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SCENARIOS FOR GLOBAL AGEING

AN INVESTIGATION WITH THE INGENUE 2 WORLD MODEL

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Scenarios for Global Ageing : an Investigation with the INGENUE 2 World Model.

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Abstract

This paper explores the consequences of pension reforms in Western Europe in a world economy setting. Whereas various economic and social consequences of ageing have been investigated in OECD countries, very few analyses have explicitly taken the worldwide aspect of the problem into account. In order to do so, we rely on the new version of the INGENUE model. This applied, international, overlapping-generations, general-equilibrium model of the world economy has been built noticeably to analyze the international capital flows and growth dynamics induced by differential ageing of the various regions of the world. After a description of the major features of the baseline scenario of the model for the world economy over the next 50 years, we explore the domestic and international macroeconomic consequences of two scenarios of pension reforms in Western Europe as well as their intergenerational distributional effects. We compare these scenarios with a specific migration scenario, which is allowed by the new features of the INGENUE 2 model.

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Contents

1 Introduction : Ageing and Capital Flows

Demographic transition and the consequent population aging are putting the pay-as-you-go (PAYG) pension systems of OECD countries under stress and fostering various reforms. The latter will have economic consequences that 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 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 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 and with different calendars 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 raises 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 ageing countries on the one hand, and developing countries with younger populations in the other hand, 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 United Nations (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.

We rely on the second version od tne INGENUE model. The first version of the model has already been used to investigate the impact of differenciated ageing on worldwide capital flows. Here we use the second version of the model which brings a number of improvements. This new version allows to investigate migration scenarios which are another key issue when discussing the adjustment to differenciated ageing throughout the world.

The first section of the paper presents the model, and discusses a number of aspects of the calibration process. The transition path of the baseline scenario is described and briefly commented in section 2. Section 3 explores the aggregate consequences, on the world economy and on regions, of two contrasted pension reform scenarios in Western Europe, and of a specific migratory scenario : a constant contribution rule; a postponement of retirement ; we compare the latter with a migratory scenario calibrated in order to limit the rise of the dependency ratio between 2000 and 2050 in Western Europe, as in the postponement of retirement age case. The comparison with pension reforms scenarios seems accurate as increasing labour mobility is a potentially important mechanism through which the global economy could respond to demographic change and is therefore an alternative to the flow of capital. We also investigate the intergenerational consequences of these reforms.

2 An international, inter-temporal model of the world economy with realistic demographic forecasts

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 Pay As You Go (PAYG) retirement pension system.

2.1 A brief overview on the Ingenue project

The first version of the INGENUE model describes a multi-region, world model, in the spirit of those developed by Obstfeld & Rogoff (1996, chap. 3), in which the structure of each regional economy is similar to that of other applied, OGGE models, such as Auerbach & Kotlikoff (1987), except that labour supply is exogenous.

In the first version of the model, the world was divided into six regions, each of which 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 was an ownership stake in the firms' productive capital ; both of them were 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 was only one world market for goods and one for financial assets.

Several studies were carried out with this first model (among which Ingenue (2002a), Ingenue (2002b), IMF (2004)), noticeably to assess the effects of pension reforms in Europe, but the model soon appeared to be unrealistic in some of its outcomes because of some irrelevant elements in its theoretical structure. So it was decided to built a new version of this model and also to improve the calibration data and procedure. The main improvements are the following :

1. Demographics : the World is now divided in 10 regions. In order to make autonomous own demographic projections the model includes 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 uncertainty 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 & Kydland (1995). This will imply the existence of real 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 prominent 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 ownership ratio.

5. Calibration improvements : introduction of inheritances based upon a bequest motive (in order to get a more realistic modelling of saving rates), age-

specific labour participation rates (exogenous), age-specific human capital (exogenous), labour income of children in some parts of the world ...

In the following, we present in more detail the demographic model (2.2) before describing the macroeconomic framework (2.3) and the world general equilibrium (2.4).

2.2 Demographics

2.2.1 Regions

The World is divided in 10 regions according mainly to geographical and demographic criteria. The content of each region is detailed in Appendix A. These regions are labelled : Western Europe, Eastern Europe, North America, Latin America, Japan, Mediterranean World, Chinese World, Africa, Russian World and Indian World.

2.2.2 Population structure and Projection Method

In the first version of the model, the demographic data selected were the 2050 projections of the United Nations (extrapolated numerically until 2100). The new version includes a specific model for demographic projections. Indeed, the demographic shifts being in the core of the model, it is crucial to be able to study the impact of various demographic assumptions on pension systems and on the flows of capital. We thus elaborate a simple methodology of construction of the demographic data. To guarantee the consistency 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-gender agents who may not live longer than 105 years. For notation purpose,age is denoted by $a \in [0, \ldots, 20]$. For instance, a=2 corresponds to the 10-14 years-old individuals. The number of people of age a at time t is denoted by $L_a^z(t)$[1]. 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 is calculated according to a standard population projection method on the basis of historical and prospective UN data. We aggregate the population structure accross the countries of each regions , with the UN data from 1950 to 1995. Then we project fertility and mortality trends (for both sexes) at the

[1]More generally, for any household variable, a subscript a denotes age and an argument t in parentheses denotes calendar time.

region-aggregate level. This, together with initial population structures in 1995, allows us to obtain the evolution of the population at a world level from 2000 until the ending date of the model. In the baseline scenario, we implicitly assume that there is no migration flow in the future. With some usual population projection methods, the evolutions of mortality and fertility tables are constructed on the only basis of life expectancy and global fertility rates evolutions in the future[2].

Mortality People die before 105 years old; If sa denotes the conditional probability of surviving between age a and age $a+1$, the number of age $a-1$ individuals then follows:

$$L^z_a(t) = s^z_{a-1}(t-1)\, L^z_{a-1}(t-1) \text{ for all } a > 0 \tag{1}$$

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

Fertility Process At each time, the number of births is equal to $L^z{}_0(t) = \sum^9_{a=3} f^z{}_a(t) L_f a^z(t)$ (where $L_f a^z(t)$ is the female population of age a at time t), and $f^z{}_a$ is the average age-specific fertility rate. Following UN projections, we implicitly assume that women fertility occurs only between 15 and 50 years old.

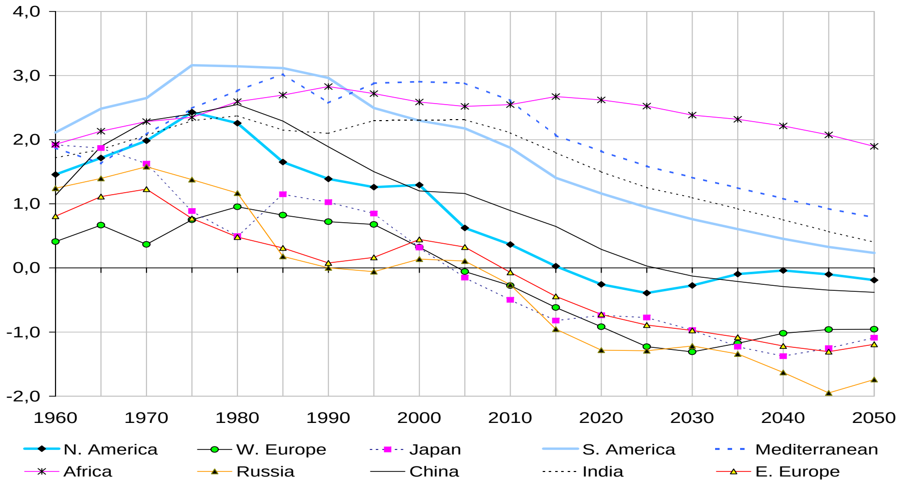
2.2.3 Main demographic features

We now comment the demographic projections from 2000 to 2050. According to this baseline scenario, Japan is the first country 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 North America region and 1.7 in Western Europe. At the same time, one must notice that the baby-boom in Japan begun earlier and was proportionally more pronounced than in Europe. The persistence of a very weak birthrate

[2] More details is available in a technical notice upon request at the authors at the following e-mail address: ingenue@cepremap.cnrs.fr.

after 1995 until 2050 accentuates this phenomenon. This evolution for birthrate after 1995 explains the decline of labour force in developed countries in the next decades (see Figure 1). Japan is the first country to experiment a negative growth rate of the working-age population, in 2005.

Figure 1: Working-age population annual growth rate (percentage) : 1960 - 2050

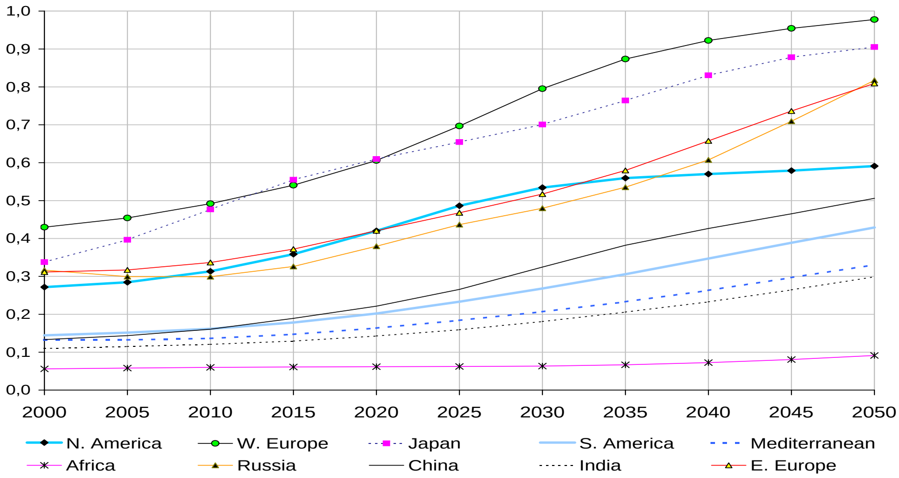


By contrast, in the North America zone, the rate of reproduction of generations, near of 1 in 1995 (0.96), drops only slightly until 2050 to stabilize at 0.93 and the birth rate remains above 1.9 child by woman. Hence, the working-age population begins to decline only in 2020.

Western Europe is in an intermediate situation, partly because extreme situations (Scandinavian countries, Germany, Ireland...) are mutually neutralized. The grouping in the same geographical area is then justified on the basis of strong interdependence between these economies (long-lived single market, Euro zone). One must note that because the institutional rules about legal age of retirement differ between Western Europe and Japan (Europeans quit earlier) the dependency ratio is greater in the former than in the latter despite the working-age population growing faster in Western Europe (see figure 2).

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 ageing population which is projected to be even more pronounced than in Western Countries around the middle of the century for Eastern Europe and especially for the Russian world (see Figure 3).
The others regions are more heterogeneous. They comprise countries in progress in their demographic revolution or for which the latter should only intervene be-

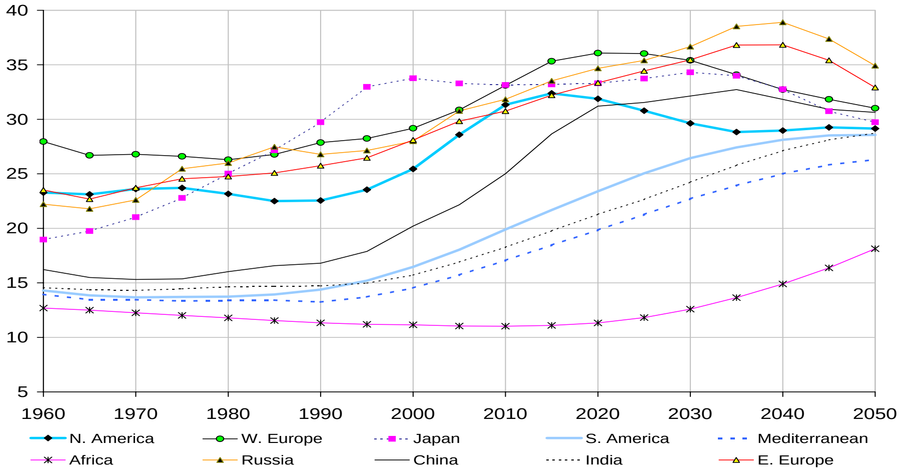
Figure 2: Dependency ratio (retirees in percentage of total working age population) : 2000 - 2050



tween 2000 and 2050 (South America, Indian World) and some countries where the demographic transition process is still at its beginning (Mediterranean World and Africa). As a consequence, they are characterized by a sustained growth of their population and then of their working-age population (figure 1). 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 ; hence the old age dependency ratio is low but it doubles throughout the period 1995-2050. As a consequence of the dynamism of their working-age population, these regions will need a lot of capital to equip their numerous potential workers.

We now look at the share of the 45-69 years old population in total population of each region, because high savers are concentrated on this age group. One can see on Figure 3 that the proportion of high savers in total population follows a wave pattern that propagates from one region of the world to the next through the decades. The ratio culminates first in Japan as soon as 1995 and remains at a high level until 2030. Then North America experiences its maximum in 2025 and Western Europe in 2030, Eastern Europe, Russia and China after this date. All are regions with declining labour force and thus hamper growth in the future. On the contrary, the regions found on Figure 1 as the potentially fast-growing regions see a progressive ageing leading to an increase of the high savers ratio which does not culminate before 2050. It follows that saving will flow from early high savers to late high savers in the coming decades. This demographic feature will influence a lot the saving rates in the next decades in our model because life cycle hypothesis is in the heart of the saving behaviour of households in the INGENUE model.

Figure 3: High savers ratio (age group 45-69 years in percentage of total population) : 1960 - 2050



2.3 Macroeconomic framework

2.3.1 Households

Individuals are assumed to become adults when they turn 20 ($a_0 = 4$ in the following formulas). At each date, the household sector is then made of 17 overlapping cohorts of "adults", aged between 20 and 105, and of 4 cohorts of "young" people. Adults can (partially) retire from age $\underline{r}^z$ and they may not stay in the labour force after a legal maximal mandatory retirement age $\bar{r}^z$. Economic choices of households concern consumption/saving. They are 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.

Labour supply is assumed to be exogenously given by the age-specific rate of participation to the labour market, noted : e_a^z. We take International Labour Organization (ILO) data and projections to characterize activity from 1950 until 2015 and we 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 children labour income into account in the budget constraint of their parents.

The intertemporal preferences of a new entrant in 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 reach the age of T (if they survive until this age)[3] :

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

where ρ is the psychological discount factor[4], C_a is consumption at age a ; η is the intertemporal substitution rate and $V(\cdot)$ is the instantaneous utility of bequest : each agent has some felicity from leaving a bequest but it is independent of the future stream of the consumption that his children draw from this bequest (*warm glow* altruism). This bequest behaviour is mainly adopted to deal with calibration issues (empirically savings for life-cycle can only explain part of saving motivations).

At any given period, the budget constraint is :

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

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 returns on assets holdings times wealth). We assume $S_{a_0-1} = 0$ and $S_{20} \geq 0$ for all $a \in [a_0, \ldots, 20]$. 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-based net disposal income.

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

[4] 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 years old.

$\tau_a^z(t)p_f^z(t)C_a^z(t)$ denotes the total consumption (that is the consumption of the parents and the one of their children). $p_f^z(t)S_a^z(t)$ represents the wealth at the end of date t. $p_f^z(t)$ denotes the price of the domestic final good (in terms of one foreign goods, see below) so $R^z(t)$ is one plus 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 this, we assume 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 receive 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 any 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 the 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. Unless special mention, pension benefits are assumed to be age independent.

The τ_a^z term is the age-specific equivalence scale. It takes into 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 :

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

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)[5]. $\zeta_a^z(t)$ is the labour income that children bring to their parents resources during their childhood (calculated in the same spirit as costs of children-rearing).

[5]Trying to get a more detailed structure would entail keeping the distribution of children with respects to their grand-parents and would complicate in an useless way the number of state variables in the system.

An agent's earning ability is assumed to be an exogenous function of his 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 regions. In the baseline case we adopt Miles (1999) human capital profile's estimation (for the United Kingdom) and ϑ_a is normalized so that $\vartheta_{a_0} = 1$.

New cohorts choose their plans 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 contributions 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), $\forall z$:

$$C^z_{a+1}(t+1) = C^z_a(t) \cdot \left[\rho R^z(t+1)\frac{\tau^z_a(t)}{\tau^z_{a+1}(t+1)}\right]^\eta \quad a \in [a_0, 20[\qquad (5)$$

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

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) : $C^z_T = \Psi^z H^z$, where Ψ indicates the degree of altruism. At the equilibrium the sum of voluntary bequest will be equal to the inheritance received by children :

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

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 $a \notin [T-9, \dots, T-3]$. For $a \in [T-9, \dots, T-3]$, we assume that bequests are distributed equally to all children. Hence h_a is proportional to the proportion 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 characterizing the tradeoff between domestic and foreign assets :

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

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 saves one unit in his domestic asset (capital) it will yield $R^z(t)$ in real terms the next period, if he chooses to invest in foreign assets he will receive in real terms $R^{\star}(t)\frac{p_f^z(t-1)}{p_f^z(t)}$. The arbitrage condition then leads to return equalization.

2.3.2 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 : the pension $P_a^z(t)$ paid is a fraction - or replacement rate $(\kappa(t))$ – of the current average (net of tax) wage $[1-\theta^z(t)]w^z(t)$. 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). Payroll tax rates $\theta(t)$ are thus endogenously determined by (9).

2.3.3 Production side

(i.) Intermediate good sector

Each zone z specializes in the production YI^z of a single intermediate good, 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 $N^z(t)$, $\forall z$:

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

The current cash-flow of the representative domestic firm of the intermediate sector (in terms of the world *numéraire*) is given by :

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

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 :

$$\Pi^z(0) = CF^z(0) + \sum_{t=1}^{\infty} \frac{CF^z(t)}{\prod_{s=0}^{t} R^\star(t)} \tag{11}$$

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

$$R^\star(t+1)\frac{p_f^z(t)}{p_f^z(t+1)} + \delta^z(t+1) - 1 = \frac{p_I^z(t+1)}{p_f^z(t+1)}\alpha A I^z(t+1)\left(k^z(t)\right)^{\alpha-1} \tag{12}$$

$$w^z(t) = p_I^z(t)(1-\alpha)AI^z(t)\left(k^z(t-1)\right)^{\alpha} \tag{13}$$

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

For a world macroeconomic model to be realistic, the world asset capital market has 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 $\varepsilon > 0$:

$$\delta^z(t) = \bar{\delta}^z + (1-\bar{\delta}^z)\Delta^z \cdot \text{Max}\left(1 - \frac{S^z(t-1)}{K^z(t-1)}; 0\right)^{\varepsilon} \quad \text{for all z} \tag{14}$$

where $S^z(t) = \sum_{a=a_0}^{19} L_a(t)S_a(t)$ is the aggregate wealth across all 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 to the rest of the world.

The depreciation ratio is asymmetrically[6] dependent on the ownership ratio (total wealth of households/ capital stock). An ownership ratio less than one indicates that the region is a net debtor. In those regions the imperfections of international financial markets raise the cost of capital the more the larger foreign debt. It shows up in a higher rate of economic depreciation of the capital stock. In creditor

[6]With this formulation the domestic cost of capital for the intermediate good sector may be greater than the world cost but never be lower.

regions (ownership ratio above one) the rate of depreciation is a constant, thus independent on financial condition.
This differenciated depreciation rate corrects for the fact that the world interest rate is used for calculating the value of the firm (equation (11). In a net debtor region, δ^z will be higher, hence CF^z lower an Π^z also lower. This will reduce the incentive to produce the intermediate good.

(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 according to a combination of two intermediate goods : a "domestic" intermediate good in proportion B^z and a "World" intermediate good in proportion M^z, according to the following CES technology, where $\sigma \geq 0$ denotes the elasticity of substitution, $\forall z$:

$$YF^z(t) = AF^z(t) \left[(\omega^z)^{\frac{1}{\sigma^z}} \left(B^z(t)\right)^{\frac{\sigma^z - 1}{\sigma^z}} + (1-\omega^z)^{\frac{1}{\sigma^z}} \left(M^z(t)\right)^{\frac{\sigma^z - 1}{\sigma^z}} \right]^{\frac{\sigma^z}{\sigma^z - 1}} \quad (15)$$

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*, $AF^z(t)$ being total factor productivity. Taking prices as given, the 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 (15), 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 a specific intermediate good used as the *numéraire* (see below). The static maximization problem of a representative competitive firm gives at the equilibrium the following first order conditions :

$$\begin{aligned} B^z(t) &= \omega^z \left(\frac{p_I^z(t)}{p_f^z(t)} \right)^{-\sigma^z} \frac{YF^z(t)}{\left(AF^z(t)\right)^{1-\sigma^z}}, & (16) \\ M^z(t) &= (1-\omega^z) \left(\frac{p^\star(t)}{p_f^z(t)} \right)^{-\sigma} \frac{YF^z(t)}{\left(AF^z(t)\right)^{1-\sigma^z}} & (17) \end{aligned}$$

where p_f^z can be shown to be equal to the following aggregate price index :

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

2.3.4 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 exists a fictive world producer that uses all 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 :

$$Y^\star(t) = A^\star(t)\left[\sum_z \gamma^z(t)^{\frac{1}{\mu}} X^z(t)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{18}$$

This fictive producer is assumed to act competitively, taking prices as given. Hence, 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 (18). This yields at the equilibrium the following factor demand function :

$$X^z(t) = \gamma^z(t)\left(E^z(t)\right)^{-\mu} Y^\star(t)A^\star(t)^{\mu-1} \qquad \text{for all z} \tag{19}$$

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

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

2.4 The world general equilibrium

2.4.1 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 in each 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 ≥ 1 :

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

(ii) profit maximization of firms in the intermediate sector (10)–(13), and (14),

(iii) profit maximization in the final good sector gives (15)–(17),

(iv) world producer profit maximization (18) and (19),

(v) market clearing at each date :

$$\begin{aligned} C^z(t) + I^z(t) &= YF^z(t) \qquad \forall z \qquad (20) \\ N^z(t) &= \sum_{a=2}^{\bar{r}_a} \mathbf{e}_a^z(t) L_a^z(t) \qquad \forall z \qquad (21) \\ X^z(t) + B^z(t) &= YI^z(t) \qquad \forall z \qquad (22) \\ \sum_z M^z(t) &= Y^\star(t) \qquad (23) \end{aligned}$$

where $C^z = \sum_{a \geq a_0} \tau_a^z L_a^z c_a^z$ is the aggregate consumption in region z. (20) is the equilibrium condition on the final good domestic markets in all regions, (22) is the intermediate goods market in all regions, (21) is the labour market equilibrium in all regions and (23) is the equilibrium condition in the market for the world intermediate good.

2.4.2 Walras'law and additional accounting identities

It can be easily shown that these equations (20)–(23) 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. the *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 values can be expressed in US intermediate good units in our model.
It is then possible to recover standard aggregate budget constraint of national accounts as well as the equilibrium of the world capital market from previous equilibrium equations.

Regional accounts

One can check that the sum of budget constraints over all individuals (3) give an expression of C^z that can be substituted in (20) in order to obtain (together with the PAYG constraint (9)) :

$$p_f^z YF^z = w^z N^z + p_f^z[K^z + (1-\delta)K^z(-1)] + p_f^z[R^z S^z(-1) - S^z] \tag{24}$$

Since YI^z is linearly homogeneous, using the *Euler rule* and substituting prices for quantities in the equation (24), with equations (12) and (13), gives :

$$p_f^z YF^z - p_I^z YI^z = p_f^z[K^z - R^z K^z(-1)] - p_f^z[S^z - R^z S^z(-1)] \tag{25}$$

From (22) 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 :

$$p_f^z YF^z - p_I^z YI^z = p^\star M^z - p_I^z X^z \tag{26}$$

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

$$GDP^z(t) = p_I^z(t)YI^z(t) = p_f^z(t)YF^z(t) + p_I^z(t)X^z(t) - p^\star(t)M^z(t) \tag{27}$$

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

We now show that, at the equilibrium, the world capital market is balanced. Competitive behaviour of the World producer and $Y^\star$ being linearly homogenous gives : $Y^\star(t) = \sum_z \frac{p_I^z(t)}{p^\star(t)} \cdot X^z(t)$. This together with the world market equilibrium for the world intermediate good (23) implies that the sum of trade accounts accross the world is equal to zero :

$$\sum_z [p_I^z(t)X^z(t) - p^\star M^z(t)] = 0 \tag{28}$$

Then summing identities (25) over the regions implies (knowing from (26) that this is equivalent to (28) : $\sum_z p_f^z[K^z - R^z K^z(-1)] = \sum_z p_f^z[S^z - R^z S^z(-1)]$. Then once the world market is cleared at time $t-1$ this implies (with eq. (8)) that it also clears at time t :

$$\sum_z p_f^z K^z = \sum_z p_f^z S^z \tag{29}$$

2.4.3 Growth, technological diffusion and economic convergence

The level of Total Factor Productivity (TFP) is exogenous and grows at a constant rate, in each region. For 1950 until 2000, the growth rate of TFP is given by historical data. After this date the rate of growth of the TFP is the result of a given, exogenous growth of 1.5% per annum in the "North America" region, 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 :

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

Eastern Europe, Russia, Mediterranean World, Africa :

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

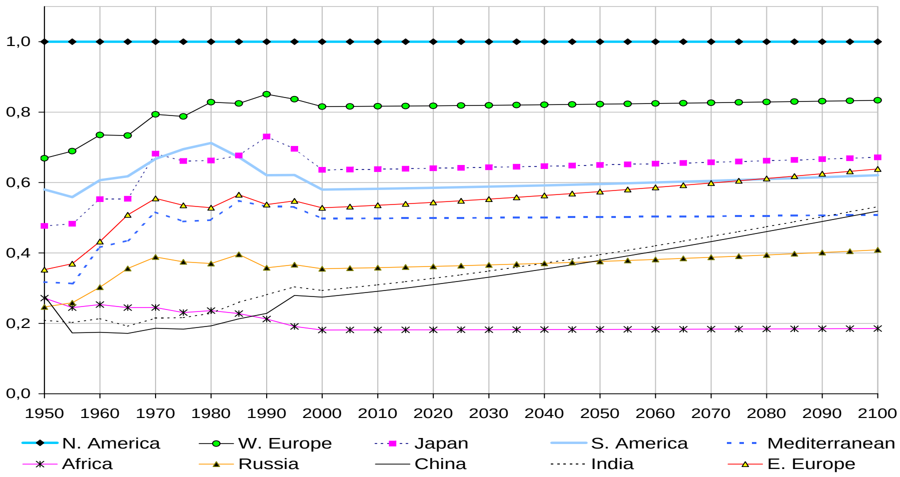
where AI^z is a measure of this level of knowledge ; λ is an acceleration factor of technological growth common to all catching up regions (equal to 0.001 in the baseline scenario), while Ω^z is a brake on the convergence of technological levels. One must notice that in our baseline scenario, we assume implicitly two convergence clubs : one group of regions converges towards "North America", while the other one converges towards "Western Europe". As a matter of fact, because "Western Europe" converges towards "North America", in the steady state, every region will have the same level for TFP. Notice also that the rhythms of convergence will differ not only because the initial (i.e. in year 2000) levels and the targets are different but also because we assume different values for Ω^z (see 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.
Ω^z	0.99975	0.999	0.99975	0.999	0.99975	0.999	0.99975	1.00	1.00

Figure 4 compares the profiles of TFP in the world regions of the INGENUE 2 model. Western Europe and Japan are assumed to resume their catching-up, meaning that they absorb the IT revolution after North America. The takeoff

Figure 4: Baseline Scenario - Total Factor Productivity (percentage of the "North America"'s level) : 1950 - 2100



in China and India, which has already started in the 1990's, gains momentum. Eastern Europe is also assumed to be a fast-growing region due to its participation to the European Union. We take a dimmer view of the other regions. A relatively slow catching up is assumed in South America and in the Mediterranean countries where there are perennial difficulties in establishing efficient market institutions, in promoting a large class of entrepreneurs and in generating non-corrupt and competent governments. The same arises more seriously in Russia where the catastrophic decline of the population is a further handicap. Finally we are more pessimistic about Africa where we assume no catching-up in the level of TFP. Yet the rise in TFP at the same rate of the leading region, even if it will entail no catching-up, is a marked improvement compared to the last quarter of a century which saw no progress at all and thus a relative setback on the rest of the world.

2.4.4 The calibration of the model

The departure point of our numerical analysis is the year 2000. So, in our calibration strategy, the model must match the historical data at this date. To do this simply, and in order to avoid any 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 the parameters and exogenous trajectories for sectoral factor productivity in order to get values for the endogenous variables of the model near their observed values in 2000 (see Table 2). The international macroeconomic data are taken from the Heston, Summers & Aten

(2002) database.

Table 2: Exogenous Parameters of the model :

ρ	α	η	δ	Ψ	σ	μ
0.95	0.33	0.75	0.28	0.8	1.01	1.5

One must notice that in order to reproduce the selected stylized facts for each region considered, the time preference parameters are neither set constant nor similar between the different regions during the calibration period (i.e. between 1955 and 1995). Furthermore, the regional parameters of the CES production functions are calibrated in order to reproduce the international trade shares for each regions. In the calibration process, the relative productivity between sectors are set in order to reproduce the exchange rates, and the human capital variables are calibrated in order to reproduce the GDP per capita levels.

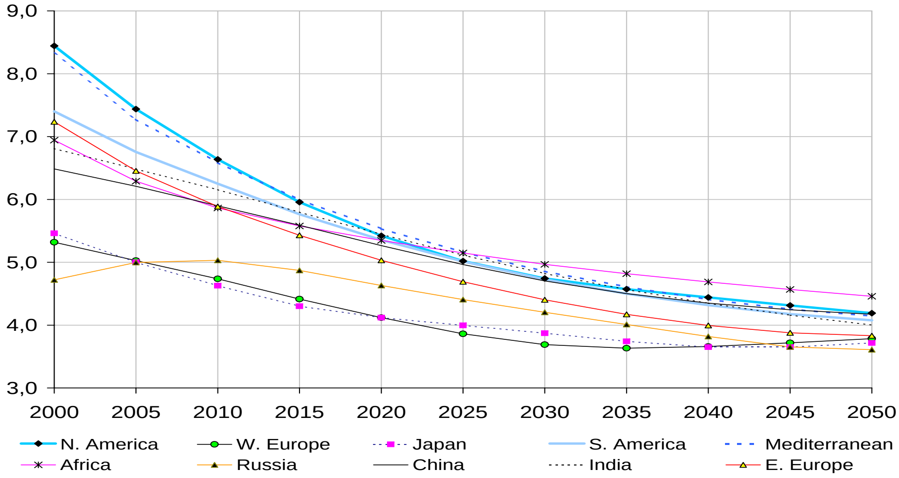
Despite numerous attempts, the model seems unable to reproduce the negative current account of the North America region observed in 1995-2000. The deficit in the early years of the century is due to the low saving rate of households in the United States. It is assumed that this behaviour will not be sustainable in the long run. So American households will converge to the saving behaviour observed in other regions in the early decades. In terms of calibration strategy, we assume that the psychological discount factor is initially lower (in 2000) in the "North America" region than elsewhere, and that this parameter converges to the "world" value during the first half of the XXI° century.

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

3.1 Interest rates

According to the model, the world real interest rate declines over the fifty years period. This is due to global ageing. Figures 1 and 3 show that the working age population is decelerating or declining while the age group of high savers is growing in one region after another. As a result, the world saving-investment balance is tilted more and more towards a lower interest rate. This downward trend provides the general profile of regional real interest rates (see Figure 5).
The hierarchy of regional real interest rates is linked to the rate of change of the real exchange rates. The real interest rates regulate investment and saving flows as

Figure 5: Regional interest rates :



explained below. The gap between investment and saving is the current account balance of each region. It is financed by capital flows whose amounts are such that yield differentials between different regions cancel out in every period.

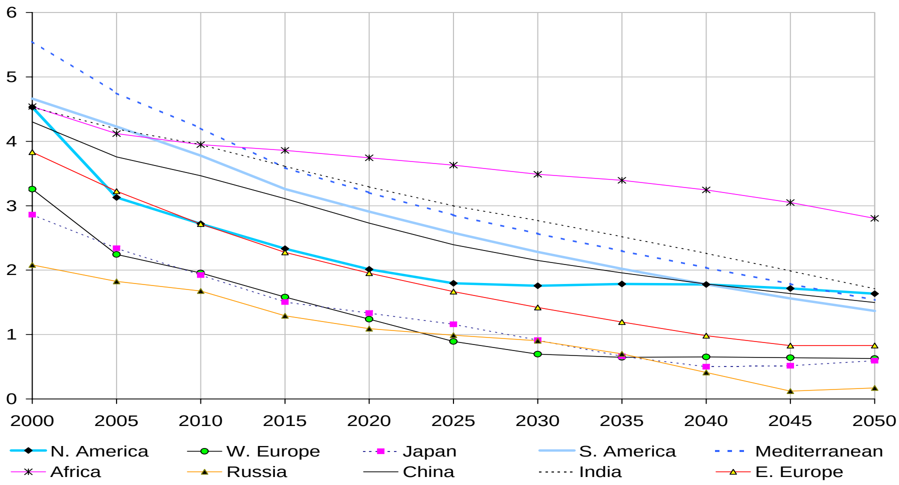
3.2 Regional economic growth

Assumptions regarding technological convergence are conservative in the baseline scenario. Besides, the parameters that define public pension systems perpetuate existing policies in the beginning of the XXI° century. Therefore the pattern of the GDP regional growth rates largely follows that of the regional labour force growth rates.

Two characteristics stand out (see Figure 6). Firstly, there is a general slowdown in growth because the working age population growth rate diminishes in all regions but Africa after 2000. Secondly the dispersion in the growth rates is almost as large in 2050 as in 2000, because ageing is a lengthy process with countervailing impacts on the labour force of less-developed countries. Nevertheless convergence in total factor productivity has an impact since the dispersion in the growth rates of the labour force is substantially higher in 2050 than in 2000, while the dispersion in the GDP growth rates is slightly lower. The Chinese region, which encompasses already developed countries, is the one where the catching up is the fastest. It is why its growth rate matches other regions with much higher growth in their labour force.

North America and Europe have growth profiles that partly differ from the general pattern. In North America, GDP growth decelerates precipitously in the first

Figure 6: GDP growth rate (2000-2050)



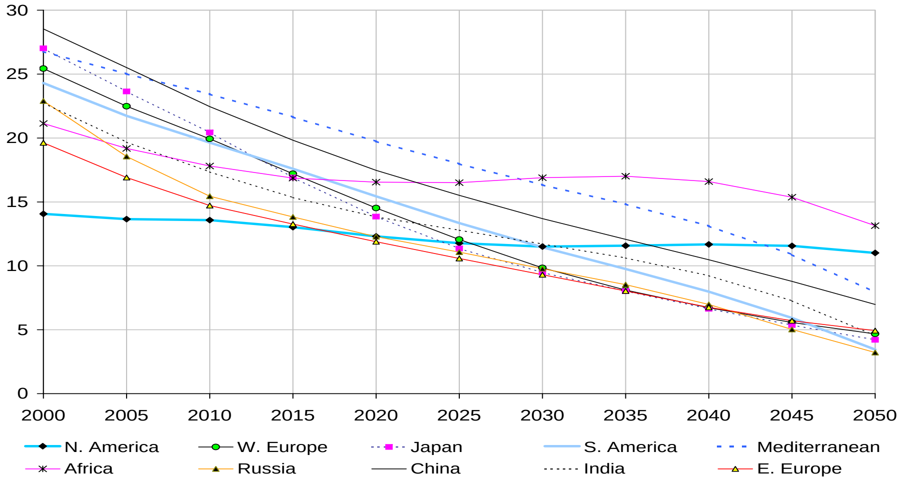
decade after 2000, because both the labour force and productivity do so. But the working age population stops declining in 2025, recovers and remains stationary thereafter. It ensues that GDP growth converges to nearly 2% per annum, one of the highest growth rates in 2050. Europe (both West and East) and worse Russia have a somber future. Western Europe follows a similar profile as North America but at much lower growth rates. GDP growth decelerates fast after 2000 until 2030 from 3.2% to 0.7% and keeps this poor performance until 2050. The Russian world is the region with the lowest growth rate almost throughout the half century and ends up in complete stagnation.

3.3 Investment and Saving

Because the model works at full employment with an exogenous labour force, the stock of capital in each period is a rising function of employment adjusted for labour efficiency and of capital intensity (capital/effective labour). The ratio of capital intensity is itself increasing with TFP and decreasing with the gross return to capital. The latter is the sum of the regional real interest rate and the depreciation ratio. Prices enter the picture and they bring the whole system of intertwined relationships. The regional net rate of interest is the sum of the world interest rate which clears the world financial market and of the rate of change of the region's real exchange rate against the US. Those relationships proceed from the risk-neutral arbitrage in financial markets.

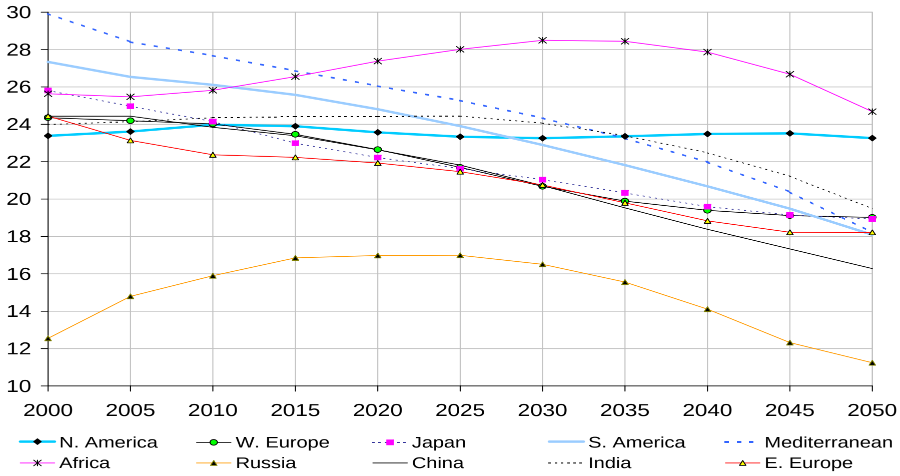
Gross investment rises with net capital accumulation and with replacement, which is modulated by the change in the rate of depreciation in debtor regions. Therefore in regions with a fast growth of the labour force and high foreign indebtedness,

Figure 7: Net saving (as a % of GNP)



raising markedly the rate of economic depreciation, the rate of gross investment to GDP will increase until 2030. Such conditions explain African pattern, the initial capital stock being very low in this region. India follows a similar pattern albeit less strongly. With a constant depreciation ratio, and an interest rate declining compared to the world rate, North America keeps a rate of gross investment to GDP remarkably steady (see figure 8).

Figure 8: Gross Investment (as a % of GDP):

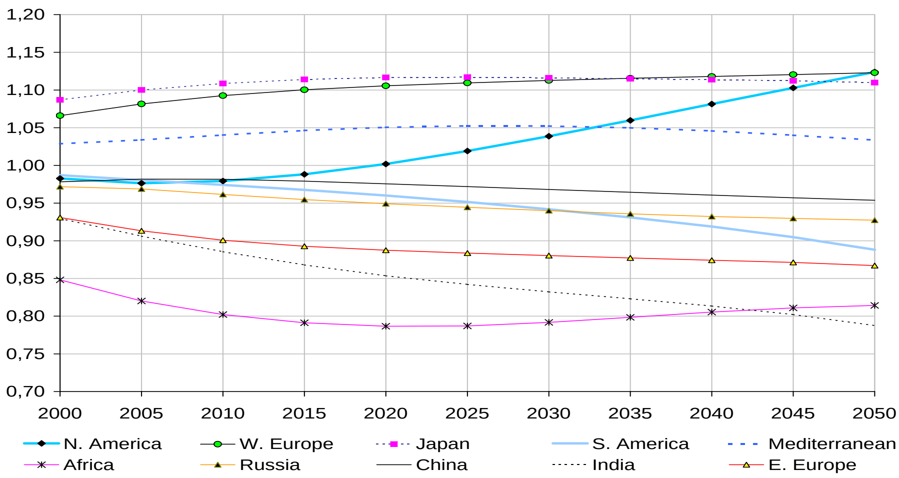


This is not the case of Japan and Western Europe. Despite the lowest real interest rates due to the continuous appreciation of their real exchange rates, leading to a low cost of capital, these regions have such a declining labour force that it impinges negatively upon capital accumulation. Yet the rise in capital intensity counteracts the effect of the labour force. It is why the rate of investment declines less than it does in faster growing regions like China and South America. Finally Russia has a peculiar profile, because there is an exogenous shock on investment in the early 2000's to recover from the collapse of the 1990's which led to the scrapping of more than half of the capital stock; hence the humped-shape curve of Russian rate of investment, which remains by far the lowest of all regions.

3.4 Exchange rates and world finance

The world financial equilibrium allocates capital flows so as to fill finance current account imbalances. Nevertheless the equilibrium in financial markets is a stock equilibrium. Exchange rates are affected by net foreign assets. They move with the net financial positions of the regions to create future surpluses or deficits, so that current accounts are balanced in the very long run, i.e. there is no more accumulation of net foreign assets or debts. In INGENUE the magnitude of financial positions is measured by the ownership ratio. This is the ratio of the aggregate wealth accumulated by households in the region to the capital stock laid out in the region. Hence a ratio above one is tantamount to a creditor position against the rest of the world, a ratio less than one to a debtor position (see Figure 9). Despite the general interdependence of prices one can roughly say that the world interest rate is the price which equilibrates the world financial market as a whole, matching total aggregate wealth and world capital stock. Real exchange rates appreciate relatively to North America in the two regions that have consistently an ownership ratio higher than North America : Western Europe and Japan (see Figure 10.

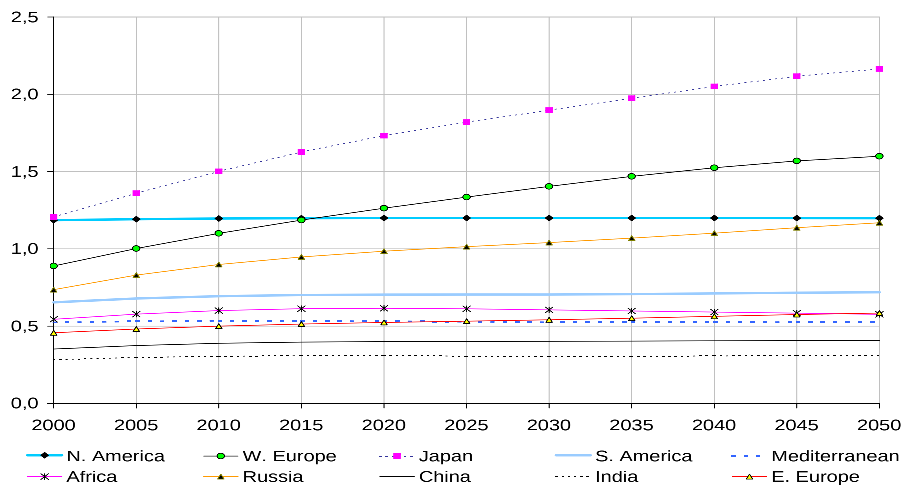
Figure 9: Ownership ratio :



Nevertheless, except in these two regions and in Russia, the latter due to terms of trade effects, exchange rate changes are not much sensitive to the stocks of financial assets. The paths of the exchange rates are mostly parallel to the one of North America.

The ownership ratios are determined by cumulative current account balances. The most striking feature is the divergent profile of North America (see figure 9). As it has been explained above, it is due to an assumed change in household saving behaviour. With this structural change and with a population consistently younger than in Japan and Europe, the rise in saving in North America is conveyed into a double improvement in the current account balance and the ownership ratio.

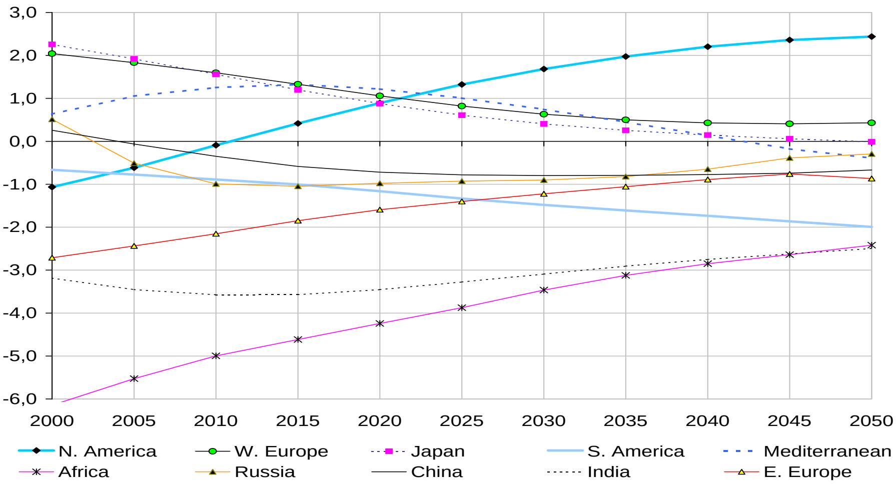
Figure 10: Real Exchange Rate :



The main conclusion for the other regions is a shrinking of the discrepancies in current accounts along the half century. Japan and Western Europe remain continuously in surplus but less and less with the rise in their dependency ratio. The Mediterranean region is in surplus for most of the time but goes into a slight deficit in the last two decades. Africa, the Indian world and Eastern Europe, with large current account deficits at the start of the century, are reducing it as long as their growth rate is diminishing and their households save more because they get older and richer. Ownership ratios do not show the same converging pattern, because regions accumulate either net foreign assets or debts because the sign of the current account balance does not change along the fifty year period.

Figure 11 depicts current account balances as a percentage of regional GDP. It shows that the polarization between creditor and debtor regions will persist with

Figure 11: Current Account (as a % of GDP)



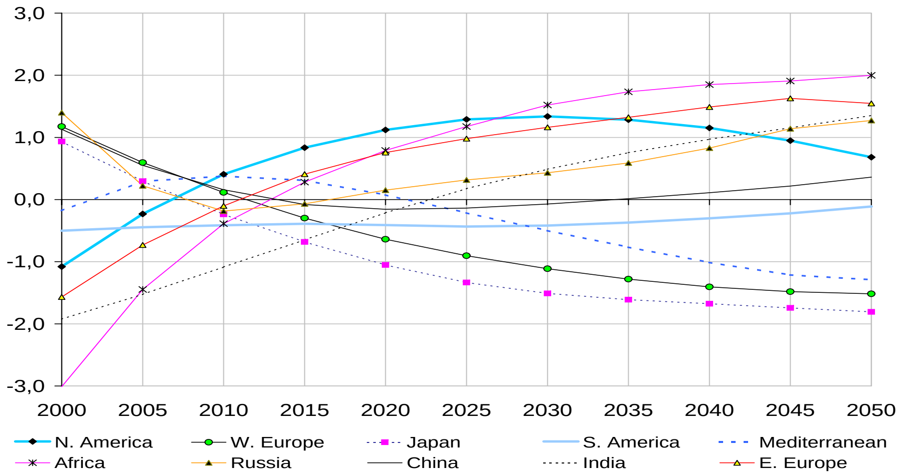
the notable exception of North America. Therefore the profiles of the ownership ratio do not exhibit any convergence (see figure 9). The building of a strong creditor position in North America stands out. The slight improvement in the debtor position of Africa and Eastern Europe stems from the steady reduction of the deficit in those two regions. In India, where the improvement is less pronounced, the ownership ratio is continuously deteriorating. India will become the largest debtor according to this measure in the last decade before 2050.

3.5 Foreign trade

In the INGENUE model, tradable goods are intermediary and the competitiveness of each region depends on the terms of trade against the world producer whose price is itself an average of intermediate goods prices in the different regions. Three regions have ever-rising terms of trade, i.e. loss of competitiveness: Japan, Western Europe, Russia. The other regions have constant or slightly declining terms of trade. The weak growth in the three former regions, much weaker than in others (see figure 6), pushes prices upwards. In Japan and Western Europe those rising prices generate the widening trade deficit to match the demand of intermediate goods by the final goods sector (see figure 12).

In the Russian world, the population declines more than anywhere else and the consumption per capita is lower. Furthermore, Russian intermediate products are primary commodities in strong world demand. It ensues that the valuing effect of the terms of trade takes over. After deteriorating alongside Japan and Western Europe, the Russian trade balance turns around to an increasing surplus there-

Figure 12: Trade balance (as a % of regional GDP) :



after. Most other regions with little change in competitiveness improve their trade balance, moving from deficit to surplus.

4 Pension reforms in Western Europe

In the baseline scenario (BS), the European pension system is characterized by two major features, which we have supposed untouched all along the 21$^{\text{st}}$ century : a low legal retirement age (62.5 years on average) and a fairly high replacement rate (48%). We now propose to investigate the consequences, in our model, of two kinds of pension reforms in Europe and of a migratory scenario, keeping the institutions in other regions of the world identical to baseline :

- Scenario 1 : Constant contribution rate (CCR): Maintaining the European pension contribution rate to the level it reached at the end of the XX° century (18%) (see left-hand side of figure 14). The result is a progressive and significant decline of the replacement rate as European population ages: by 2050, it would be reduced by 55%. But in the baseline scenario, keeping the replacement rate constant induces a marked increase in the contribution rate that reaches 32% by mid-century, and stabilizes around 25% in the very long run, in the aftermath of the baby-boom shock.

- Scanario 2 : Postponing the legal retirement age progressively over the period 2000-2025 (PRA). We choose a reform that implies a five-year switch of the participation rate for people aged between 45 years old and 65 years old. This reform is put in place progressively between years 2000 and 2020.

Then, for example, the participation rate of the age-group 60 to 64 yrs in 2020 will be set equal to the participation rate of the 55 to 59 yrs old in the year 2000. In the baseline case, about 22% of West-European aged 60-64 are working in 2020. With the PRA reform put in place, 55% of West-European aged 60-64 are working (see left-hand side of figure 13). In this scenario, the replacement rate is held constant at its 2000 level, and, as a result, the contribution rate increases much less than in the baseline scenario : it reaches 27% in 2050.

- Scenario 3 : Migratory scenario (MIG) : We also investigate the macroeconomic consequences of a specific migratory scenario. Such a scenario cannot be considered strictly as a pension reform. Nevertheless, the comparison with pension reforms scenarios seems accurate as increased labour mobility could transitorily alleviate the financial burden on the public retirement system (by limiting the increase of the dependency ratio and therefore the rise of the contribution rate)[7]. Several papers have studied this specific question[8]. The value-added of the INGENUE model is that it is fit to describe the consequences of migrations on both the regions receiving and losing migrants.

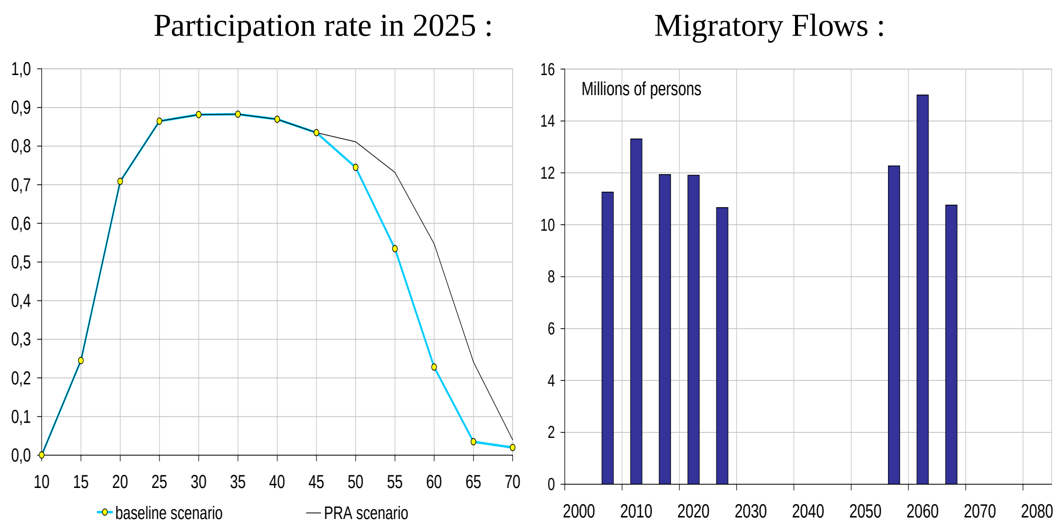
In our migratory scenario, the flows of migrants into Western Europe are calibrated in order to get a dependency ratio between 2000 and 2080 close to the one that we get in the PRA pension reform mentioned just above (see left-hand side of figure 14). In this scenario, migratory flows are substantial between 2005 and 2025 such that the dependency ratio is similar to the one that we get in the PRA case (see right-hand side of figure 13). During this period, the numbers of migrants is 11.8 millions of persons on average for each five-year periods considered[9]. From 2025 and until 2055, no migrant moves into Western Europe but the dependency ratio is then below the one of the PRA case as the children of the first cohorts of migrants are entering the labour force. In 2050-2060, the dependency ratio peaks at the same level in the two scenarios (about 0.8 compared with 1.0 in the baseline scenario). At each period, the migrants are assumed to be young adults (aged between 20 and 24 years) who adjust to the productivity of the host regions as soon as they enter the labour force. Furthermore, we assume that they move into Western Europe without any capital.

[7]While migrations has generally not been an important source of population growth in most advanced countries in recent years, in the past there have been periods when substantial flows of labour have occured, most notably during the 1820-1913 when large numbers of migrants moved from Europe to the United States and other countries of the new world.

[8]See for example Fehr, Jokisch & Kotlikoff (2004).

[9]11% of total migrants are coming from Eastern Europe, 29% from the Mediterranean, 25% from Africa and 35% from the rest of the world.

Figure 13: Pension Reforms in Europe:



4.1 Macroeconomic consequences

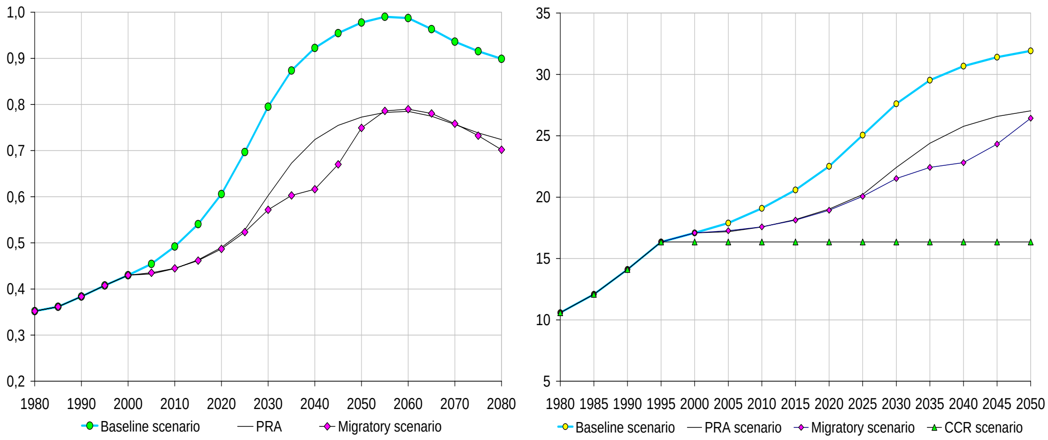
Because these reforms are assumed to be perfectly anticipated as soon as they are announced (beginning of the XXI° century), their major direct and most immediate effects are, of course, on individual saving behaviour, and hence, on aggregate saving.

Unsurprisingly, compared to the baseline scenario, the CCR reform raises the saving rate of Western Europe all along the half century (see Figure 15) : as the public pension system is made less generous, European households save and accumulate more in order to compensate the effect of lower pensions on consumption in retirement.

Because labour 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. As a consequence, consumption per capita is below its level in the baseline scenario during the first periods, until 2035 (see figure 17). Such an adverse demand shock tends to lower the price of the final goods and therefore, leads to a depreciation of the real exchange rate. The latter induces an improvement of the trade balance surplus in comparison with the baseline scenario as European exports (as a share of GDP) are sustained until 2030. After that date, consumption per capita is above its baseline level and the real exchange rate is higher than in the baseline scenario (see figure 17). Households have accumulated saving and

Figure 14: Pension Reforms in Europe :

Dependency ratio : Contribution rate :

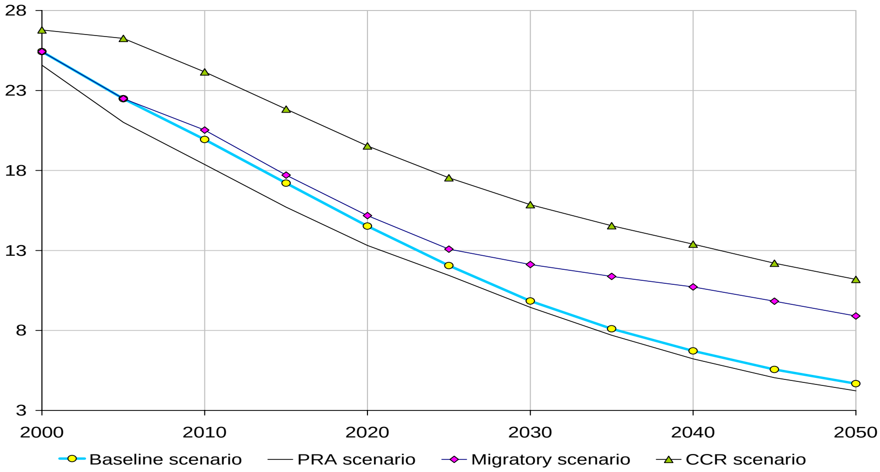


the ownership ratio is above its baseline level (see figure 19) : hence, due to the households saving decisions, Western Europe becomes a permanent exporter of capital to the rest of the world, with a large initial current account surplus.

By contrast, the implementation of the postponement of retirement-age (PRA reform) slightly reduces aggregate saving in Western Europe all along the half century (see figure 15). This reform induces an increase of the permanent income of the West-European households. This positive effect on their life cycle income leads to an increase of consumption per capita (and of GDP per capita). As a consequence, European saving falls substantially as soon as the reform is put in place.

The saving stays well below its baseline level until 2025 (about 1.25 point) ; after this date, net saving increases but still remain below the baseline level by about 0.5 point. 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. Besides, the postponing of the legal retirement age leads to a substantial increase of the annual growth of the working age population between 2005 and 2025. This increase induces a rise of investment during that period. With lower saving and higher investment, the West-European interest rate is therefore substantially higher than is the baseline case until 2025. The initial rise of the regional interest

Figure 15: Pension Reforms in Europe : Saving rate



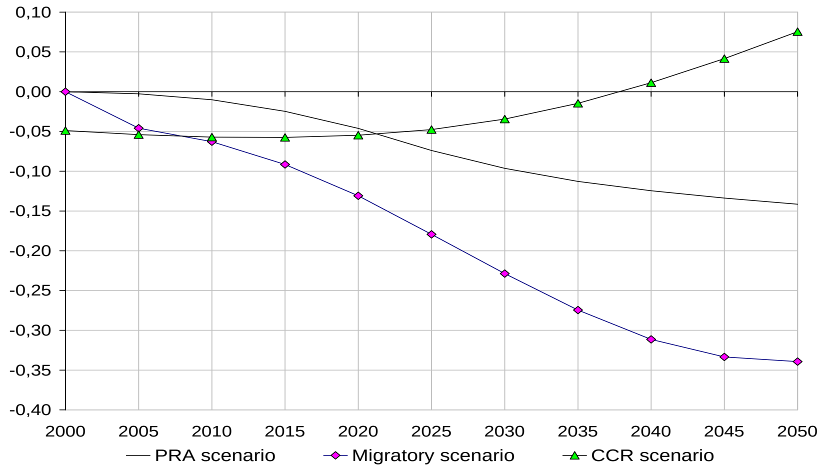
rate comes from the decrease of capital supply (i.e. the fall of the net saving) and the increase of the capital demand for investment. After 2025, investment growth decelerates and comes back to its baseline level[10]. The European real exchange rate stays below its baseline level throughout the study period[11] (see figure 16). Such a depreciation of the exchange rate could be explained noticeably by the decrease of the price of the European final good. The latter is induced by the positive supply shock (coming from the working age population rise) that exceeds the demand shock coming from the positive effect on the life-cycle income of the West-European households. The trade balance is below its baseline level during the first periods (until 2020) in relation with the increase in imports growth due to the sustained domestic demand (see figure 18).
Afterwards, imports growth rate is below its baseline level whereas the West-European exports growth is above its baseline level, explaining the improvement observed in the trade balance surplus. The current account stays below its baseline level throughout the study period as the ownership ratio is decreasing from the baseline case (the saving rate stays below its baseline level and the investment growth is sustained).

The impact of the migratory scenario on the GDP growth rate is more important than in the PRA scenario (see right-hand side of figure 20). Nevertheless, after 2025, GDP growth rate remains sustained, though decelerating : even if there is no migratory flow into Western Europe between 2030 and 2050, the working age

[10]The European GDP growth rate (in difference from the baseline scenario) follows a similar pattern (see right-hand side of figure 20).

[11]A similar pattern could be observed for the terms of trade.

Figure 16: Pension Reforms in Europe : Real exchange rate : difference from baseline scenario



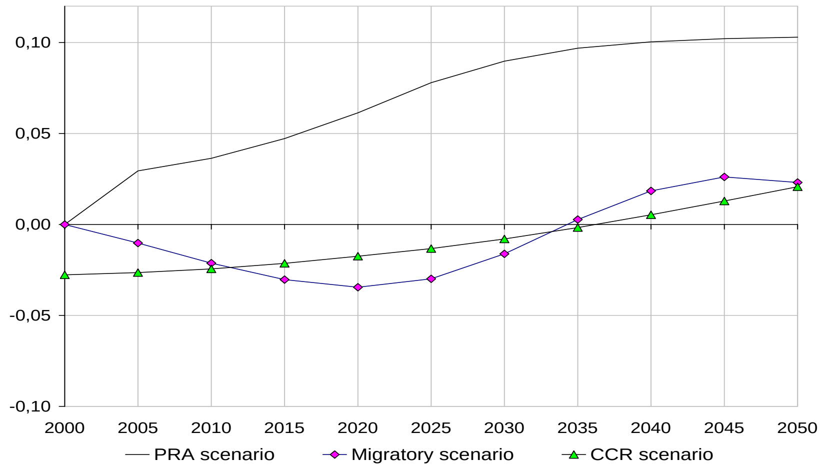
population in this region is still growing thanks to the children of the first cohorts of migrants[12]. Furthermore, the investment to GDP ratio is well above its baseline level throughout the study period, whereas it is close to the baseline level in the PRA case. Initially, the level of consumption per capita is lower than in the baseline scenario. The reason lies in the production sector : the inflow of workers reduces capital intensity relative to baseline. The marginal productivity of capital is raised and the interest rate as well. Conversely, labour productivity is diminished with a lower capital intensity. The real wage rate, being a decreasing function of the return on capital on the factor price frontier, is itself on a slower path than in baseline. It ensues that relatively to the baseline scenario consumption is less magnified than total population ; hence consumption per capita is lower. Around 2030, when saving gains momentum (see figure 15) the interest rate recedes a bit because saving grows faster than investment[13]. Therefore the growth of consumption per capita relative to baseline turns positive from 2020 onwards and the level moves overtake the baseline one in 2035. The sharp increase of saving (compared to the baseline trajectory) from 2030 is mainly explained by the facts that the first cohorts of migrants are now entering the "high saver" cohorts (aged between 45 and 69).

Because of the rise in interest rate, the saving investment balance stays more in surplus than in the baseline scenario. The current account balance, which was al-

[12] One must note that in the PRA case, there is no effect on the working age population growth after 2040.

[13] Furthermore, the flow of new migrants will disappear between 2030 and 2055.

Figure 17: Pension Reforms in Europe : Consumption per capita : difference from baseline scenario



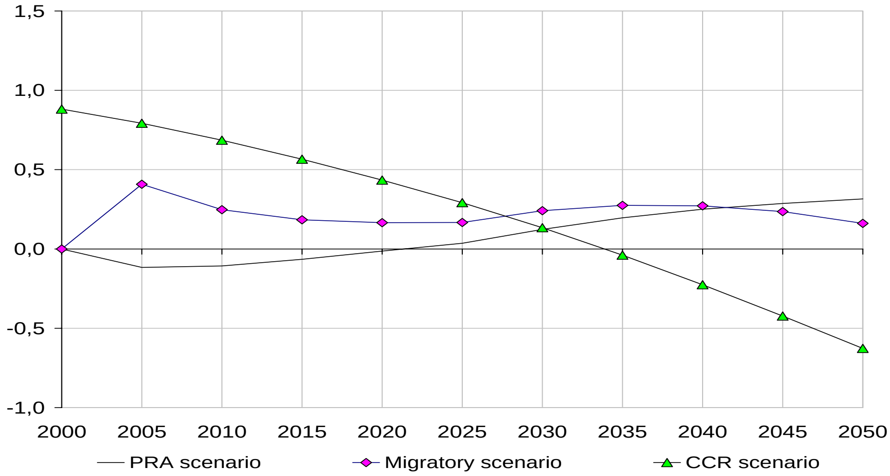
ready in surplus in baseline, is therefore more so. It follows from the improvement of the current account balance that Western Europe reinforces its creditor position in the world economy. The ownership ratio rises systematically above baseline (see figure 19).

The effects of the various European pension reforms on the world interest rate are shown in the left-hand side of figure 20. As expected, the CCR reform is associated with a permanently lower interest rate, as European saving rate is constantly above its baseline level. The same adjustment apply for the migratory scenario. On the contrary, the PRA reform induces a permanently higher interest rate.

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 Western Europe (see figure 19). In the PRA reform, the European ownership ratio is permanently lower than in the baseline case, as European investment is permanently increased. Conversely, the migratory scenario leads to an improvement of the foreign position of Western Europe as saving increases much more than investment.

Compared to the baseline current account evolution, the PRA reforms scenarios yields to a substantially smaller European surplus over the study period. In the CCR reform scenario, on the contrary, Europe is a permanent exporter of capital to the rest of the world, with a large initial current account surpluses. In the rest

Figure 18: Pension Reforms in Europe : Trade Balance (as a % of GDP) : difference from baseline scenario



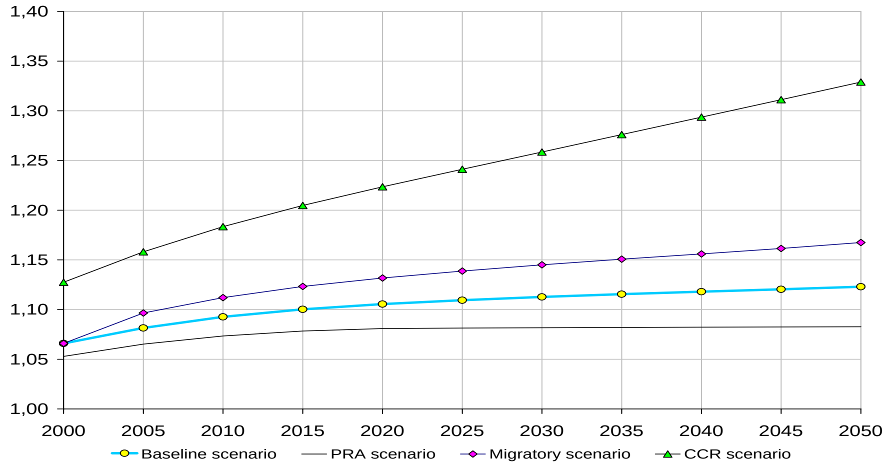
of the world, the constellation of regional current accounts is only mildly affected by European pension reforms, their consequences being only indirect, mainly via the world interest rate.

4.2 Distributional consequences of pension reforms

More capitalization (as a consequence of the CCR reform) leads to an increase in the financial position of European households. In the rest of the world, the effects of the two reforms are the opposite to those in Western Europe. Indeed, with 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 during the first periods. As time passes, Europeans reduce their extra saving (because they have funded enough their retirement income), the interest rate increases, 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 households (through capital income flows) consumption in these countries is 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 labour demand. 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

Figure 19: Pension Reforms in Europe : Ownership ratio



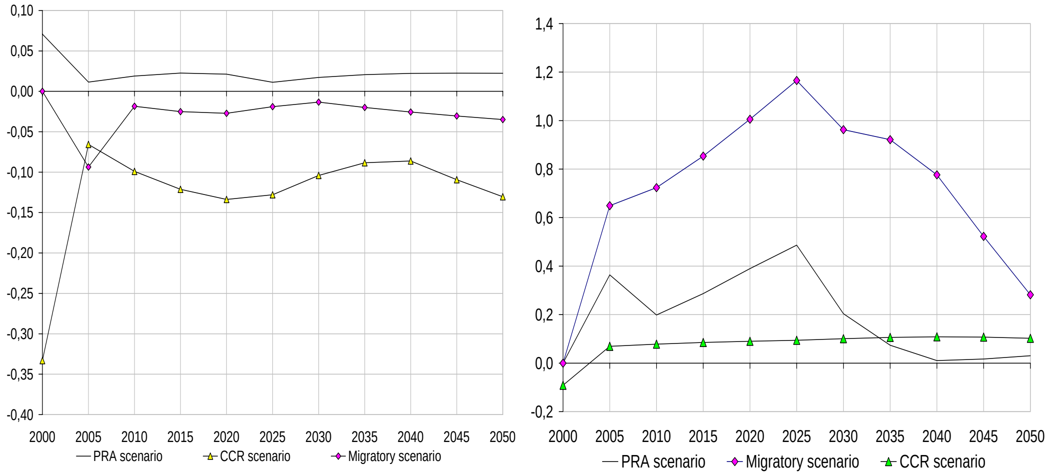
marginal productivity of capital rises with European labour) so in those regions, consumption will decrease at this time. In the long run, this policy implies an obvious increase of resources at the world level : Europeans still have a greater consumption level than in any other scenario (GDP per capita is higher). But this reform is also profitable to the rest of the world which has previously accumulated more West-European assets than in the CCR case.

Concerning the migratory scenario, the mirror effect of the improving economic situation in Western Europe due to immigration is a deterioration in the regions of emigration, and noticeably in Eastern Europe. The magnitude of the deterioration depends on the loss of potential workers relative to the total of the labour force in the region. One must notice that, in our scenario, Eastern Europe undergo the most adverse consequences of emigration as it is a region much advanced in the ageing process, and is already suffering from a declining population.

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 (see figure 21).
When the CCR reform is put in place, consumption per capita is lower than in the baseline scenario for the generations of households aged between 30 and 80. In 2050, the intergenerational redistribution induced by this pension reform leads to a consumption per capita sharply higher for the younger households than in the baseline scenario whereas it is lower for the older (households aged 60 and more, born before 1990). This kind of intergenerational redistribution may be justified by the fact that, in our benchmark economy, European households with more than

Figure 20: Annual rate - Pension Reforms (difference to baseline trajectories)

World interest rate : European GDP growth rate :

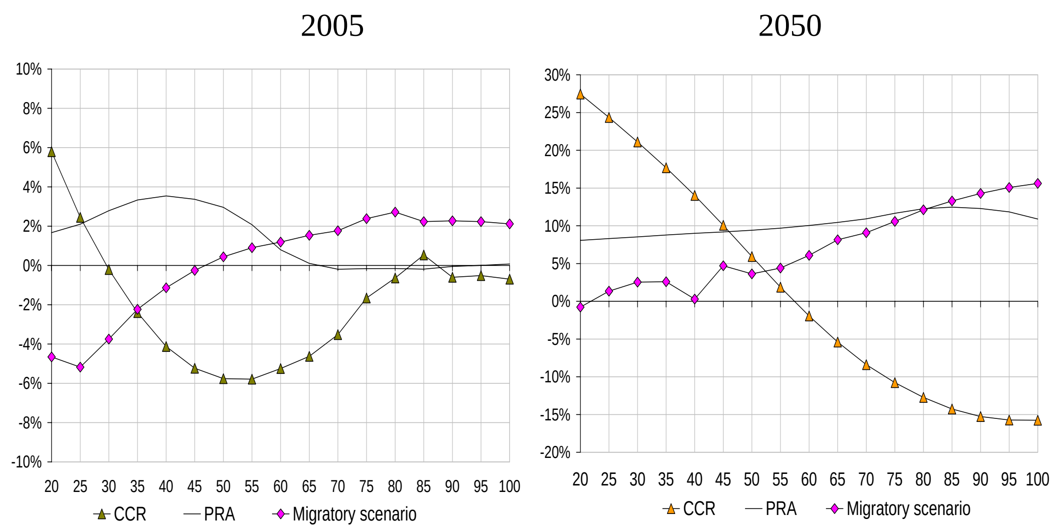


60 years-old have, at the end of the last century, a standard of living which is the double of the one of the people with less than 40 years-old. Concerning the PRA case, consumption per capita is higher than in the baseline case in 2005 only for the households whose age are inferior to 65 years. In 2050, consumption per capita is higher than in the baseline scenario for all the generations. The migratory scenario leads initially to an increase of consumption per capita for the households who are 50 years-old and more. In 2050, consumption per capita is higher for almost all the generations but it is not evenly distributed : the rise does not exceed 5% for young people (aged below 55, born after 1995) and is superior to 10% for the older generations (aged above 75, born before 1975).

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 ob-

Figure 21: Europe : Average consumption by age-groups (% changes to BS)



tain 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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Appendix A:

The 10 regions of the model :

The World is divided in the ten following regions according mainly to geographical and demographic criteria.

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. **"Latin 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'.

AGIR – Ageing, Health and Retirement in Europe

AGIR is the title of a major study on the process of population ageing in Europe and its future economic consequences. This project was motivated by an interest in verifying whether people are not only living longer but also in better health. It aims at analysing how the economic impact of population ageing could vary when not only demographic factors, but also health developments are taken into consideration. The project started in January 2002 for a period of three years.

The **principal objectives** of the study are to:

- document developments in the health of the elderly, ideally since 1950, based on a systematic collection of existing national data on the health and morbidity of different cohorts of the population;
- analyse retirement decisions and the demand for health care as a function of age, health and the utility of work and leisure;
- combine these results, and on that basis to elaborate scenarios for the future evolution of expenditure on health care and pensions; and
- analyse the potential macroeconomic consequences of different measures aiming at improving the sustainability of the European pension systems.

The **AGIR** project is carried out by a consortium of nine European research institutes, most of which are members of ENEPRI:

- **CEPS** (Centre for European Policy Studies), Brussels
- **CEPII** (Centre d'Etudes Prospectives et d'Informations Internationales), Paris
- **CPB** (Netherlands Bureau for Economic Policy Analysis), The Hague
- **DIW** (Deutsches Institut für Wirtschaftsforschung), Berlin
- **ETLA** (the Research Institute of the Finnish Economy), Helsinki
- **FEDEA** (Fundación de Estudios de Economía Aplicada), Madrid
- **FPB** (Belgian Federal Planning Bureau), Brussels
- **NIESR** (National Institute for Economic and Social Research), London
- **LEGOS** (Laboratoire d'Economie et de Gestion des Organisations de Santé, Université de Paris-Dauphine), Paris

It has received finance from the European Commission, under the Quality of Life Programme of the 5th EU Research Framework Programme. The project is coordinated by Jorgen Mortensen, Associate Senior Research Fellow at CEPS. For further information, contact him at: jorgen.mortensen@ceps.be.

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The European Network of Economic Policy Research Institutes (**ENEPRI**) is composed of leading socio-economic research institutes in practically all EU member states and candidate countries that are committed to working together to develop and consolidate a European agenda of research. **ENEPRI** was launched in 2000 by the Brussels-based Centre for European Policy Studies (CEPS), which provides overall coordination for the initiative.

While the European construction has made gigantic steps forward in the recent past, the European dimension of research seems to have been overlooked. The provision of economic analysis at the European level, however, is a fundamental prerequisite to the successful understanding of the achievements and challenges that lie ahead. **ENEPRI** aims to fill this gap by pooling the research efforts of its different member institutes in their respective areas of specialisation and to encourage an explicit European-wide approach.

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IER	Institute for Economic Research, Ljubljana, Slovenia
IHS	Institute for Advanced Studies, Vienna, Austria
ISAE	Istituto di Studi e Analisi Economica, Rome, Italy
ISWE-SAS	Institute for Slovak and World Economy, Bratislava, Slovakia
NIER	National Institute of Economic Research, Stockholm, Sweden
NIESR	National Institute of Economic and Social Research, London, UK
NOBE	Niezalezny Osrodek Bana Ekonomicznych, Lodz, Poland
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