, ’Nepal’, ’Pakistan’, ’Sri Lanka’, ’Tajikistan’, ’Indonesia’, ’Malaysia’.

2.1.2. Population structure and Projection Method

In the first version of the model, the demographic data selected are the 2050 projections of the United Nations (extrapolated numerically until 2100). In the new version, it was decided to build our own demographic projections. Indeed, the demographic shifts being in the core of the model, it was prejudicial with the analysis not to be able to study various demographic assumptions, and their precise impact on the financing of the retirements and flows of capital. We thus elaborate a simple methodology of construction of the demographic data. To guarantee the coherence of this method, a central scenario is calibrated to reproduce UN data.
The period of the model is set to five years. In each region z, the economy is populated by 21 overlapping generations of one-sex agent who may no live longer than 105 years. For notation purpose cohorts will be indexed by $a \in [0, \dots, 20]$. The number of people of age a at time t is denoted by $L_a^z(t)$ (for any household variable, a subscript a denotes age and an argument t in parentheses denotes calendar time). At date t the number of “births” (individuals between 0 and 4 years old) is then denoted by $L_0^z(t)$ and total population alive at time t in the region z is $L^z(t) = \sum_{a=0}^{20} L_a^z(t)$.

Population evolution are exogenously calculated according to a standard population projection method on the basis of historical and prospective UN data. We have aggregated population structure, with the UN data from 1950 to 1995, over countries to build Ingenue’s regions (see above). Then we have projected fertility and mortality trends (for both sexes) at the region-aggregate level, this together with initial population structures in 1995, allow us to obtain population evolution in the future from 2000 until the ending date of the model. We implicitly assume that there is no migration flows in the future. With some usual population projection methods, we construct evolution of mortality and fertility tables on the only basis of life expectancy and global fertility rates evolutions in the future[1].

Mortality People can die before 105 year ; let s_a the conditional probability of surviving between age a and age $a+1$, the number of age $a-1$ people then changes as :

$$L_a^z(t) = s_{a-1}^z(t-1) \cdot L_{a-1}^z(t-1) \quad \text{for all } a > 0 \tag{1}$$

$\prod_{i=0}^{a-1} s_i(t+i)$ is then the unconditional probability of being alive at age "a" when born at date t. For population projection we then need some process to describe evolution of $\{s_{a-1}^z(t-1)\}_{a>0}$ for $t = 2000, \ldots, T$ (for both sexes). For this we first have to precise beginning and ending mortality tables. Beginning table is given from UN data between years 1995 and 2000. Ending table are chosen among UN "typical" long run mortality tables (from Coale and Demeny, 1966). We then have to choose a date when the convergence to the long run table will be achieve and a process for convergence between initial date and this date. According to UN methods we extrapolate future mortality tables on the basis of a expected trend for life expectancy. We adopt a linear process of convergence.

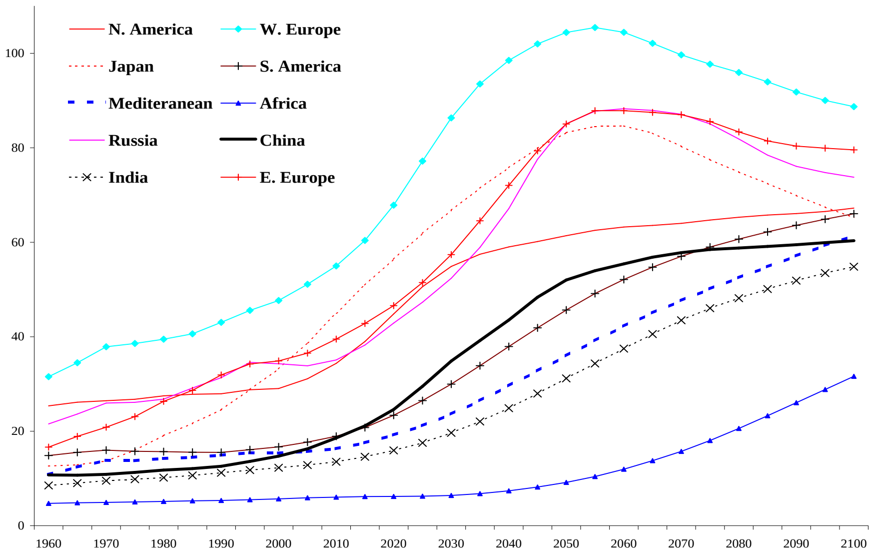
Fertility Process At each time period the number of births will be equal to $L_0^z(t) = \sum_{a=3}^{9} f_a^z(t) L_a^z(t)$ (here L is only female population), where f_a^z are the average age-specific fertility rates, we implicitly assume following UN projections that women fertility occurs only between 15 and 50 years old.

2.1.3. Main demographic features

Japan is the first to undergo the most severe demographic shock. The lengthening of the life expectancy is accompanied by a collapse of the birthrate, which reaches 1.43 child by woman in 1995, against 1.99 in the United States and 1.7 in Europe. At the same time the baby-boom in Japan started earlier and was proportionally more pronounced than what Europe could experiment. The persistance of a very weak birthrate after 1995 and until 2050 accentuates this phenomenon. This evolution for birthrate after 1995 will explain the decline of labor force in western countries in the next decades (see chart 2).
A contrario, in the America zone, the rate of reproduction of generations, near of 1 in 1995 (0.96) drops only slightly until 2050 to stabilize at 0.93 and the birth rate remains above 1.9 child by woman.
Western Europe is in an intermediate situation partly because extreme situations (Scandinavian countries, Germany, Ireland...) are mutually neutralized.

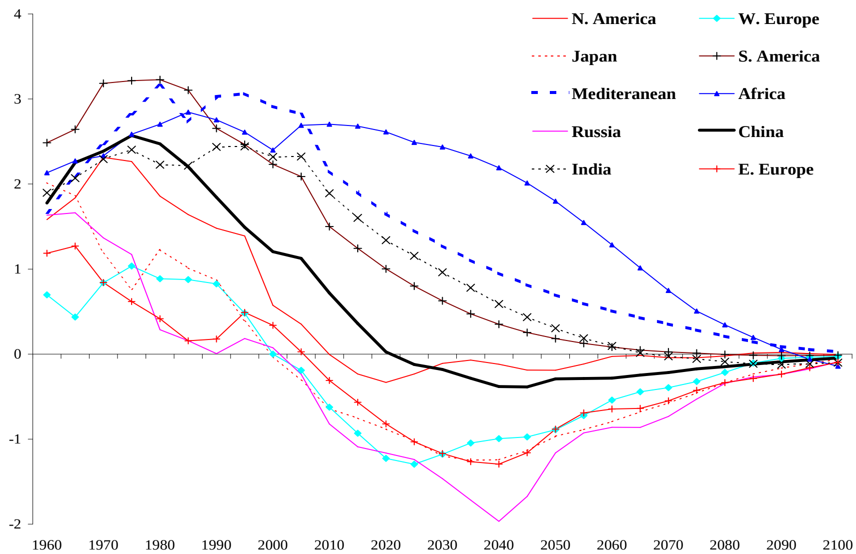
[1] More details could be provide in a technical notice about population projections upon request at the authors at the following e-mail address : ingenue@cepremap.cnrs.fr.

Figure 1: Dependency ratio (retirees in percentage of total active population) : 1960 - 2100



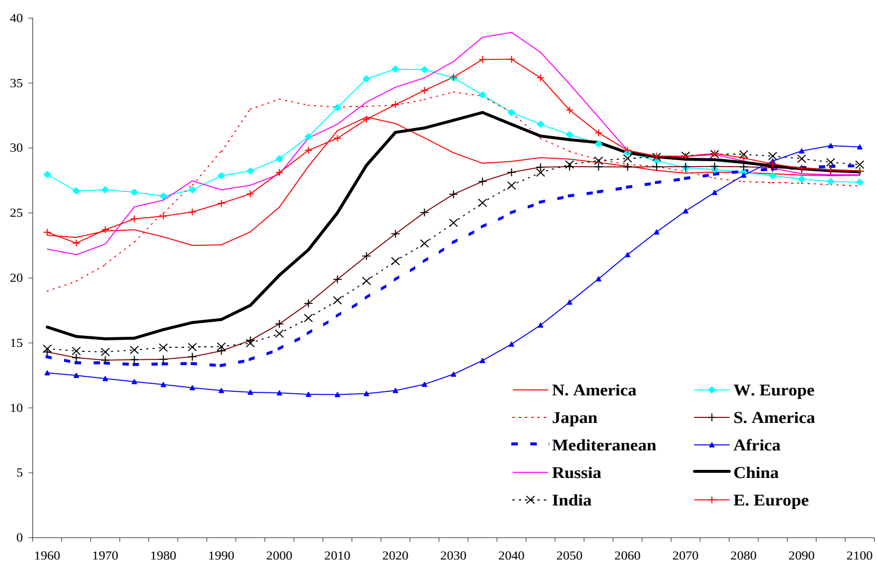
The grouping in the same geographical area is justified especially because an important degree of interdependence exists between these economies (EMU, Euro zone). Notice that because that institutional rules about legal age of retirement differs in the two zones (Europeans quit earlier) the dependance ratio is greater in Europe than in Japan (see chart 5).
Concerning the emerging or in transition countries advanced in their demographic transition process (i.e Chinese World, Eastern Europe and Russian world) they are characterized by a rapidly aging population which is projected to be even more pronounced than in Western Countries around the middle of the century for Eastern Europe and Russian world (see chart 2).
The others regions are more heterogeneous. They comprise countries in progress in their demographic revolution or for which the latter should only intervene after 2000 but before 2050 (South America, Indian World) and some countries where demographic transition process is still at its beginning (Mediterranean World and Africa). They have a strong growth of their population and then of their active population (chart 2). The profile is different with respect to the previous groups : demographic growth rates are higher; the population comprises a higher proportion of young people but life expectancy is on average appreciably shorter; the old age dependency ratio is relatively lower. Thus, throughout the period 1995-2050, the difference between the old dependency ratios doubles. As a consequence of the dynamism of their active population these regions will need a lot of capital to equip their numerous potential workers.

Figure 2: Active population annual growth rate (percentage) : 1960 - 2100



From 1960 to 2000 the population of high savers in total population (according to life cycle behaviour) is steadily increase in western countries until it reaches a peak, around 2000 in Japan and around 2020 in Western europe and North America (see 3). After this it will progressively decline. This demographic feature will influence a lot saving rates in the next years in our model because life cycle hypothesis is in the heart of saving behaviour of our model. A similar phenomenon for Chinese World, Eastern Europe and Russian world can be observed but with a delay with regards to western world : it begins latter and the upper bound will be attain later (around 2020). In the chinese world these changes will even occur very fastly : from 1995 to 2020 the high savers ratio will increase from 16% to 30 %!

Figure 3: High savers ratio (age group 45-69 yrs. in percentage of total population) : 1960 - 2100



2.2. MACROECONOMIC FRAMEWORK

2.2.1. Households

Individuals are assumed to become adults when they turn 20 ($a_0 = 4$ in formula). During any period, the household sector is then made of 17 overlapping cohorts of "adults", of age between 20 and 105, and 4 cohorts of "young". Adults may not stay in the labor force after a legal maximal mandatory retirement age $\bar{r}^z$. Economic decisions are their consumption and saving decisions, made with perfect foresight at the beginning of their adult life. Between 15 and 50 yrs. adults are supposed to give birth to children, according to the fertility calendar. Children are dependent until they turn 20, they consume with a cost per child that is supposed to be proportional to the parents consumption.

Labor supply is assumed to be exogenously given as the age-specific rate of participation to labor market : e_a^z. We take ILO data and projections to characterize activity from 1950 until 2015 and assume that after this date participation rates remain fixed at their 2015 level. According to this database people may work since the age of 10 so we will take into account children labor income to the budget constraint of their parents.

The intertemporal preferences of a new entrant on working-life are given by the following life-time utility function over uncertain streams of consumption c_a^z and leaving a voluntary bequest H^z to their children when they'll reach an age of T (if they survive until this age)[2] :

$$\begin{aligned} U_{a_0}^z(t) &= \sum_{a=a_0}^{20} \rho^{a-a_0} \left[\prod_{i=a_0}^{a-1} s_i^z(t+i) \right] \frac{\eta}{\eta-1} c_a^z(t+a-a_0)^{\frac{\eta-1}{\eta}} \\ &+ \rho^{T-a_0} \prod_{i=a_0}^{T} s_T^z(t+T-a_0) V\left(H^z(t+T-a_0)\right) \end{aligned} \tag{2}$$

where ρ is the psychological discount factor[3], C_a is consumption at the age a ; η is the intertemporal substitution rate and $V(\cdot)$ is the instantaneous utility of bequest, so agent has some felicity from leaving a bequest but it is independent of the future stream of the consumption that the children draw from this bequest (*warm glow* altruism). This bequest behaviour is mainly adopted to calibration issues (empirically savings for life-cycle can only explain a part of saving motives).

[2]Usually in these kind of model the age T is the biological limit to life (here 105 yrs.) but in order to imply a realistic pattern of inheritance among the children of deceased households, we will assume that T is equals to 80 yr old.

[3] Notice that the effective discount rate is equal to $\prod_{i=a_0}^{a-1} s_i^z(t+i)\frac{\eta}{\eta-1}\rho^{a-a_0}$, meaning that agents only care of their future as long as they stay alive. In other words the expectation takes into account that the agent can die before 105 yrs. old.

At any given period, the budget constraint is (with additional constraints $S_{a_0-1} = 0$ and $S_{20} \geq 0$) for all $a \in [a_0, \ldots, 20]$:

$$\begin{aligned} & \tau_a^z(t) p_f^z(t) C_a^z(t) + p_f^z(t) S_a^z(t) = Y_a^z(t) + p_f^z(t) S_{a-1}^z(t-1) \frac{R^z(t)}{s_{a-1}(t-1)} \\ + \quad & p_f^z(t) h_a^z(t) - p_f^z(t) H^z(t) \Upsilon_T(t) \qquad (3) \\ & Y_a^z(t) = \begin{cases} \zeta_a^z(t) + (1-\theta^z(t)) w(t)^z e_a(t) \vartheta_a & \text{for} \quad a < \underline{r}^a \\ (1-\theta^z(t)) w(t)^z e_a(t) \vartheta_a + (1-e_a(t)) P_a^z(t) & \text{for} \quad \underline{r}^a \leq a < \bar{r}^a \\ P_a^z(t) & \text{for} \quad a \geq \bar{r}^a \end{cases} \end{aligned}$$

where S_a^z denotes the stock of assets held by the individual at the end of age a and time t, $R^z(t) \cdot S_a(-1)$ is financial income (domestic real return on assets holdings times wealth), τ_a is the age-specific equivalence scale that takes into account costs of child-rearing (see details hereafter), and Y_a is the non-assets net disposal income. $p_f^z(t)$ is the price of the domestic final good so $R^z(t)$ is the return to capital income expressed in units of this final good. Due to life uncertainty at the individual level one may think that there exists unintended bequests, instead of we assume here following Yaari [1965] that there exists perfect annuities markets that pool death risk within the same generation so that the return to capital is "corrected" by the instantaneous survival probability of the generation. Besides children received inherited assets $h_a^z(t-1)$ from the voluntary bequests of their parents. People will leave bequest $H^z(t)$ to their heirs only at the age of T, so in equation (3) $\Upsilon_T(t)$ is a dummy that will be equal to 1 if $a = T$ and zero in other case.

For full-time active years ($a \in [a_0, \underline{r}^a[$), Y_a is simply equal to the net labor income after social security taxes (at rate θ), where w is the real wage rate per efficient unit of labour at time t. When agent is partly retired ($a \in [\underline{r}^a, \bar{r}^a[$), she also receives a pension benefit P_a^z for the unworked hours. And when she is full-time retired ($a \in [\bar{r}^a, 20]$) she only receives the pension benefit . As a matter of fact, unless notice otherwise, pension benefit is assumed to be age independent.

The τ_a^z term is the age-specific equivalence scale, it takes account the direct and indirect private costs of child-rearing. In order to calculate this relative cost of child-rearing for each cohort we need first to know the age distribution of children for each parent (from their past fertility behaviour) and second we need the age "c" (for child) equivalence scale of children β^c, which will be assumed here to be constant :

$$\tau_a^z(t) = 1 + \sum_{c=\max(0,a-12)}^{\min(3,a-3)} \beta^c \cdot L_a^{c,z}(t) \qquad a = 4, \ldots, 12 \qquad (4)$$

where the average number L_a^c of children of age c raised by cohort of age a can be recovered from fertility evolution (given the fertility calendar and the early death of both children and parents). For simplicity, the children depending of parents younger that 20 years old are assumed to be "allocated" between the adults that have children of the same age (allocation with age-specific weights)[4]. $\zeta_a^z(t)$ is the labour income that children bring to their parents resources during their childhood (calculated in the same spirit that costs of children-rearing).

An agent's earning ability is assumed to be an exogenous function of its age. These skill differences by age are captured by the efficiency parameter ϑ_a which changes with age in a hump-shape way to reflect the evolution of human capital. For simplicity, we assume that this age-efficiency profile is time-invariant and is the same in all region. In the baseline case we adopt Miles (1999) human capital profile's estimation (for UK) and normalize ϑ_a such that $\vartheta_{a_0} = 1$.
New cohorts choose plan for current and future consumption as well as bequest in order to maximize their lifetime utility 2 under their intertemporal budget constraint taking prices, social contribution and benefits as given. At the equilibrium the first order conditions for this program will yield (together with (3 and the transversality condition $S_{20} = 0$ assumed to be satisfied), $\forall z$:

$$C_{a+1}^z(t+1) = C_a^z(t) \cdot \left[\rho R^z(t+1) \frac{\tau_a^z(t)}{\tau_{a+1}^z(t+1)}\right]^\eta \qquad a \in [a_0, 20[\tag{5}$$

$$C_T^z(t)^{-\frac{1}{\eta}} = V'\left(H^z(t)\right) \tag{6}$$

Voluntary bequests are distributed to children according to the fertility calendar of their deceased parents. Taking Blinder (1975) functional form for V, we obtain a simple linear relation for (6) : $C_T^z = \Psi^z H^z$, where Ψ indicates the degree of altruism. At the equilibrium the sum of voluntary bequest will be equal to the inheritance received by children :

$$L_T^z(t) H^z(t) = \sum_{a=T-3}^{T-9} L_a(t) h_a(t) \tag{7}$$

Notice that people of age T have only children between age $T-9$ and $T-3$ so we have $h_a(t) = 0$ for all $a \notin [T-9, \ldots, T-3]$. For $a \in [T-9, \ldots, T-3]$, we assume that bequests are distributed equally to all children then h_a is proportional to the size of the children born from cohort of age T (according to her past fertility calendar).

In our international context, households can choose the region they want to invest their wealth. So we need another equilibrium equation that characterizes the trade off between distinct assets :

[4]Being more precise will need to conserve the distribution of child with respects to their grand-parents and will complicate in an useless way the number of state variables in the system.

$$R^z(t) = R^\star(t)\frac{p_f^z(t-1)}{p_f^z(t)} \qquad \text{for all t} > 0 \tag{8}$$

where $R^\star(t)$ is the unique world interest factor (in terms of the world *numéraire*), the condition 8 means that if a region z'household save one unit in is domestic asset (capital) it will yield $R^z(t)$ in real terms at the next period, if he chooses to invest on international market he will receive in real terms $R^\star(t)\frac{p_f^z(t-1)}{p_f^z(t)}$. Positive assets holdings of both kind of savings will imply that the two returns will equalize at the equilibrium.

2.2.2. The public sector

The public sector is reduced to a social security department; it is a pay-as-you-go (PAYG) public pension scheme, that is supposed to exist in all regions of the world. It is financed by a payroll tax on all labor incomes and pays pensions to retired households. The regional PAYG systems operate according to a defined-benefit rule: pensions π paid to individual retired are a fraction - or replacement rate $(\kappa(t))$ – of the current average (net of tax) wage. We assume a time-to-time balanced-budget rule :

$$\frac{\theta^z(t)}{1-\theta^z(t)} = \kappa(t)\cdot\frac{\sum_{a\geq\underline{r}^a}(1-e_a(t))L_a(t)}{\sum_{a\leq\bar{r}^a}e_a(t)L_a(t)} \tag{9}$$

In the baseline case, the regional age $\underline{r}^a$ of minimum legal retirement age as well as the maximum age $\bar{r}^a$ and the ratio $\kappa(t)$ are fixed (at least after year 2000), then payroll tax rates $\theta(t)$ are endogenously determined by (9).

2.2.3. Production side

(i.) Intermediate good sector

Each zone z specializes in the production YI^z of a single intermediate good labelled, where subscript ^{z} indicates that the specific nature of this good lies in its region of origin. Production in period t takes place with a constant return to scale-Cobb Douglas production function using capital stock $K^z(t-1)$ installed at the beginning of the period t in the country z and the full domestic labor force $N^z(t)$, $\forall z$:

$$YI^z(t) = AI^z(t)\left(K^z(t-1)\right)^\alpha\left(N^z(t)\right)^{1-\alpha} \qquad 0<\alpha<1 \tag{10}$$

With this formulation YI^z also denotes GDP in the country z in terms of the local intermediate good. The current cash-flow of the representative domestic firm of the intermediate sector (in terms of the world *numéraire*) :

$$\begin{aligned} CF^z(t) &= p_I^z(t)YI^z(t) - w^z(t)N^z(t) - p_f^z I^z(t) && \text{for t} > 0\\ CF^z(t) &= p_I^z(t)YI^z(t) - w^z(t)N^z(t) - p_f^z(1-\delta^z(t))K^z(t-1) && \text{for t} = 0\end{aligned}$$

where p_I^z is the price of the domestic intermediate good ; $I^z(t) = K^z - K^z(t-1)(1-\delta^z(t))$ are the gross investment expenses in domestic final good and $\delta^z(t)$ is the rate of economic depreciation. In time 0 the present value of the firm is equal to :

$$\Pi^z(0) = CF^z(0) + \sum_{t=1}^{\infty} \frac{CF^z(t)}{\prod_{s=0}^{t} R^\star(t)}$$

where $R^\star(t)$ is the factor of interest on the world financial market. Let us denote $k^z(t-1) = K^z(t-1)/N^z(t)$ as the capital-labor ratio, the maximization of the firm value will imply at the equilibrium $(\forall t)$:

$$R^\star(t+1)\frac{p_f^z(t)}{p_f^z(t+1)} + \delta^z(t+1) - 1 = \frac{p_I^z(t+1)}{p_f^z(t+1)}\alpha A I^z(t+1)\left(k^z(t)\right)^{\alpha-1} \quad (11)$$

$$w^z(t) = p_I^z(t)(1-\alpha)AI^z(t)\left(k^z(t-1)\right)^{\alpha} \quad (12)$$

(ii.) A "trick" to model real imperfections on world financial market

For a world model to be realistic the world asset capital market have to be imperfect. Because sources of imperfection and asymmetries in financial markets are various and uneasy to model with rigourous micro-foundations in such a large scale model as Ingenue we adopt the following *ad hoc* formulation for δ^z the region-specific rate of economic depreciation, with $\varepsilon > 0$:

$$\delta^z(t) = \bar{\delta}^z + (1-\bar{\delta}^z)\Delta^z \cdot \text{Max}\left(1 - \frac{S^z(t-1)}{K^z(t-1)}; 0\right)^{\varepsilon} \qquad \text{for all z} \qquad (13)$$

where $S^z(t) = \sum_{a=a_0}^{19} L_a(t) S_a(t)$ is the aggregate wealth across overall cohorts in region z. Aggregate financial wealth is equal to the sum of the region capital stock and the net assets on the rest of the world. This equation then indicates that capital invested in a region z depreciates more rapidly than the average when the region is a net debtor of the rest of the world. In other world the net-of-depreciation return from capital invested in indebted regions are, other things being equal, lower than in creditor regions. With this formulation the domestic cost of capital for the intermediate good sector may be greater than the world cost but never be lower.

(iii.) Final good production sector

In the spirit of Backus et al. [1995], we assume that the domestic, composite final good of region z (consumption and investment) YF^z is produced thanks to a combination of two intermediate goods : a "domestic" intermediate good in proportion B^z and a "World" intermediate goods in proportion M^z, according to the following CES technology, where $\sigma \geq 0$ denotes the elasticity of substitution, $\forall z$:

$$YF^z(t) = AF^z(t)\left[(\omega^z)^{\frac{1}{\sigma^z}}\left(B^z(t)\right)^{\frac{\sigma^z-1}{\sigma^z}} + (1-\omega^z)^{\frac{1}{\sigma^z}}\left(M^z(t)\right)^{\frac{\sigma^z-1}{\sigma^z}}\right]^{\frac{\sigma^z}{\sigma^z-1}} \quad (14)$$

with $\omega^z \in [0,1]$. This CES combination of external and internal good to produce domestic final good is a *reminiscence* of *Armington [1969] aggregator*. Taking prices as given and competitive behaviour the producer determines B^z and M^z that minimizes current profit: $p_f^z(t)YF^z(t) - p_I^z(t)B^z(t) - p^\star(t)\cdot M^z(t)$ subject to (14), where p_I^z is the price of the home-specific intermediate good and $p^\star$ is the price of the world intermediate good, both expressed in terms of the specific final good. The static maximization problem of a representative competitive firm gives at the equilibrium the following first order conditions :

$$B^z(t) = \omega^z\left(\frac{p_I^z(t)}{p_f^z(t)}\right)^{-\sigma^z}\frac{YF^z(t)}{\left(AF^z(t)\right)^{1-\sigma^z}}, \quad (15)$$

$$M^z(t) = (1-\omega^z)\left(\frac{p^\star(t)}{p_f^z(t)}\right)^{-\sigma}\frac{YF^z(t)}{\left(AF^z(t)\right)^{1-\sigma^z}} \quad (16)$$

where p_f^z can be shown to be equals to the following aggregate price index formulation that at the equilibrium:

$$p_f^z(t) = \frac{\left[\omega_z^z p_I^z(t)^{1-\sigma^z} + (1-\omega^z)\, p^\star(t)^{1-\sigma^z}\right]^{\frac{1}{1-\sigma^z}}}{AF^z(t)}$$

2.2.4. The world producer of an homogenous world intermediate good

In order to simplify the exchanges of intermediate goods between regions of the world we assume that there exist a fictive world producer that uses region-specific intermediate goods in quantities $X^{\star,z}$ in order to produce a specific world intermediate good $Y^\star$ according to the following CES function :

$$Y^\star(t) = A^\star(t)\left[\sum_z \gamma^z(t)^{\frac{1}{\mu}} X^z(t)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \quad (17)$$

where $\gamma^z(t)$ is a weighted coefficient that represents the importance of the region z specific intermediate good in the world trade market (for instance think of oil producer regions, with respect to traditional theoretical trade determinants their share in world trade would be relatively small so one way to reproduce their actual huge trade balance is to allow an important size to this parameter).

This fictive agent is assumed to act competitively, taking prices as given, he chooses $\{X^z(t)\}_z$, at each period, to maximize its static profit : $p^\star(t)Y^\star(t) -$

$\sum_z p_I^z(t) \cdot X^z(t)$, subject to (17). This yields at the equilibrium the the following factor demand functions :

$$X^z(t) = \gamma^z(t) \left(e^z(t)\right)^{-\mu} Y^\star(t) A^\star(t)^{\mu-1} \qquad \text{for all z} \qquad (18)$$

where for convenience $e^z(t) = \frac{p_I^z(t)}{p^\star(t)}$ is defined as the real exchange rate. It can be shown that at the equilibrium $p^\star$ equals to :

$$p^\star = \frac{\left[\sum_z \gamma_z p_I^z(t)^{1-\mu}\right]^{\frac{1}{1-\mu}}}{A^\star(t)}$$

2.3. THE WORLD GENERAL EQUILIBRIUM

2.3.1. Definition : the competitive world-equilibrium with social security schemes

Given the initial stock of capital installed in each zone $\{K^z(0)\}_{z=1,..,10}$ *; initial distributions* $\{S_a^z(0)\}_{z=1,..,10;a=a_0,..,19}$ *of savings across age groups a and zone z ; initial prices for domestic commodities* $\{p_f^z(0)\}_{z=1,..,10}$ *and exogenous population prospects* $\{L_a^z(t)\}_{t\geq 1;z=1,..,10;a=0,..,20}$ *with* $\{L_a^{c,z}(t)\}_{t\geq 1;z=1,..,10;a=0,..,20;c=0,..,9}$ *the children distributions ; the technical progress process* $\{AI^z(t), AF^z(t)\}_{t\geq 1;z=1,..,10}$ *and social security policies* $\{\bar{r}^a, \underline{r}^a, \kappa^z(t), \theta^z(t)\}_{t\geq 1;z=1,..,10}$ *that satisfy (9), a competitive world-equilibrium with social security is a set of sequences for regional prices and social security transfers* $\{w^z(t), R(t)^z, p_I^z(t), p_f^z(t)\}_{t\geq 1;z=1,..,10}$ *and* $\{P_a^z(t)\}_{t\geq 1;z=1,..,10;a\geq \underline{r}^a}$*, for international prices* $\{R^\star(t), p^\star(t)\}_{t\geq 1}$*, and an allocation of quantities* $\{H_T^z(t)\}_{t\geq 1;z=1,..,10}$*,* $\{h_a^z(t)\}_{t\geq 1;a=T-9,..,T-3;z=1,..,10}$*,* $\{K^z(t), \delta^z(t), YI^z(t), YF^z(t), X^z(t), B^z(t), M^z(t)\}_{t\geq 1;z=1,..,10}$ *and* $\{S_a^z(t), C_a^z(t),\}_{t\geq 1;a=a_0,..,20;z=1,..,10}$ *such that the following equations are satisfied for each period* $t \geq 1$ *:*

(i) households maximization behaviour gives (3)–(8),

(ii) profit maximization of firms in intermediate sector gives (10)–(12), and (13) holds, for all z,

(iii) profit maximization in final good sector gives (14)–(16), for all z,

(iv) world producer profit maximization gives (17) and (18),

(v) markets are cleared at each date, ie the followings equations hold :

$$C^z(t) + I^z(t) = YF^z(t) \qquad \forall z \qquad (19)$$

$$N^z(t) = \sum_{a=2}^{\bar{r}_a} \mathrm{e}_a^z(t) L_a^z(t) h_a^z \qquad \forall z \qquad (20)$$

$$X^z(t) + B^z(t) = YI^z(t) \qquad \forall z \qquad (21)$$

$$\sum_z M^z(t) = Y^\star(t) \qquad (22)$$

where $C^z = \sum_{a \geq a_0} \tau_a^z L_a^z c_a^z$ is the aggregate consumption in region z. (19) is the equilibrium condition on the final good domestic markets in all regions, (21) is the intermediate goods market in all regions, (20) is the labor market in all regions and (22) is the equilibrium condition in the market for the world intermediate good.

2.3.2. Walras'law and additional accounting identities

It can be easily shown that these equations (19)–(22) together to the previous equilibrium equations are sufficient to describe the real equilibrium of the world economy. As a matter of fact the equilibrium of the world capital market does not appear in the previous definition because it is redundant here (i.e. *Walras' Law*). But because only relative prices are relevant to obtain equilibrium allocation one can also drop (or fix) one absolute price in the model. For calibration purpose we will choose that at each time the price of the intermediate good in the region "North America" will be set to one ($p_I^{US}(t) \equiv 1$), so all the value can be expressed in dollars in our model.
Notice that implicitly one can recover standard aggregate budget constraint of national accounts as well as the equilibrium on world capital market from previous equilibrium equation.

Regional accounts

One can verify that the sum of budget constraint over all individuals (3) give an expression of C^z that can be substituted in (19) in order to obtain (together with the PAYG constraint (9)) :

$$p_f^z YF^z = w^z N^z + p_f^z[K^z + (1-\delta)K^z(-1)] + p_f^z[R^z S^z(-1) - S^z]$$

YI^z is linearly homogeneous then using the *Euler rule* and substituting prices for quantities in the equation, with eqs. (11) and (12), gives :

$$p_f^z YF^z - p_I^z YI^z = p_f^z[K^z - R^z K^z(-1)] - p_f^z[S^z - R^z S^z(-1)] \tag{23}$$

From (21) and given $p_f^z YF^z = p^\star M^z - p_I^z B^z$ (resulting from YF^z being linearly homogenous) we also have :

$$p_f^z YF^z - p_I^z YI^z = p^\star M^z - p_I^z X^z \tag{24}$$

one can then recovers the following accounting identities (for all z) :

$$PIB^z(t) = p_I^z(t) YI^z(t) = p_f^z(t) YF^z(t) + p_I^z(t) X^z(t) - p^\star(t) M^z(t) \tag{25}$$

where : $p_I^z(t)X^z(t) - p^\star(t)M^z(t)$ is the trade balance of region z expressed in units of the domestic final good.

Equilibrium of the world financial market

Let now show that at the equilibrium the world capital market is equilibrated. Competitive behaviour of the World producer and $Y^\star$ being linearly homogenous gives to us $Y^\star(t) = \sum_z \frac{p_I^z(t)}{p^\star(t)} \cdot X^z(t)$. This together with the world market equilibrium for the world intermediate good (22) implies that the sum of trade balance over the world is equal to zero :

$$\sum_z [p_I^z(t)X^z(t) - p^\star M^z(t)] = 0 \tag{26}$$

Then summing identities (23) over the regions implies (knowing from (24) that this is equivalent to (26) : $\sum_z p_f^z[K^z - R^z K^z(-1)] = \sum_z p_f^z[S^z - R^z S^z(-1)]$. Then once the world market is cleared at time $t-1$ this implies (with eq. (8)) that it also clears at time t :

$$\sum_z p_f^z K^z = \sum_z p_f^z S^z \tag{27}$$

2.4. Few remarks on the calibration procedure

The point of departure of our numerical analysis is the year 2000. So we need our model to match the historical data at this date. To do this simply and to avoid initial jump in the equilibrium variables we choose to start our simulation in year 1955 taking as given first the historical values for state variable in 1950 and demographic and participation rates historical trajectories and projections. We then choose parameter and exogenous trajectories for sectoral factor productivity in order to imply values for the endogenous variables of the model near their historical values in the period 1990-2000.

2.4.1. The calibration process

The calibration process of the model is in four steps :

1. Given historical values for aggregate state variable in 1950, we assume that at this date that each region is autarkic and is on a steady-state path corresponding to a partial equilibrium model where agents take domestic interest rate as give. This is done in order to get an initial distribution of assets across households for each region.

2. We assume that in 1955 economy are now suddenly opening. According to historical data each region is characterized by their own degree and pace of openness in the world trade market. We also assume that the level of total factor productivity in the intermediate good sector or Total Factor Productivity (TFP corresponds to $AI^z(t)$ in eqs. (10)) are given by historical data from 1955 to 1990 (i.e. the date where ex-communist countries became ...) and that after this date TFP in all regions will

converge in a similar way toward "North America"'s TFP, "North America"'s TFP being characterized by a constant growth rate equals to 1.51 % (that implies an exogenous growth of labour productivity on 2.27 % which corresponds to the average value for this parameter over the period 1950-2000 in the "North America" region). In the same spirit we assume historical changes in the level of factor productivity in the final good sector relative to the level of factor productivity in the intermediate good sector for the period 1950 to 2000 and a constancy after this date. We deduce this historical evolution for relative productivity in both domestic sector from the evolution of real exchange rate (defined in our model by the ratio $p_f^z / p_f^{\text{N. Amer}}$.).

3. Given the previous trajectory for the equilibrium we assume the following unexpected shocks in 1990 : more rapid openness in China ; the fall of "*Berlin's Wall*" that we traduce here by the huge and rapid openness of "Eastern Europe" and "Russian World", a unexpected important depreciation rate of the capital stocks of these both region ; the "*internet revolution*" ie acceleration of the TFP of the "North America" and an assumption of a permanent higher rate of growth of this TFP.

4. The baseline scenario, given the previous trajectory we assume the following unexpected shocks in 2000 : the increase in the rate of growth of the TFP for the "North America" in the late 1990's is now seeing as just temporary and it will return at its previous long run level of 1.51 % in the near future ; and some difference in TFP convergence according to the regions (see details in the next paragraph).

2.4.2. Growth, technological diffusion and economic convergence

The level of TFP is exogenous and grows at a constant rate, in each region. For 1950 until 2000 it is given by historical data. After this date the rate of growth of the TFP is the result of a given, exogenous growth of 1.51 % per annum in "North America", supposed to be the technological leader, and a region-specific, exogenous, catching-up factor, reflecting international diffusion of technological progress, according to the following law of diffusions :

For Western Europe, Japan, India, South America, China :

$$\frac{AI^z(t)}{AI^z(t-1)} = [1+\lambda] \times \frac{AI^{US}(t)}{AI^{\text{N. Amer}}(t-1)} \times \left[\kappa^z + (1-\kappa^z)\,\frac{AI^{\text{N. Amer}}(t-1)}{AI^z(t)}\right]$$

Eastern Europe, Russia, Mediterranean World, Africa :

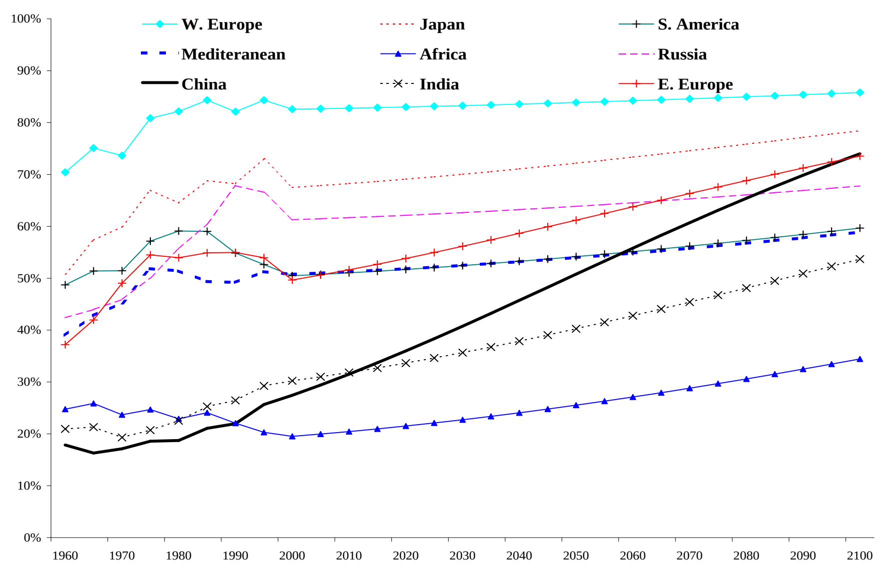
$$\frac{AI^z(t)}{AI^z(t-1)} = [1+\lambda] \times \frac{AI^{N\cdot}(t)}{AI^{\text{W. Eur}}(t-1)} \times \left[\kappa^z + (1-\kappa^z)\,\frac{AI^{\text{W. Eur}}(t-1)}{AI^z(t)}\right]$$

where AI^z is a measure of this level of knowledge ; λ plays a role of a accelerator to the convergence in the growth rates (chosen to be equal to 0.001), while κ^z is a brake on the convergence in terms of levels. Notice that in our central scenario we assume implicitly two convergence clubs : one group of countries converge towards "North America", while the other converge towards "Western Europe". As a matter of fact because "Western Europe" converge towards "North America", in the steady state every regions will have the same level for TFP. Notice also that the rhythms of convergence will differs not only because the initial (i.e. in yrs 2000) levels and the targets are different but also because we assume different values for κ^z. These values are calibrated in order to extend the actual tendencies observed in the last decade, these are reported in the table 1. The corresponding relative levels of TFP are then reported in the figure 4.

Table 1: Exogenous Catching-up : Baseline Scenario

region	W.Eur.	E.Eur	Jap.	Ind.	S.Amer.	Chin.	Rus.	Afr.	Med.
κ^z	0.9995	0.9975	0.999	0.999	0.9995	0.9975	0.999	0.9995	0.9995

Figure 4: Baseline Scenario - Total Factor Productivity (percentage of the "North America"'s level) : 1960 - 2100



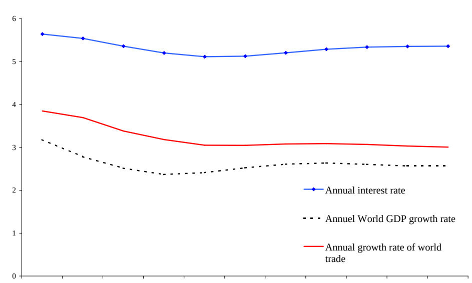
3. Baseline Case : a path for the world economy in the first part of the XXIst Century

Under our assumptions described above, simulating the INGENUE model yields a dynamic equilibrium path for the world economy that slowly converges in the very long run of stationary populations and a steady-state economic growth of 2.27% per annum. Over the XXI century, this equilibrium path of the world economy may be characterized along three major dimensions: the world capital market equilibrium, economic growth in the various regions, and the distribution of wealth and current accounts, i.e. the magnitude of international capital flows.

3.1. The world interest rate and international capital market equilibrium

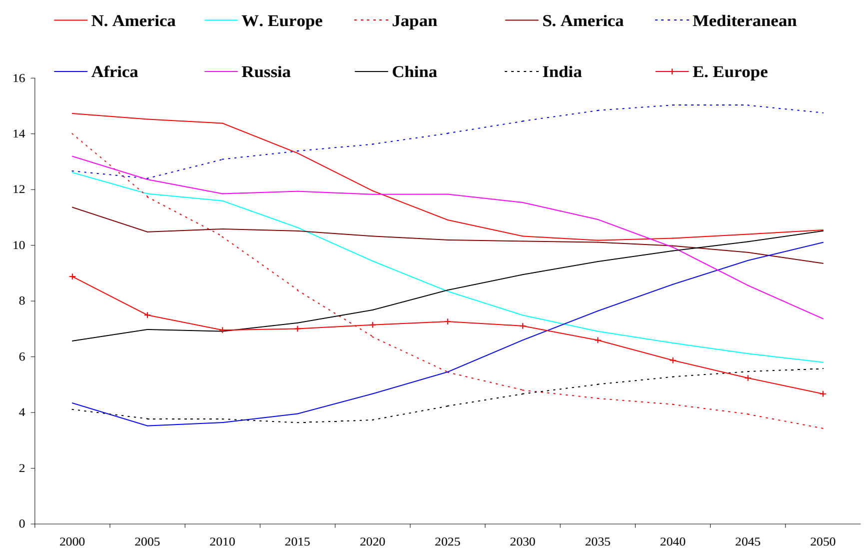
At each point in time, the world real interest rate is determined on the single world capital market by equating world capital demand and world capital supply, or equivalently the stocks of accumulated productive capital and accumulated wealth. Due to the fact that the consequences of demographic evolutions in the various regions of the world partly cancel out in terms of investment and saving, the interest rate does not vary much (left-hand side of Fig. 5), after its initial, marked decline : from over 5.6% in 2000 to about 5.1% in 2025 and slight recovery up to a little over 5.3% in 2045. But, insofar as the interest rate is the discounting factor for all decisions, small fluctuations in the interest rate would have large consequences on regional wealth distribution and on the constellation of current accounts, as well as on inter-generational distribution of wealth and welfare.

Figure 5: Baseline Scenario : International Variables, annual Rate in percentage - 2000 - 2050



The interest rate fluctuations are mostly attributable to those of regional saving rates, while the demands for capital are relatively smooth. Indeed, the latter depend on technical factors, working-age populations in the various regions –

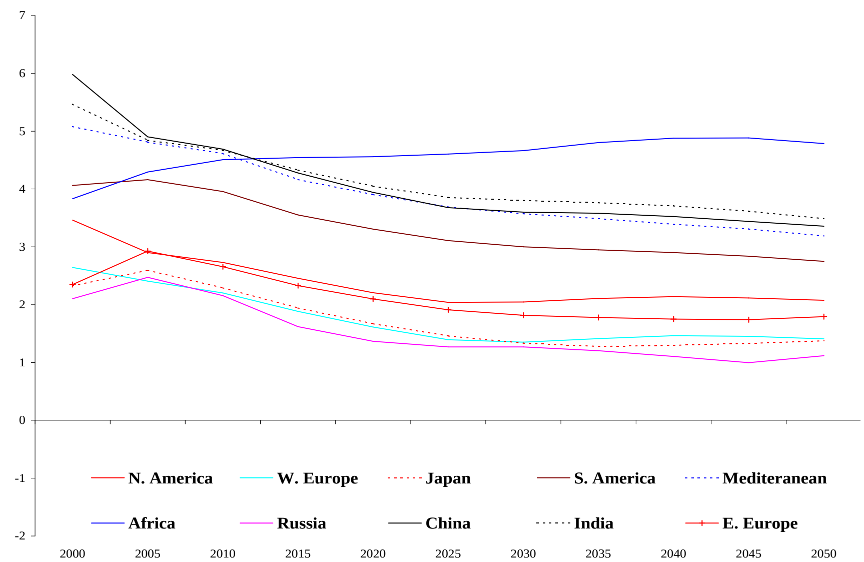
Figure 6: Evolution of net saving rates : 2000 - 2100 (percentage of GNP)



initially rapidly growing in the three developing regions, but then stabilizing, or even decreasing in developed regions–, the speed of productivity convergence, assumed to be slow in the baseline scenario, and the capital intensity of production, which in turn depends on the interest rate. Most of the action moving the world interest rate is on the supply side of the world capital market and results from demographic changes: the aggregate households' saving rates of the six regions amply fluctuate, and especially those of the two out of the three most developed regions: Europe and Japan, whose saving rates are initially high, but decline quite sharply until 2050 (Figure 6).

The impact of such fluctuations in regional saving rates on the world interest rate is all the more important in the first decades of the century as these regions have a relatively large weight in world GDP and total world wealth and developing region that is most advanced in the demographic transition process (China, Eastern Europe and Russia) has a similar profile of aggregate saving rate. In the other regions, including North America, aggregate saving rates fluctuate relatively less over the first four decades of the century, then gently decline as populations age. As a result of these regional saving fluctuations, the world capital supply markedly increases up until 2025, then much more slowly until about 2050. Afterwards, the relative stabilization of the world interest rate is mostly attributable to a slight recovery in saving rates of those regions having experienced the sharpest decline and a mild reduction in those of the others, in particular the two youngest developing regions whose weight in world population and world accumulated wealth has increased in the meantime.

Figure 7: Base Scenario: Evolution of the annual GDP growth rates : 2000 - 2050 (percentage)



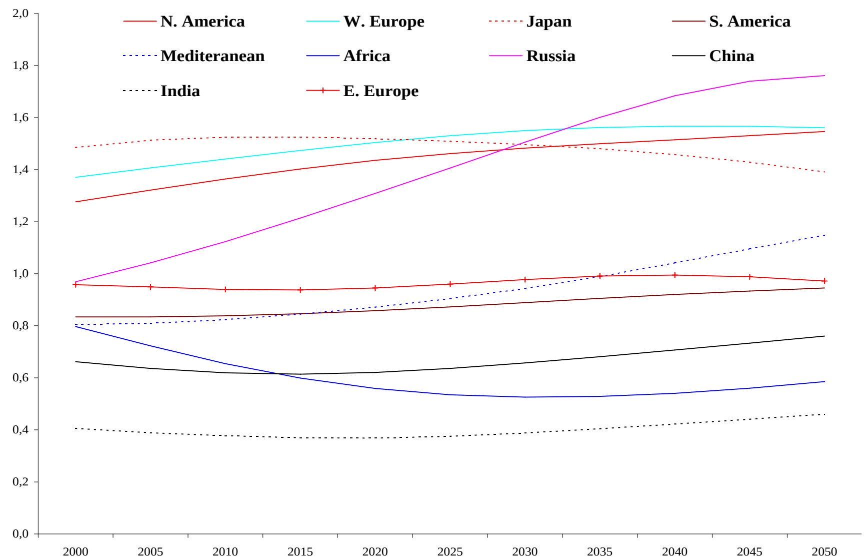
3.2. Economic growth

Because of the assumed technology and slow convergence, the regional growth rates (Figure 7) are essentially determined by working-age population dynamics, especially over the first half-century ; afterwards, the effects of the, albeit slow, diffusion of technical progress is noticeable on the growth rates of relatively backward regions, with annual growth rates around 3%. Over the first decades of the century, Europe and Japan experience a marked decline in annual growth, reflecting the reduction in working-age populations.
The resulting time profile of aggregate world GDP growth rate (right-hand side of Fig. 5) is roughly parallel to the movement of the world interest rate, mostly due to our conservative assumption with respect to technological convergence.

3.3. Regional current accounts and the distribution of wealth

Given the small magnitude of the fluctuations in regional capital demands, most of the action on regional current accounts is the result of differences in time profiles of wealth accumulation across regions, such differences being in turn largely due to discrepancies in demographic evolutions, especially time lags in the changes in the share of high-savers in total populations of the six regions. Resulting differences between domestic saving and domestic investment in each of the ten regions yield current account surpluses or deficits. In stock terms, at a point in time, the ratio of the stock of productive capital installed in a region and the stock of accumulated wealth of households resident in that region (ownership ratio) is an indicator of the net external position of the region considered.

Figure 8: Scenario: regional ownership ratio (assets / capital stock)



Given the differentiated effects of variations in the interest rate and other economic variables on the saving and investment behaviors in the various regions, these regional ownership ratios do fluctuate considerably over the century in our baseline scenario (Figure 8). Starting from a net lender initial position – ownership ratios above one –, Japan, Europe and, to a much lesser extent, the China and Russian regions have ownership ratios that increase until 2015 for Japan, 2025 for Europe then decrease thereafter, mostly reflecting the evolution of the shares of high savers in the three regions. Strikingly, though, Europe, one of the large creditors at the beginning of the century, turns into an equilibrated position in the second half of the century : this is due to the low saving rate of Europe over the first half of the century, a result of the low retirement age and generous pension scheme; although the saving rate rises again afterwards, with the decline in the old-age dependency ratio, this is just enough to restore the net external position of Europe. In the other three regions, ownership ratios are initially well below one, and they mostly raise all along the century, except for an initial mild decrease the regions with the youngest population. In particular, North America becomes a net creditor region in the last third of the century.
Consistent with the changes in regional saving and investment flows, and the resulting evolutions of ownership ratios, the current accounts, and hence the international capital flows, reach significant magnitudes, and do vary a great

Figure 9: Base Scenario: regional current accounts (% of regional GNP)

[Insert Figure]

deal over the century (Figure 9). The relationship between stocks and flows is, indeed, simple in steady state: in the very long run, when populations have become stationary, an ownership ratio above (resp. below) one is associated with a current account surplus (resp. deficit). But during transitions, this simple relationship does not hold. At the beginning of the century, thanks to the large shares of high-savers in their populations, Japan and Europe are the two regions exporting capital, while the three developing regions, but also America, whose demographics are more dynamic than those of other developed regions and which we endowed with a larger time preference parameter, attract these capital flows. After 2020, the Japanese current account is no longer in surplus; it starts fluctuating around equilibrium. And after 2030 Europe plunges into a persistent current account deficit.

4. Pension reforms in europe in a world model [To be completed]

In the baseline scenario (BS), the European pension system is characterized by two major features, which we have supposed untouched all along the century: a low legal retirement age (60 yrs.); and a fairly high replacement rate (70%). We now propose to investigate the consequences, in our model, of three kinds of pension reforms in Europe, keeping the institutions in other regions of the world identical to baseline:

- Constant contribution rate (CCR): Blocking pension contribution rates to the level they reached at the end of the XX century (18.5%). The result is a progressive and significant decline of the replacement rate as European population ages: by 2050, it would be reduced by 50%. But in the baseline scenario, keeping the replacement rate constant induces a marked increase in the contribution rate that reaches 37.5% by mid-century, and stabilizes around 32% in the very long run, in the aftermath of the baby-boom shock.
- PRA: Postponing the legal retirement age from 60 to 65, progressively over the period 2000-2020 (one additional year of working life per five-year period). In this scenario, the replacement rate is held constant at its initial level, and, as a result, the contribution rate increases much less than in the baseline scenario: it reaches 29% in 2050, and about 25% in the very long run.
- Constant gross replacement (CGR): Indexing pensions on gross, instead of net wages. This, of course, corresponds to a scenario whose philosophy is opposite to the two previous ones: the replacement rate is actually fixed

at a higher level, so that the contribution rate raises even higher than in the baseline scenario[5].

4.1. Macroeconomic consequences

Because these reforms are assumed to be perfectly anticipated as soon as they are announced (end of the XX century), their major direct and most immediate effects are, of course, on individual saving behavior, hence on aggregate saving. Unsurprisingly, compared to the BS scenario, CCR raises the saving rate all along the century, while CGR lowers it (Figure 10): as the public pension system is made less (more) generous, households save and accumulate more (less) in order to compensate the effect of lower pensions on consumption in retirement. Because labor supply is exogenous, this saving effect is the only direct effect on households, and it corresponds to a change in the time profile of their budget constraint. The direct effects of the PRA reform are less easily depicted and explained: initially, the announcement and progressive implementation of the postponement of retirement-age reduces aggregate saving in Europe, as those initially concerned are the high-savers, who immediately expect a higher life-cycle income and the necessity to finance consumption over a shorter retirement period. But after 2025, the European aggregate saving rate is, in the PRA scenario, permanently above those of the baseline and CGR, due to general-equilibrium, indirect effects mostly via the world interest rate and to the important increase in the incomes resulting from the rise in the labor factor.

Figure 10: Pension Reforms - Europe

Saving Rate (% change to BS trajectory) — Contribution Rate (percentage)

[Insert Figure]

The effects of the various European pension reforms on the world interest rate are shown in the left-hand side of Fig. 11. As expected, the CCR reform is associated with a permanently lower interest rate, as European saving rate is constantly above its baseline level; symmetrically, the CGR reform yields a persistently higher world interest rate. The effects of the PRA reform are more ambiguous. Initially, the world interest rate is higher than in any other scenario, mostly as a result of two mechanisms: as already stated, European aggregate savings are initially lower than in the baseline scenario; and in addition, there are more working-age workers in the economy, that have to be equipped with capital, so that European investment is permanently higher than in the baseline scenario. Consequently, until 2035, the world interest rate is higher than in

[5] This reform scenario may be interpreted as representing the case in which health care costs of aging would rise significantly and would be financed by a public scheme that levies a contribution over wages, in addition to the retirement pension schemes adopted here.

the baseline; afterwards, it is almost identical, as the PRA reform has little persistent effect with stationary population.

Figure 11: Annual rate - Pension Reforms (% changes to baseline trajectories)

World interest rate European GNP growth rate
[Insert Figures]

These European pension reforms thus have induced consequences on the rest of the world, via the changes in the world capital market equilibrium, hence on the world interest rate. As expected, the CCR reform that increases European aggregate savings over the whole century also improve the ownership ratio of Europe (right-hand side of Fig. 12); conversely for the CGR reform, the ownership ratio is always below the baseline, and its deterioration is much more pronounced after 2035, so that it reaches a very low level (around 55%) at the end of the century. In the PRA reform, the European ownership ratio is permanently lower than in the baseline case, as European investment is permanently increased, whereas the initial increase in savings is only temporary.

Figure 12: Europe : Pension Reforms

Current account (% of GNP) Ownership ratio
[Insert Figure]

In this last case, therefore, Europe exports much less capital to the rest of the world over the first decades of the century (left-hand side of Fig. 12). Compared to the baseline current account evolutions, two reforms scenarios (PRA and CGR) yield a substantially smaller European surplus over the first two decades of the century. After 2025, however, the outcomes are opposite: the PRA reform leads to increasing current account surpluses in Europe, as the transitory implementation effects of the reform on saving and investment have vanished; thereafter, the European current is close to its baseline. In the CCR reform scenario, on the contrary, Europe is a permanent exporter of capital to the rest of the world, with very large initial current account surpluses. In the rest of the world, the constellation of regional current accounts is only mildly affected by European pension reforms, their consequences being only indirect, via the world interest rate.

4.2. Distributional and Welfare consequences of pension reforms [to be completed]

4.2.1. Static indicators

Both CGR and CCR scenarii have a low influence on world economic growth rates with respect to the baseline, then reform effects on consumption per capita are opposite in Europe and in the other regions (Figure 13). More capitalization leads to a decline in the financial position of European households until 2040 relative to BS scenario, and to a increase after 2040. For CGR it is roughly the opposite as the effects of the reforms are inversed. In the rest of the world the effects of the two reforms are the opposite to those in Europe. Indeed, in integrated capital markets the extra-savings in Europe for retirement motives implies necessarily international capital export flows under CCR which implies increase in the GDP and in the wages in the other countries, and then an increase in their consumption. As time passed, Europeans reduce their extra-saving (because they have founded enough their retirement income), interest rate will increase, and retired people begin to have more important asset income from their domestic investment but also from financial investment abroad. Because a more important share of the other countries GDP is now going to European household (through capital income flows) consumption in these countries will be reduced with respect to the baseline in the long run.
In the PRA case, the main effect of the reform is to increase directly european GDP with the employment. The resulting increase in the european wage bill leads to an important rise in the consumption. But this also implies new opportunities of investment in Europe for the rest of the world in the short run (as european marginal productivity of capital rise with european labour) so in those countries consumption will decrease at this time. In the long run this policy imply an obvious increase of resources at the world level : Europeans still have a greater consumption level than in any other scenario (GDP per capita is higher). But this reform is also profitable to the rest of the world which have previously accumulate more title of ownership on European stock of capital than in CCR or BS scenarii.

Figure 13: World - Consumption per capita (% change to baseline)

[Insert Figure]

Over the next fifty years, the CCR reform seems to be the more accurate policy in order to redistribute resources to people with less than 60 years-old (fig. 14). This kind of intergenerational redistribution may be justified by the fact that, in our benchmark economy, european household with more than 60 years-old have at the end of the las century a standard of living which is the double of the one of the people with less than 40 years-old. A similar wedge in the consumption per capita of the different generations is only perceptible in Europe.

After 2050, the effects of the reforms on the distribution of consumption over the age are progressively faded. In the long run, whatever the pension policy chosen the relative fall of average consumption due to ageing will bear essentially on the consumption per capita of the more aged people.

Figure 14: Europe : Average consumption by age-groups (% changes to BS)

[Insert Figure]

4.2.2. Longitudinal indicators

In agent-based models, the welfare of each generation are the standard criterions to evaluate the relevance of a reform. Here because leisure brings out no satisfaction it is obvious that every reform which increase the level of labor supply will be welfare-enhancing. So this kind of criterion must be taken very cautiously in our context. PRA reform then increase the welfare of all the generations in Europe (Figs 15) because it acts as a global and permanent rise of the GDP. The two other reforms have opposite effects. The CCR reform benefits to generations born after 1985 while the CGR reform only benefits to generations born before the same date. Indeed, the important increase of baby-boom retirees between 2005 and 2015 will imply a sharp rise in contribution rate (right-hand side of figs 10) if replacement rate would stay constant or a drastic fall of this rate if contribution rate stay fixed. So the CGR reform is welfare-enhancing only for actual generations because the burden of demographic transition will be only supported by future generations. On the opposite the CCR reform put effort on the current generation, letting the future generations accumulate wealth for their old days.
It is interesting to notice that if reforms in Europe have only a very small effects on the welfare of generations in the rest-of-the world (through interest rate changes) the signs of these effects are not trivial. The most notable feature is that the CCR reform in Europe has a negative impact on welfare of all cohorts in the other regions. Because in the beginning of the century this extra-saving will implies a fall in the world interest rate and then a fall of income of older people in the other regions of the world where personal saving is the main source of income of retired individuals. On the life cycle this is not compensated by higher wage rates between 20 and 40 yrs. old (due to European extra accumulation). In the middle of the century the extra de-saving of European will implies a rise in the world interest rate and then a slightly amelioration of welfare of individuals born after 1980 in the other regions. The PRA reform also presents a non-monotonic profile on welfare by cohorts in the other regions resulting from similar changes in the world interest rate.
Pension reforms are usually evaluated in terms of their effects on equity thanks to a financial criterion: the internal rate of return of the PAYG system. This

Figure 15: World - Welfare By Cohort (% change to baseline)

[Insert Figure]

is the discounting factor calculated by equalizing the present value of the total lifetime contributions paid by a cohort to the present value of the total lifetime pensions received by the same cohort (reported in Figure 16). As the PAYG system is time-to-time balanced, if there are demographic transitions and/or reforms in the system the previous criterion will be different for the different cohorts. In 1995 the more aged cohorts are the more concerned by reforms which modify pension rights : the CGR reform is then very interesting for them (their rate of return of PAYG is increasing) whereas it penalizes younger generation which support the rise of contribution rates (their rate of return of PAYG is decreasing). The CCR reform is on the contrary more favourable to future generations (only generations born after 1995 benefit of this reform compared to the BS case) but also tends to smooth the criterion over all the generations. When age of retirement is postponed contribution period increases and pension-benefit period is reduced the rate of return then decrease for the actual adults. But in the future, the resulting decrease of the contribution rate (in respect of the BS) will allow better returns for future cohorts than in the BS case. Moreover in the long run (for generation born after 2060) this reform appears to be the best in term of return of the PAYG system. Except for generations born between 1985 and 1994, the intergenerational criterion and the lifetime welfare gives the same insights about "loosing-generations" and "wining-generations" in the CCR and CGR reforms. PRA reform reveals some "loosing-generations" compared to other scenarios in term of PAYG return whereas it was always the best reform in terms of welfare.

Figure 16: Criterion of intergenerational equity

[Insert Figure]

5. Concluding Remarks

When analysing the prospects of public, pay-as-you-go pension systems in OECD countries, the emphasis, in most studies over the past two decades, has been on the macroeconomic and inter-generational, distributional consequences of aging populations in the framework of models that have tended not to take into account, or conversely to over-stress the implications of economic and financial globalization on domestic evolutions. The model used here to accommodate such analytical needs and this paper has tried to present its major features, its functioning, as well as a number of distinctive results that differ markedly from what would obtain in either autarkic, closed-economy models, or small, open-economy models. The interplay between aging populations displaying different time profiles in the various regions of the world and pay-as-you-go pension systems with different characteristics yields significant fluctuations and discrepancies in world and regional economic variables, as well as fairly large international capital flows in our baseline scenario and in the various pension reforms studied. Such large capital flows on average help smoothing the long accumulation cycles that arise from aging and fluctuations in population sizes. Although they may seem excessive, our paper shows that they are significantly smaller in an integrated world model than in models that treat developed countries in isolation as small, open economies.

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