Labour market characteristics and the burden of ageing : North-America versus Europe

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Abstract

A transition from pay-as-you-go pension systems to more private funded systems is often suggested as a solution to finance pension systems threatened by ageing. This paper analyses alternative potential remedies linked to changes in labour market characteristics, within an international computable overlapping-generations model of the world economy. A prolongation of the working life of skilled or unskilled individuals, an increase in the demand for skills, a rise in the education levels and increased skilled or unskilled immigration have very different outcomes in North-America and in Europe. In the latter region, a postponement in the retirement age of unskilled individuals has the most beneficial effect in relieving the fiscal pressure on pension systems, because the proportion of unskilled workers is relatively larger in Europe than in North-America. In North-America, where skilled labour is more abundant, an acceleration in skill-biased technical change has the biggest impact on pensions systems, as it raises the productivity of skilled workers.

Key words: OLG-CGE Model, ageing, labour market, migration
JEL classification: C68; H55; O30; J26; J61

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1 Introduction

Population is ageing all over the world due to rising life expectancy and declining fertility. During the next 50 years, the number of people of working age for one pensioner will strongly decrease in many countries. In the United States and Europe-15, the average number of working-aged per retiree was equal to 5.2 respectively 4.2 in 2000; this number is expected to reach 2.7 respectively 1.9 in 2050.[1] As public transfers are strongly ascending, such a demographic transition imposes a strong pressure on the fiscal policy. In many developed countries, it will be impossible to maintain current levels of taxes/pension benefits and pay-as-you-go (PAYG) pension systems are thus undergoing several reforms.

A transition from PAYG pension systems to more private funded systems is often discussed in countries with important welfare states. However here we will take another perspective. We are concerned with the consequences of changes in labour market characteristics on the financing of pension systems. Can PAYG pension systems be sustained by postponing the retirement age of unskilled (or of skilled) individuals, by an acceleration in skill-complementary technology, by a rise in education levels or by increased unskilled-biased (or skilled-biased) immigration? Do these modifications in labour market characteristics have a different outcome when they are applied in the United States or in Europe? Our analysis relies on a computable general equilibrium (CGE) model of the world economy and focuses on the economies of two of the model's developed regions: North-America (United States and Canada) and the Advanced Countries (Western Europe plus Australia and New-Zealand). The model features also two types of individuals: skilled (tertiary education) and unskilled (secondary and primary education). The potential alternative remedies to ageing suggested here can be thought of being "realistic" i.e. the magnitude of these policy changes is not excessive. Let us describe the modifications in labour market characteristics considered here, before relating our model to the literature and summarizing the results.

The first *scenario* that we take into account is a prolongation of the working life. More precisely we compare the outcomes of raising the retirement age of unskilled workers (scenario 1) with the postponement of the one of skilled individuals (scenario 2). In the United States (US) and in many European countries governments plan to or have already delayed mandatory retirement age. But how much does raising the retirement age help in financing the fiscal burden due to ageing? Retirement regimes vary across countries, but also within countries, and mandatory retirement age may for example differ across sectors or professions. Thus another issue raised here is if changes in retirement age of unskilled professions have a different impact on the financing of pension systems than changes in the one of skilled professions. In fact, skilled workers spend more time in school than unskilled workers and have thus shorter periods of contributions. But when they enter the labour force, they usually contribute by higher amounts to (and also benefit less from) welfare systems. Besides, some countries or regions may be endowed by more skilled workers than others and policies affecting retirement age of a certain type of workers may not have a similar result everywhere. Thus do these reforms have a different outcome whether they are applied in the United States (US) or in Europe?

Another important labour market characteristic is the demand for skills. In fact, the last decades have been characterized by an increase in skill complementary technologies causing a rise in wage inequality (between skilled and unskilled workers) and in overall inequalities Acemoglu (2002, 2003). An acceleration of SBTC (scenario 3) may also have implications for fiscal policy through changes in the wage differential between skilled and unskilled workers. A modification in the skill premium will affect the tax base and thus the contribution to the welfare state.

[1] Medium variant of the population prospects of the U.N. (2007) and own computations.

It would thus be worthwhile to know how much technical progress alters the fiscal burden and, in general, the economy. Again the results may differ whether an acceleration of skill-biased technical progress happens in the United States or in Europe. As the supply of skills is relatively high in the US compared to Europe, it would also be interesting to investigate how pension systems in Europe would be affected when the education levels of the European population approach the ones of the US (scenario 4).[2]

Furthermore, we investigate if replacement migration can mitigate the pressure on the fiscal burden. In most developed countries the ageing process strongly modifies the labour force. Compared to policies that intend to raise the fertility rates in countries with a projected declining population, replacement migration has the advantage of augmenting immediately the population of working age. However immigration changes the demographic structure as well as the skill composition of the labour force. The education level of immigrants will thus also have an impact on the supply of skills. We thus compare how public finances react when a non-selective immigration policy (scenario 5) and a selective immigration policy (scenario 6) are carried out.

The first *computable general equilibrium models* (CGE) with overlapping generations - dealing with the viability of pension systems under the threat of ageing - were carried out in a closed-economy setting (see e.g. the seminal work of Auerbach & Kotlikoff (1987) on the US economy). However it might be important to investigate the issue with open economy models. Demographic projections for the 21^{st} century indicate that the population is ageing in various regions of the world, but this ageing process occurs at different paces all over the world. While it is quite advanced in OECD countries, like in Europe and Japan, other world regions will experience lower old-age dependency ratios and their working-age population will still rise. The heterogeneous ageing process can induce inter-temporal trade, through international capital flows, mitigating the effects of ageing compared to a situation of economic and financial autarky. To take into account economic openness, small open economy models have been developed, as for example Raffelhüschen & Risa (1995) for Norway. As pointed out by Aglietta et al. (2007), these models lack to explain important relative prices of the economy, because they are based on an exogenous interest rate which establishes the capital intensity of production. In short, they are not "real" general equilibrium models.

Hence recent models worked out multi-country or multi-region frameworks, built upon demographic projections, to examine the implications of ageing on pension systems when capital is mobile. Such models have been developed by Fehr et al. (2003), Börsch-Supan et al. (2006), Ingenue (2005) and Aglietta et al. (2007). The two last studies based on the world model developed by the French team Ingenue (2001).[3][4] Börsch-Supan et al. (2006) compare the effects of a generous with a less generous pension system on the economy of different OECD countries. Fehr et al. (2003) analyse the effects of a privatization of pension systems in the US, Europe and Japan. Aglietta et al. (2007) and Ingenue (2005) analyse pension reforms for one of their six respectively

[2]Following Cheeseman Day and Bauman (2000) , who carry out projections of school attendance for the US until 2028, we can consider that the proportion of highly skilled individuals in North-America will not increase in the future, justifying why we do not carry out a simulation of a rise in the educational attainment for the North-American region.

[3]Actually, Aglietta et al. (2007) exploit the first version of the Ingenue world model (with six regions), while the study of Ingenue (2005) builds on an augmented version of the same model (with 10 regions).

[4]Other large scale CGE models examine the consequences of ageing on international capital flows (Attanasio & Violante, 2000; Brooks, 2003; Ingenue, 2001; Feroli, 2003). However as they do not model PAYG pension systems, they can neither address issues concerning the financing of the fiscal burden neither take into account the effects of pension reforms on saving patterns which in turn have implications on international capital flows.

ten world regions: Europe. Still all these studies are mainly interested in the impact of pension reforms on international capital flows and put a lesser focus on the sustaining of pension systems.

The *contributions* of this paper are thus manifold. From a methodological point of view, the open economy CGE model of the world economy presented in this paper has the advantage to be a "real" general equilibrium approach compared to small open economy models. Interest rates will also react less to demographic changes in a framework that considers 10 world regions than e.g. in the three-region model of Fehr et al. (2003). Moreover, like the Ingenue models but unlike Fehr et al. (2003) and Börsch-Supan et al. (2006), we aggregate all the countries in the world in several regions and we thus take into account in a more global way the effects of the non-synchronous ageing process on capital movements.

From the point of view of the issues addressed here, the implications of changes in various labour market characteristics can be addressed with the model presented in this paper as it features heterogeneous agents unlike the above cited open economy multi-country/region models [5] Our model allows us to assess the economic impact of changes in skilled or unskilled retirement age, in skill-biased technologies, in education levels and in skilled- or unskilled-biased immigration policies on the U.S. and Europe. Regarding for example the consequences of a prolongation of the working life on pension systems only the study of Aglietta et al. (2007) investigates this issue.[6] However Aglietta et al. (2007) analyse the effects of a prolongation of the working life only for the European economy and give more attention to its impact on savings, the real exchange rate and the trade balance. They can moreover not analyse if postponing the retirement age of skilled individuals has different implications than postponing the one of unskilled individuals. The other changes in labour market characteristics have not been dealt with in similar models.

Finally this paper is also related to another strand of the literature that analyses the role of replacement migration in financing pension systems. This question has been raised in various frameworks ranging from a generational accounting methodology (partial equilibrium), to a theoretical OLG approach and to a single-country closed-economy CGE model.[7] Again applying a open economy CGE approach can give further insights to this topic by taking into account capital movements that operate in response to the heterogeneous ageing pattern in the world. To our knowledge, only two *multi-country open economy* dynamic CGE models cope with the fiscal consequences of replacement migration. These studies simulate the impact of a doubling of immigration in the economies of developed regions and their results differ. Fehr et al. (2004) find that "increased immigration does very little to mitigate the fiscal stress facing the developed world", whereas Ingenue (2005) conclude that "the financing of the pay-as-you-go systems is dramatically improved" by immigration. Unlike Ingenue (2005) we compare the effects of a selective with a non-selective immigration policy on the financing of pension systems. Unlike Fehr et al. (2004) we calibrate the regions of origin of the migrants. The modelling of the destination countries is important in taking into account of the general equilibrium effects induced by the loss of their (skilled or unskilled) workers by the regions of origin. In addition to these two studies, we exploit the data available in the World Bank sponsored study of Docquier & Marfouk (2006) to accurately compute the number of migrants per region of origin.

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[5] Except Fehr et al. (2003, 2004), who distinguish individuals by three income classes, but do not consider the impact of changes in labour market characteristics.

[6] Also Ingenue (2005), which use an augmented version of the model of Aglietta et al. (2007), analyse the effects of a postponement of retirement age on pension systems.

[7] To assess the impact of increased immigration on public finances, Bonin et al. (2000) and Collado et al. (2004) use a general accounting methodology for Germany respectively for Spain, Razin & Sadka (1999) develop a theoretical OLG model and Storesletten (2000) applies a closed-economy CGE model to calibrate the US economy.

Our *main result* is that the various labour market characteristics have a different impact on North-American and European pension systems. In the Advanced Countries, postponing retirement age of unskilled individuals by 2 years from 2010 onwards has the most beneficial effect in reducing the tax-to-GDP ratio (minus 3 to 4% compared to the baseline scenario). In North-America on the other hand, a linear augmentation in SBTC, from 1% in 2010 to 5% in 2050 compared to the baseline, has the biggest impact in reducing the tax-to-GDP ratio (4 to 4.5% compared to the reference case in the long term). Another result is that an acceleration in skill-biased technical change has different effects on the economies of North-America and of the Advanced Countries. It raises per capita GDP in the former and reduces it in the latter. The intuition behind these results is that the proportion of unskilled workers is relatively larger in Europe than in North-America, raising unskilled retirement age will have a bigger impact in Europe, while the expansion of skill-biased technologies will enhance the productivity in North-America, where skill labour is more abundant.

We also find that increasing immigration by 25% over the period 2010-2050 has a beneficial effect on public finances as long as migrants augment the number of contributors compared to number of pensioners. When migrants get old, the beneficial effect on pension systems disappears. Moreover there is not much difference in choosing a selective immigration policy (70% of additional migrants are skilled) or a non-selective policy (30% of additional migrants are skilled) in order to act against population ageing.

The paper is organized as follows. Section 2 introduces the 10 regions of the world and presents the model. The calibration of the baseline scenario is provided in section 3. Section 4 explains the results of the different scenarios. A variant of model, featuring unemployment for unskilled individuals, is described in section 5. Section 6 concludes.

2 The Model

This study builds upon a 10 region CGE-OLG model developed in Marchiori (2007) and where individuals live for 8 periods each of 10 years. Age classes go from 15-24 to 85-94 years, implying that individuals are born at the age of 15 and die at the age of 95. However there is a probability of being alive at each period, because some individuals are assumed to die before the age of 95. There are moreover two types of individuals, skilled and unskilled individuals. "Skilled individuals" identify individuals with an education above high-school degree (tertiary education), whereas "unskilled individuals" comprise individuals having an educational level less than high-school (primary education) and with a high-school degree (secondary education). The educational choice (e) and thus also the proportion of skilled individuals among one generation (ϕ) is exogenously determined.

As in De la Croix & Docquier (2008), we postulate the existence of an insurance mechanism à la Arrow-Debreu (or à la Yaari 1965). Each time an individual dies, her/his assets will be equally distributed among individuals belonging to the same age class. In other words, individuals do not leave any bequests to their children (or to next generations). Furthermore, there is only one consumption good and its price is the numeraire of the model. There is one leading economy (North-America), in the sense that the total factor productivity (TFP) of each region is expressed in terms of the TFP of the leading economy. The leader is always ahead in terms of TFP compared to the other regions. Besides, the evolution of the TFP is exogenous.

The model introduces skill heterogeneity among individuals. A constant elasticity of substitution (CES) transformation function for efficient labour is used to define the mix of skilled and unskilled labour forces in the production process. Moreover, the model is characterized by full-employment. Finally, each economy has three agents: households, a representative firm and a public sector. In the following subsections, we describe the regional decomposition of the world, agents' behaviour and the equilibrium of the model.

2.1 Regions

The model shares the world in 10 regions (or groups of countries). Three of them consist of developed countries: Japan, North America (NAM), which comprises the United States plus Canada, and a group of other developed countries with Europe-15 as the major member. This region is labelled the 'Advanced Countries' (ADV), and includes Western European Countries plus Australia and New-Zealand. The seven other regions are composed of developing countries (more details can be found in appendix).

2.2 Demography

At each date, some individuals die and a new generation appears. Households reaching age 15 (labelled as age 0 in our notations) at year t belong to generation t. The size of the young generation increases over time at an exogenous growth rate:

$$N_{0,t} = m_{t-1} N_{0,t-1}, \tag{1}$$

where $N_{0,t}$ measures the initial size of generation t and m_{t-1} is one plus the demographic growth rate, including both fertility and migration. Each household lives a maximum of 8 periods ($a = 0, ..., 7$) but faces a cumulative survival probability decreasing with age.[8] The size of each generation declines deterministically through time.

$$N_{a,t+a} = P_{a,t+a} N_{0,t}, \qquad j = s, u \tag{2}$$

where $0 \leq P_{a,t+a} \leq 1$ is the fraction of generation t alive at age a (hence, at period $t + a$). Moreover, $P_{0,t} = 1$. Obviously, total population at time t amounts to $N_t = \sum_{a=0}^{7} N_{a,t}$.

2.3 Preferences

The expected utility function (U) of skilled (upperscript s) and unskilled (upperscript u) individuals is assumed to be time-separable and logarithmic:

$$E(U_t^j) = \sum_{a=0}^{7} P_{a,t+a} ln(c_{a,t+a}^j), \qquad j = s, u \tag{3}$$

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

The budget constraint of unskilled (u) and skilled (s) individuals requires equality between the expected value of expenditures and the expected value of income, which consists of labour

[8] To avoid agent heterogeneity, migration flows are allowed only among individuals of the first age class. Population is calibrated to match the population prospects of the U.N. (2007).

income (w), pension benefits (b) and other welfare transfers (ζ). It writes as follows for $j = s, u$:

$$\sum_{a=0}^{7} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} (1+\tau_{t+a}^{c}) c_{a,t+a}^{j}$$
$$= \sum_{a=0}^{7} \lambda_{a,t+a}^{j} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} (1-e_{t+a}^{j})(1-\tau_{t+a}^{w}) w_{t+a}^{j}$$
$$+ \sum_{a=0}^{7} (1-\lambda_{a,t+a}^{j}) \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} b_{t+a}^{j} + \sum_{a=0}^{7} \psi_{t+a} \zeta_{a}^{j} w_{t+a}^{j}, \tag{4}$$

where $\lambda_{a,t+a}^{j}$ is the labour participation rate for a j type individual of age class a, w_t is labour income, R_t is one plus the interest rate, τ_t^c is consumption tax, τ_t^w income tax, b_t^j (individual) pension benefits, tr_a^j are other welfare transfers received by an individual of type j and they are represented as a time-constant fraction of labour income, the generosity factor ψ_t is the factor by which these other welfare transfers are multiplied at time t. Education is exogenous and individuals spend a fraction e_t^j of their total time (which is only positive in their first period of life).

We assume that individuals are born with no assets at time t, or in other words, there are no bequests. At time $t + a$ with $a > 0$, assets of skilled and unskilled individuals ($Z_{a,t+a}^{j}$) depend on their assets in the previous period ($Z_{a,t+a-1}^{j}$) plus an interest rate as well as on current expenditures (consumption) and income (labour income, pension benefits and other welfare transfers). Formally, at the beginning of their first period of life (when $a = 0$), $Z_{0,t}^{j} = 0$ for all t. For $a > 0$, aggregated assets, for $j = s, u$, correspond to:

$$Z_{a+1,t+a+1}^{j} = R_{t+a} Z_{a,t+a}^{j} + \phi_t^j N_{a,t+a}[(1-\tau_{t+a}^{w})(1-e_{t+a}^{j})\lambda_{a,t+a}^{j} w_t^j$$
$$-(1+\tau_{t+a}^{c}) c_{a,t+a}^{j} + (1-\lambda_{a,t+a}^{j}) b_{t+a}^{j} + \psi_t \zeta_a^j w_t^j] \tag{5}$$

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

For a household already living at the initial date, i.e. belonging to the age class a = 1...6 at date 0, the budget constraint is:

$$\sum_{a=0}^{7} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} (1+\tau_{t+a}^{c}) c_{a,t+a}^{j}$$
$$= \frac{R_{a-1} Z_{a-1,a-1}^{j}}{\phi_{a-1}^{j} N_{a-1,a-1}} + \sum_{a=0}^{7} \lambda_{a,t+a}^{j} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} (1-e_{t+a}^{j})(1-\tau_{t+a}^{w}) w_{t+a}^{j}$$
$$+ \sum_{a=0}^{7} (1-\lambda_{a,t+a}^{j}) \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} b_{t+a}^{j} + \sum_{a=0}^{7} \psi_{t+a} \zeta_{a}^{j} w_{t+a}^{j}, \tag{6}$$

2.4 Firms

At each period of time and in each region, a representative firm uses efficient labour (L_t) and physical capital (K_t) to produce a composite good (Y_t). We assume a Cobb-Douglas production function with constant returns to scale:

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

where α measures the share of wage income in the national product, and A_t is an exogenous process representing Harrod neutral technological progress.

Total efficient labour force combines the *demands*[9] of skilled (L_t^s) and unskilled labour (L_t^u) according to a CES transformation function:

$$L_t = [\nu_t (L_t^s)^\sigma + (1-\nu_t)(L_t^u)^\sigma]^{1/\sigma}, \tag{8}$$

where ν_t is an exogenous skill-biased technical change (SBTC), σ is defined as σ=$1-\frac{1}{\varepsilon}$, with ε being the elasticity of substitution between skilled and unskilled labour.

2.5 Government

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

$$\begin{aligned} S_t = \tau_t^w L_t w_t + \tau_t^c \sum_{j=\{s,u\}} \sum_{a=0}^{7} \phi_{t-a}^j N_{a,t} c_{a,t}^j \\ - \sum_{j=\{s,u\}} b_t^j \sum_{a=0}^{7} \phi_{t-a}^j N_{a,t} (1-e_t^j)(1-\lambda_{a,t}^j) \\ -\psi_t \sum_{j=\{s,u\}} w_t^j \sum_{a=0}^{7} \phi_{t-a}^j N_{a,t} (1-e_t^j) \zeta_a^j - c_t^g Y_t, \end{aligned} \tag{9}$$

where c_t^g is a part of national income used to finance general public spending.

The government also issues bonds and pays interests on public debt. Thus the government's budget constraint may be written as:

$$d_{t+1} Y_{t+1} = R_t^* d_t Y_t - S_t, \tag{10}$$

where d represents the debt-to-GDP ratio, R^* is one plus the international interest rate and S is the government's surplus. Equation (10) says that public debt in $t+1$ depends on past debt in t and its interests, minus the government's surplus S. The government's budget constraint (10) is satisfied each period by adjusting the wage tax rate. The model's regions are actually characterized by different levels of investment risk. Thus a region's interest rate is equal to the international interest rate (R^*) plus a risk premium. The risk premia are computed from the OECD (2006a). For North-America and the Advanced Countries the investment risk is zero and thus their regional interest rate corresponds to the international one (for country risk calibration see section A.1.2 in appendix).

Finally, the pension system is modelled in order to allow for different pension systems in each region. The regional pension systems are partly Bismarckian and Beveridgian depending on the value of ρ comprised between 0 and 1.

$$b_t^u = \chi_t w_t^u, \tag{11}$$

$$b_t^s = \chi_t (\rho w_t^s + (1-\rho) w_t^u), \tag{12}$$

where χ_t is the replacement rate ($0 < \chi_t < 1$).

[9]In the benchmark model the demands of efficient labour equal the supplies of efficient labour: $L^j = \bar{L}^j$ for $j = s, u$. The labour supplies are defined in equation (15).

2.6 Equilibrium

In an economy with perfect capital mobility (up to a risk premium), the aggregate value of world assets equals the market value of the world-wide capital stock plus the sum of the debts of all regions:

$$\sum_{x\in X} \Omega_t^x = \sum_{x\in X} (K_t^x + d_t^x Y_t^x), \tag{13}$$

where X is the set containing each world region. Moreover, K_t^x is the sum of the capital stock of region x at time t, Ω is the sum of the assets of all the cohorts of region x, $d_t^x Y_t^x$ is the level of region x's debt at time t. An economy with perfect capital mobility is also characterized by the arbitrage condition of the returns to capital which requires the equality between the rates of return to capital in each region.

$$R_t^x = R_t^*(1+\pi^x) \tag{14}$$

The domestic interest rate of region x, R^x equals the international interest rate R^* up to the region's risk premium π^x (see section A.1.2 in appendix).

Definition (Competititve Equilibrium) *Given an initial stock of capital* $\{K_t\}_{t=0}$*, an exogenous demographic structure summarized by* $\{N_{a,t}\}_{a=1..7,t\geq 0}$*, an exogenous distribution of skilled individuals* $\{\phi^j_{a,t-a}\}_{a=1..7,j=s,u,t\geq 0}$ *and an initial distribution of wealth* $\{Z^j_{a,t+a}\}_{a=1..7,t=0,j=s,u}$ *with* $\{Z^j_{a,t}=0\}_{a=0,t\geq 0}$*, a competitive equilibrium of the economy with perfect capital mobility (up to a risk premium) in each region is*

- *a vector of individual variables* $\{c^j_{a,t}\}_{a=0..7,t\geq 0,j=s,u}$ *that are the optimal solutions to the households' maximization problem, i.e. equation (3) subject to (4);*
- *a vector of individual variables* $\{c^j_{a,t}\}_{a=1..7,t=0..7-a,j=s,u}$ *such that utility (3) of the first old generations is maximized subject to (6);*
- *a vector of the firm's variables* $\{K_t, L^j_t\}_{t\geq 0,j=s,u}$ *that maximise the firm's profits subject to technology (7);*
- *a vector of income taxes* $\{\tau^w_t\}$ *balancing the budget of the government (10);*
- *a vector of wages* $\{w^j_t\}_{t\geq 0,j=s,u}$ *such that the labour markets are in equilibrium ;*
- *an interest factor* $\{R_t\}_{t\geq 0}$ *satisfying the no arbitrage condition of the rates of return to capital, i.e. equation (14) holds;*
- *and finally, an international interest factor* R^*_t *satisfying the equality between the aggregate value of world assets and the market value of the world-wide capital stock plus the sum of the debts of all regions, i.e. equation (13) holds.*

3 Calibration of the baseline scenario

In this section we explain the calibration of the parameters as well as of the observed and unobserved exogenous variables. We also define the baseline scenario and the assumptions on the future. Finally we focus on the different scenarios characterised by changes in the retirement age, skill-biased technical progress and education levels.

The model is calibrated in such a way that it matches regional structures and world disparities over the period 1950-2000. We start from an initial steady-state in 1870 and we focus on the transitional path of the world economy until it reaches the final steady-state in 2200. Our period of interest is 2000-2100.

3.1 Parameters and exogenous variables

Parameters are set a priori and are identical in all the regions. The capital share in output α equals to 0.33. We follow Acemoglu (2002) in fixing the elasticity of substitution ε to 1.4 and thus the parameter in the CES labour demand function, σ, which corresponds to $1 - \frac{1}{\varepsilon}$ equals 0.2857.

Observed exogenous variables comprise public debt d_t, among generation t the share of skilled individuals ϕ_t, the population growth rate m_t and the probability of being alive $P_{a,t+a}$. Public debt d_t is computed from the World Bank Development Indicators (WDI, 2006), except the public debt of the Advanced Countries and Japan, which are obtained from the OECD (2006b). To compute the share of skilled individuals among one generation ϕ_t, we use the Barro & Lee (2001) dataset, which gives the share of skilled individuals aged 25 to 74 for the years 1950 to 2000. We compute the probability for an individual of generation t of being alive at time $t+a$, $P_{a,t+a}$, and the population growth rate m_t from the population prospects of the U.N. (2007).

Unobserved exogenous variables include total factor productivity A_t, the growth rate of the leading economy g_t and skill-biased technical change ν_t. To obtain technical progress A_t, we use the GDP ratio (Y_t/Y_t^*), where Y_t^* is the leader's GDP. We proceed as in De la Croix & Docquier (2008), who use a backsolving identification method to calibrate technical progress. It consists in swapping the exogenous variables A_t for the endogenous variables Y_t/Y_t^* and then solving the identification step with the Dynare algorithm Juillard (1996). We do the same for skill-biased technical change ν_t by the using full-employment wage differential, h_t ($= \bar{w}_t^s/\bar{w}_t^u$), where $\bar{w}$ is full-employment wage. The ratio of GDP's is computed by employing the data of the GDP per purchasing power parity from the World Bank Development Indicators (WDI, 2006) for the three years 1980, 1990 and 2000.[10] We hold the value of 1980 (respectively 2000) constant for the years preceding 1980 (respectively following 2000). The skill premium h_t is fixed at 2.3 for the Advanced Countries and 3 for North-America for the year 2000 and depicts the fact that skill premium is higher in the US than in Europe. These two values reflect the pattern of the US college wage premium in Acemoglu (2003) during the period 1950-2000. Finally, the technical progress growth of the leader, g_t=A_{t+1}^*/A_t^*, where A^* is the leader's technical progress, is calibrated on observations. The growth rate of the North-American technical progress is calibrated to 1.2, which means that the annual growth rate is equal to 1.84%. The calibration of a region x's risk premium π^x is explained in section A.1.2 of the appendix.

3.2 Baseline and assumptions on the future

In the baseline scenario, the distance of the technical progress of each region to the technical progress of the leading economy is assumed to be constant after 2000 (except for three developing

[10]We take the 5-year average value for the three time periods 1980, 1990 and 2000: 1978-1982, 1988-1992 and 1998-2002.

regions of the model, see appendix). Furthermore, like the policies conducted in many developing countries, the baseline already features less generous pension systems in the near future because of population ageing, e.g. a postponement by 1 year of the retirement age of skilled and unskilled individuals between 2000 and 2050 (see appendix). In addition, we hold the proportion of skilled individuals among each new generation constant from 2000 onwards.

3.3 Scenarios on labour market characteristics

Table 1 presents the "realistic" changes in the various labour market characteristics with the benchmark model. Five scenarios are considered for North-America and six for the Advanced Countries. In the first scenario, retirement age of unskilled individuals is postponed by two years beyond the baseline level from 2010 onwards both in the Advanced Countries and in North-America. In a second simulation, the same scenario is run for the retirement age of skilled individuals. In scenario three the firms augment their demand for skilled labour in the production process scenario during the first half of the 21^{st} century. This scenario is characterized by a continuous acceleration in skill-biased technical change with respect to the baseline from 2010 to 2050: from a 1% augmentation in 2010 to reach a 5% increment in 2050 compared to the baseline.[11]

In simulation four we assume that the proportion of educated individuals rises during the first half of the 21^{st} century, but only in the Advanced Countries. The proportion of young educated people augments steadily from 2 percentage points in 2010 to 10 percentage points in 2050 with respect to the baseline scenario. There will be no scenario of increased supply of skills in North-America, because according to Cheeseman Day and Bauman (2000) the proportion of skilled among young skilled individuals may not vary much in the near future in the US. Finally, we consider two policies of increased immigration. We track migration flows from the seven developing regions to North-America and the Advanced Countries.[12] To avoid additional agent heterogeneity, we also assume that migrants enter at the age of 15 when they have no assets (the integration of migration flows in the model is explained more in detail in appendix). In the two immigration scenarios, 25% of additional immigrants (compared to the baseline scenario) arrive to North-America and to the Advanced Countries between 2010 and 2050. When the non-selective immigration policy (scenario 5) is applied, 30% of these additional migrants are skilled and 70% unskilled whereas 70% of these migrants are skilled and 30% unskilled in the selective immigration policy (scenario 6). Table 1 shows how the proportion of young skilled individuals in the population changes according to these two policies.

The evolution of the parameters in the different scenarios can be justified in the following way. We argue that a prolongation of the working life can be implemented immediately via a public policy and thus the total augmentation in legal retirement age happens in one period. In the scenarios 3 and 4 the changes are progressive (and occur over several periods), because the proportion of skilled in a population and skill-biased technical change may not be radically influenced over a short time period.

Moreover, instead of simulating two radical policies of increased immigration (e.g. an arrival of 100% of unskilled versus 100% of skilled immigrants), we prefer to compare the effects of two more "realistic" immigration policies: 70% of skilled / 30% of unskilled versus 30% of skilled /

[11] The values of all exogenous variables are fixed after 2050 in each scenario, expect for ν_t, which continues to vary slightly from 2050 to 2100 in the baseline case.

[12] We do not quantify migration flows from the North (developed regions) to the South (developing regions) as well as North-North and South-South migrations, but they are implicitly taken into account in the UN Population data.

70% of unskilled migrants. We argue that when a country chooses to adopt a selective immigration policy, it can never "attract" 100% of skilled migrants, because a migrant may for example arrive with his family members, who are probably not all highly skilled.

Table 1: Simulations for the Advanced Countries and North-America

Scenario 1: Postponement of unskilled retirement age (+2 years in 2010)						
Both regions	2000	2010	2020	2030	2040	2050
Baseline	60	60.2	60.4	60.6	60.8	61
Scenario 1	60	62.2	62.4	62.6	62.8	63
Scenario 2: Postponement of skilled retirement age (+2 years in 2010)						
Both regions	2000	2010	2020	2030	2040	2050
Baseline	62	62.2	62.4	62.6	62.8	63
Scenario 2	62	64.2	64.4	64.6	64.8	65
Scenario 3: Rise in SBTC (ν) by 1% in 2010 to 5% in 2050						
Region and Scenario	2000	2010	2020	2030	2040	2050
ADV: Baseline	48.1%	51.8%	54.2%	55.3%	55.5%	55.5%
ADV: Scenario 3	48.1%	52.4%	55.3%	57%	57.8%	58.2%
NAM: Baseline	73.3%	75.3%	76.2%	76.7%	76.9%	76.9%
NAM: Scenario 3	73.3%	76%	77.8%	79%	80%	80.8%
Scenario 4: Increase in the share of young skilled (ϕ) from 2pp in 2010 to 10pp in 2050						
Region and Scenario	2000	2010	2020	2030	2040	2050
ADV: Baseline	30%	30%	30%	30%	30%	30%
ADV: Scenario 4	30%	32%	34%	36%	38%	40%
NAM: Baseline	55%	55%	55%	55%	55%	55%
NAM: No Scenario 4	—	—	—	—	—	—
Scenario 5 and 6: Share of young skilled (ϕ) when the inflow of migrants increases by 25%						
	2000	2010	2020	2030	2040	2050
ADV: Baseline	30%	30%	30%	30%	30%	30%
ADV: Scenario 5: Non-selective immigration	30%	30%	30%	30%	30%	30%
ADV: Scenario 6: Selective immigration	30%	30.78%	30.82%	30.85%	30.86%	30.87%
NAM: Baseline	55%	55%	55%	55%	55%	55%
NAM: Scenario 5: Non-selective immigration	55%	53.98%	54.04%	54.08%	54.11%	54.15%
NAM: Scenario 6: Selective immigration	55%	55.61%	55.58%	55.55%	55.53%	55.51%

ϕ is the proportion of skilled among individuals aged 15-24, ν is skill-biased technological change

Source: Docquier & Marfouk (2006) for scenarios 5 & 6 and own computations; own calibration for scenarios 1-4.

Table 2: Labour force increase under retirement age and immigration scenarios

Increase in the labor force compared to the BSL						
Advanced Countries	2010	2030	2050	2070	2090	2110
Scenario 1: postponement of RA-U	0.73%	1.51%	1.47%	1.36%	1.36%	1.36%
Scenario 2: postponement of RA-S	3.60%	3.91%	3.43%	3.17%	3.18%	3.18%
Scenario 5: increase in Immi-U	0.13%	1.02%	2.59%	3.40%	3.40%	3.23%
Scenario 6: increase in Immi-S	0.25%	1.73%	4.71%	7.09%	7.92%	7.92%
North-America	2010	2030	2050	2070	2090	2110
Scenario 1: postponement of RA-U	1.94%	2.19%	2.49%	2.47%	2.53%	2.53%
Scenario 2: postponement of RA-S	2.20%	1.98%	2.03%	2.02%	2.07%	2.07%
Scenario 5: increase in Immi-U	0.33%	2.83%	7.02%	10.24%	11.30%	11.19%
Scenario 6: increase in Immi-S	0.67%	3.33%	7.16%	9.33%	9.77%	9.63%

RA-S and RA-U stand for retirement age of skilled respectively unskilled individuals, while Immi-U and Immi-S represent increased unskilled respectively skilled immigration. Source: Docquier & Marfouk (2006) and own calculations

Besides, unlike Ingenue (2005) and Fehr et al. (2004) who double immigration flows to sending countries/regions, the immigration scenarios presented here do only augment by 25% the migrants coming to the Advanced Countries and to North-America. The reason is that we prefer to follow again the aim of more "realistic" changes on the labour supply. Table 2 shows how a prolongation (of two years) in the working life of unskilled or skilled individuals and an increase (by 25%) in skilled or unskilled migration inflows affects the labour supply compared to the baseline. The rise in the labour supply (compared to the baseline) due to a postponement of the legal retirement age is obviously relatively constant (because it is a one-time change in labour supply), while immigration constantly increases the labour supply as additional migrants arrive each period to their destination region until 2050. We see that the increase in the labour force due to any of the two immigration policies is more than two (four) times higher than the increase in the labour supply due to a prolongation of the working life in the Advanced Countries (North-America). Thus doubling immigration would have an excessive effect on the labour supply.

4 Results

In this section we present the effects of the different potential remedies on the tax-to-GDP ratio and on per capita GDP of the Advanced Countries and of North-America. First, we investigate if any of the scenarios can mitigate the old age crises, by helping to finance pension systems. But we will also analyse their implications for per capita GDP, as they are likely to have an impact on the economic performance of these two regions.

4.1 Public Finance

Figure 1 displays the effect of the different policy changes on the tax-to-GDP ratio with respect to the baseline.[13] In the Advanced Countries, postponing retirement age of unskilled individuals is the most effective one among all the scenarios in reducing the fiscal pressure. In the first quarter of the 21^{st} century the tax-to-GDP ratio drops very rapidly, by 3.4% already in 2010 compared to the baseline. The reduction in the tax-to-GDP ratio stabilizes at 3% in the long run. When postponing the retirement age of skilled individuals, the tax-to-GDP ratio decreases only slowly in the beginning of the 21^{st} century and the cut is around 2% in the long term (with respect to the baseline).

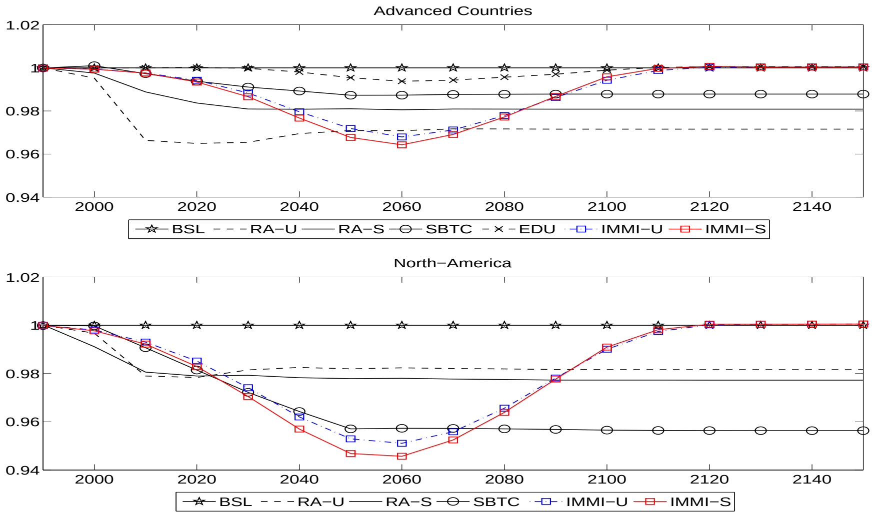
The stronger impact on the tax-to-GDP ratio due to postponing unskilled retirement age is due to the fact that the majority of the labour force is unskilled in the Advanced Countries. Because the share of skilled individuals increases over the first half of the 21^{st} century[14], the difference in the reduction of the tax-to-GDP ratio due to the effects of both scenarios is lower. When unskilled retirement age is delayed, the decline in the tax-to-GDP ratio lessens slightly between 2030 and 2050, whereas a higher retirement age for skilled individuals decreases taxes constantly over the 2000-2050 period. An acceleration in skill-biased technological change reduces taxes by 1.2% in the long term (compared to the baseline). Moreover, a rise in the proportion of skilled individuals has a very negligible impact on taxes.

In North-America, an acceleration in skill-biased technical change reduces the tax-to-GDP

[13]The tax-to-GDP is the ratio of the sum of income taxes times wages and consumption taxes times consumption of a region to the GDP of the region.

[14]The share of skilled among a new born generation is 24% in 1980. 27.8% in 1990 and 30% from 2000 onwards. Thus the share of skilled in the total population rises steadily in the 21^{st} century and tends to 30% in the long run.

Figure 1: Tax-to-GDP ratio with respect to the baseline



BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase, Immi-U and Immi-S represent increased unskilled respectively skilled immigration.

ratio more than postponing retirement age of any type of workers. The decrease in the tax-to-GDP ratio corresponds to 4.4% in the long run (compared to the baseline) and to less than 1.2% in the Advanced Countries. Postponing skilled retirement age has a slightly stronger effect in the reduction of the tax-to-GDP ratio than delaying unskilled retirement age. In North-America, the proportion of skilled leans to 55% in the long term.[15] Skilled and unskilled individuals are thus more equally distributed in the population than in the Advanced Countries. This explains that there is less difference in opting for longer working time of skilled instead of unskilled workers to reduce the tax-to-GDP ratio than in the Advanced Countries.

Finally, the effect of immigration in financing pension systems is quite strong compared to the other potential "remedies". In both regions it is highest in the middle of the century, but the beneficial effect on taxes disappears by the end of the century. The more realistic policy change of increasing immigration by 25% rather than doubling migration inflows reduces fiscal pressure by around 3-3.5% in the Advanced Countries and by 4.5-5.5% in North-America. If the migration flows in our migration policies would be doubled compared to the baseline, our results would contrast with the findings of Fehr et al. (2004) and confirm the conclusion of Ingenue (2005): increased immigration alleviates the future fiscal burden associated to the ageing of the population in the developed world. Interestingly, our findings also support the results of the two-period theoretical OLG model of Razin & Sadka (1999), in which individuals work in the first period of their life and are retired in the second period. Razin & Sadka (1999) find that an immigration policy is beneficial to the pension systems of the receiving countries in the period of the migrants' arrival, as they increase the labour force. We also find that the positive effects of immigration last until the immigrants retire. In addition, because our individuals live for eight periods, the beneficial effects of immigration hold several periods after the stop of the increased immigration policy. Even though the labour force remains higher than in the baseline in the long run, the number of

[15] In 1980, 50% of the 15 to 24 years old are skilled. In 1990, there are 52.5% of skilled among the same age group and 55% from 2000 onwards.

pensioners benefiting from contributions will also be higher. Furthermore, in **?**, also low-skilled immigrants may contribute to finance the pension systems of developed countries. This corroborates with our result, but differs from the outcome of the study of Storesletten (2000) , who argues that only selective immigration policies may be used to reduce the fiscal pressure on the welfare state.

The surprising result is that the two immigration policies seem to have a quite similar impact on taxes.[16] A selective policy relieves the fiscal pressure by 14.6% respectively by 12.91% more than a non-selective one in North-America respectively in the Advanced Countries.[17] The reasons why the two immigration policies create a similar effect on taxes may be twofold: - First, the definition of unskilled individuals does not include only "low-skilled" individuals (who have less than a high-school degree), but also "medium-skilled" individuals (who have a high-school degree). Medium-skilled immigrants are important contributors to the welfare state. - Secondly, the skill-composition of our immigration policies is not a "radical" one, in the sense that Policy A is not composed of 100% of unskilled migrants and Policy B not of 100% of skilled migrants. In the case of a comparison between the effects of "extreme" immigration policies, the difference in the reduction of taxes is more clear-cut (see figure 6 in appendix).

4.2 Income per capita

In the Advanced Countries, a progressive increase in the share of skilled individuals, up to a level of 40% in 2050, is the scenario that leads to the highest long term increase in per capita GDP of 7% with respect to the baseline scenario (figure 2). Postponing retirement age of either skilled or unskilled individuals increases per capita GDP by less than 2.5% compared to the reference case in the long run.

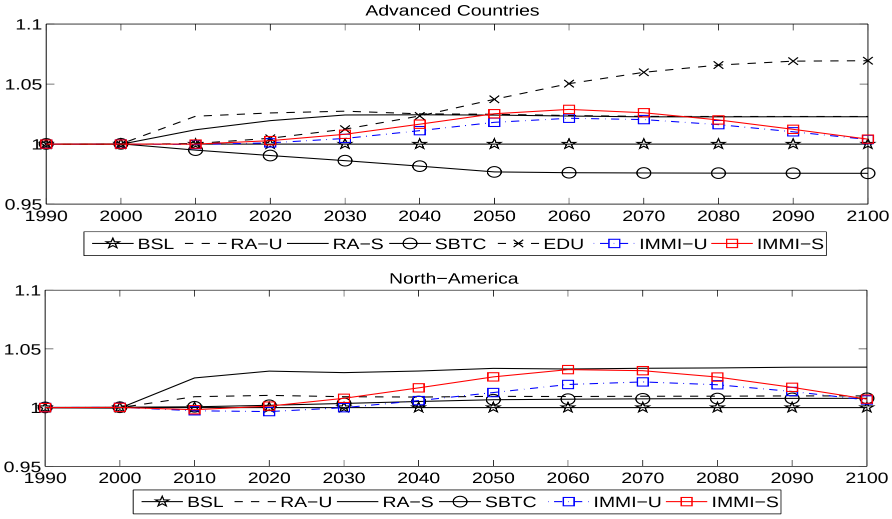
Higher skill-biased technical change leads to a long term decrease in per capita GDP of almost 2.5% compared to the baseline. In North-America, a delay in the retirement age of skilled individuals produces the most important increase in per capita GDP among all the scenarios: a 3.5% rise by the end of the 21^{st} century compared to the reference case. Higher skill-biased technical change and a delayed unskilled retirement age increase per capita GDP by around 1%.

We notice that an increase in skill-biased technical change has different effects on the economies of North-America and of the Advanced Countries. It increases per capita GDP in the former and decreases it in the latter. This is closely linked to the different education levels in both regions and can be interpreted as follows. A high supply in the skilled labour force induces North-American firms to apply more advanced technologies in the production process Acemoglu (2002, 2003). Following a reasoning à la Nelson & Phelps (1966) or à la Benhabib & Spiegel (2005) where a follower imitates the technology of the leader economy, we can argue that the skill-complementary technologies developed in North-America are adopted by the Advanced Countries. Because of lower education levels, the production process in the Advanced Countries is not adapted to use the new technologies. They create unemployment, increase the skill premium (see figures 7 and 10 in appendix) and increase per capita income gap between North-America and the Advanced Countries.

[16]When simulating the two immigration policies, general public consumption ($c_t^g Y_t$) is the same in the two scenarios of increased immigration. The government spends more public goods when additional migrants arrive (because Y_t will rise when the labour force increases). However, general public expenditure does not change if the composition of these migrants is different.

[17]A non-selective (selective) immigration policy decreases the tax-to-GDP ratio by 2.8% (3.2%) in the Advanced Countries and by 4.7% (5.3%) in North-America.

Figure 2: Per capita GDP with respect to the baseline



BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase, Immi-U and Immi-S represent increased unskilled respectively skilled immigration.

Immigration has a beneficial impact on per capita GDP but again only as long as the labour force is increased and as long as the number of pensioners does not increase (by too much). In 2050, the increase in per capita GDP is by 51% higher in the Advanced Countries and by 111% in North-America with a selective immigration than with a non-selective immigration policy. The fact that skill-complementary production process is more important in North-America (higher ν) can explain that a selective immigration policy has a more beneficial effect in North-America.

5 Unemployment variant

In this section we introduce a variant of the model, characterized by a non-competitive labour market of unskilled individuals and thus featuring unskilled unemployment. Formally, the fundamental difference with the benchmark model is the introduction of an equation determining exogenously the wage of unskilled workers.

5.1 Modelling wage rigidities

In the new framework, we have to distinguish between demand and supply of labour. Let skilled and unskilled efficient labour *supplies* $\bar{L}_t^s$ and $\bar{L}_t^u$ be defined as follows:

$$\bar{L}_t^j = \sum_{a=0}^{7} \phi_{t-a}^j N_{a,t}(1-e_t^j)\lambda_{a,t}^s, \qquad j = s, u \tag{15}$$

where ϕ_t^j is the proportion of individuals of type j among generation t.[18]

[18] ϕ_t^s is equal to ϕ_t and ϕ_t^u is equal to $1-\phi_t$.

The non-walrassian unskilled wage w_t^u is modelled as a linear combination between the competitive unskilled wage $\bar{w}_t^u$ (which is equal to the marginal productivity of unskilled labour under full-employment) and the effective skilled wage w_t^s.[19]

$$w_t^u \quad = \quad \eta_t w_t^s + (1 - \eta_t)\bar{w}_t^u, \tag{16}$$

where η is a mark-up to the competitive unskilled wage ($0 \leq \eta_t \leq 1$). A positive η implies that the supply of unskilled labour is higher than the demand ($\bar{L}_t^u > L_t^u$), which leads to unemployment. The (unskilled) unemployment rate u_t is defined as:

$$u_t \quad = \frac{\bar{L}^u - L^u}{\bar{L}^u} \tag{17}$$

There is however full-employment of skilled labour: $\bar{L}_t^s = L_t^s$.

The non-walrassian wage for unskilled individuals introduced here does not rely on any union maximisation problem. However, equation (16) implies a trade-off between unemployment and higher wages for unskilled workers. A higher η implies a higher wage for unskilled individuals than under a competitive labour market, but also an higher unemployment rate.

Finally, equations (11) and (12) determining the pension benefits for skilled and unskilled workers write now as follows:

$$b_t^u = \chi_t(1 - u_t)w_t^u, \tag{18}$$

$$b_t^s = \chi_t(\rho w_t^s + (1 - \rho)(1 - u_t)w_t^u), \tag{19}$$

where χ_t is the replacement rate ($0 \leq \chi_t \leq 1$).

5.2 Calibration and scenarios

To calibrate the mark-up of the unskilled wage to its level under full-employment, η_t, we apply the same methodology as for total factor productivity and for skill-biased technological change. We use the unemployment rate, u_t, to determine η_t via the backsolving identification method described above. To build the *unskilled* unemployment rate for the years 1980-2000, we use the share of unemployed individuals with primary and secondary education in total unemployment from the WDI database.[20] For the years before 1980, we make the unskilled unemployment rate at time $t - 1$ be equal to 80% of that at time t. In 2050, we assume that the unemployment rate reaches a level equal to 75% of that in 2000 (during the period 2000-2050, it decreases every 10 years by 5% compared to 2000). After 2050, the unemployment rate is constant. Following these assumptions, the unemployment rate in the Advanced Countries and North-America, is respectively 8.54% and 4.28% in 2000 and reaches respectively 6.74% and 3.21% in 2050.

The "unemployment" variant introduces an additional scenario with respect to the benchmark model: the wage of unskilled workers is rendered more competitive. In the Advanced Countries the mark-up to the competitive unskilled wage η_t is cut by half from 2010 onwards. On the other hand, we consider that in North-America, η_t is already at a very low value in the baseline and thus no additional simulation is considered on η_t.

[19]The effective skilled wage is higher than the skilled wage under full-employment of unskilled labour $w_t^s > \bar{w}_t^s$, where $w_t^s = MPL^s(L^u)$, $\bar{w}_t^s = MPL^s(\bar{L}^u)$ and MPL^s is marginal productivity of skilled labour.

[20]except for Sub-Saharan Africa and the Indian world, for which, we start from the gross unemployment rate for the year 2000 given by the CIA world factbook.

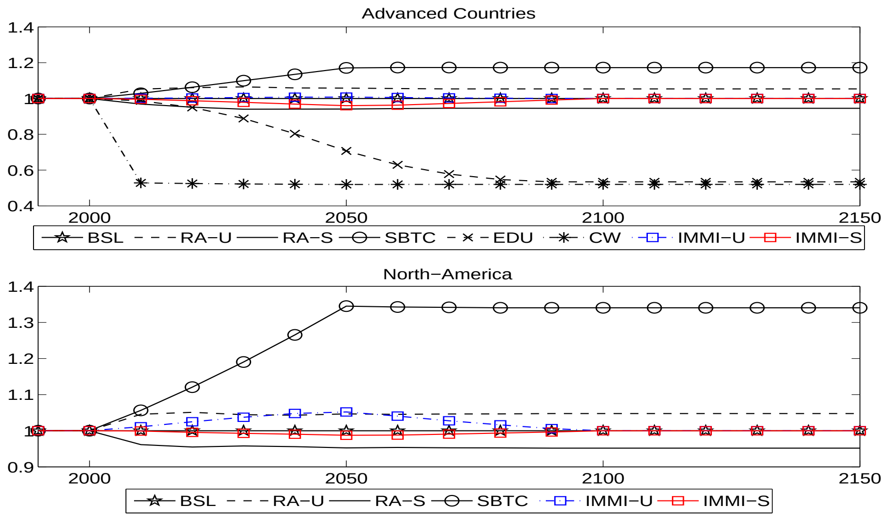
5.3 Results

The results delivered by scenarios 1 to 6 with the benchmark model (see section 4) are very robust under the variant of the model (see figures 8 and 9 in appendix). Additionally we see that a more competitive labour market in the Advanced Countries does neither have a big impact on the fiscal policy nor on the region's economic performance. A cut of 50% in the mark-up η from 2010 onwards decreases the tax-to-GDP ratio by 0.66% and raises per capita GDP by 1.7% compared to the baseline.

Figure 3 depicts how unemployment is affected under the different scenarios. In both regions, a delay in the retirement age has a similar impact on unemployment: postponing retirement age by two years of unskilled (skilled) individuals raises (cuts) unemployment by 5.5% in the Advanced Countries and by 4.9% in North-America, with respect to the baseline. A rise in skill-biased technical change creates higher unemployment in both regions, but especially in North America, with an increase of 34%, with respect to the baseline, while in the Advanced Countries unemployment augments by 17%.

Moreover, in the Advanced Countries, raising the proportion of skilled individuals from 30% to 40% has the same long term effects than cutting the wage mark-up by half. In both cases, unemployment is reduced by almost 50% compared to the baseline at the end of the 21^{st} century. A non-selective (selective) immigration policy will increase (decrease) unemployment by less than 1% (by less than 4%) in the Advanced Countries and by more than 5% (by little more than 1%) in North-America compared to the baseline.

Figure 3: Unemployment rate with respect to the baseline



BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase, Immi-U and Immi-S represent increased unskilled respectively skilled immigration. CW is the additional scenario under the variant model, in which the unskilled labour market is more competitive.

6 Conclusion

Finally, we conclude that the fiscal pressure on pension systems cannot be considerably relieved under none of the above mentioned realistic scenarios (in terms of the size of the changes in labour market characteristics). They should, at most, be considered as a solution together with other policies that act for example upon pension benefits and contributions to the social security system. Moreover, relying upon our findings, in both regions, postponing skilled retirement age would be the most adequate of the above mentioned measures. In the Advanced Countries, this proposal reduces the tax-to-GDP ratio by little less than an increase in unskilled retirement age and both have a similar impact on per capita GDP, but a higher retirement age for skilled workers does not raise unemployment. In North-America, the reduction in the tax-to-GDP ratio due to a higher retirement age for skilled individuals is half as much than the one by a rise in skill-biased technical change. However, a rise in skill-biased technical change has a less important impact on per capita GDP and increases considerably unemployment.

It can be argued that what explains the different effects of these changes in North-America and in Europe is the fact the European labour market is less competitive than the American one. Thus in a variant of the model we introduce wage rigidities in the labour market of unskilled workers, which creates unemployment. The results obtained in the benchmark model are quite robust under this new specification of the model and we cannot conclude that the difference in the effects of changes in labour market characteristics on pension systems between North-America and Europe are due to non-competitive European labour markets. In this alternative specification of the model we also show that, under an additional scenario, that a reduction the mark-up of the unskilled wage to its competitive level by half has only a negligible contribution in financing pension systems in the Advanced Countries.

If a choice would have to be made among the above mentioned measures, postponing skilled retirement age would be the most adequate in both regions. In the Advanced Countries, this proposal is less effective in reducing the tax-to-GDP ratio than an increase in unskilled retirement age and both have a similar impact on per capita GDP. A higher retirement age for unskilled workers would however raise unemployment. In North-America, a rise in skill-biased technical change reduces the tax-to-GDP ratio more than a higher retirement age for skilled individuals, but the former one has a less beneficial effect on per capita GDP and increases significantly unemployment.

Several extensions may undoubtedly enrich the model. It would be interesting to see what would be the effects of such scenarios on developing regions. Besides, endogenizing the educational choice (i.e. the time spent in education) of the individuals and the labour supply would improve the quality of the model. This last extension would allow us to have a framework where individuals choose when they want to retire. These issues are left for future research.

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A Appendix

A.1 Model

A.1.1 Regions

There are 10 regions in our model, of which the first three are composed of developed countries and the seven others of developing countries.

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

A.1.2 Government

In each region, investors face some investment risk and are compensated by a premium on the international rate of return to capital R^*. The riskier the region, the higher the premium. The risk premium of each region π is defined as

$$\pi = \frac{q}{q^o}\pi^o, \tag{20}$$

where q is the risk classification of a region as defined by the OECD (2006a), q^o is the highest attainable risk rating and π^o is the maximum risk premium. This means that in a region with a risk rating close to the maximum q^o an investor will receive a premium close to the highest possible risk premium π^o.

The risk premium π is modelled here as a government tax on investment. In a risky region, a part of an investor's return to capital is levied by the government, who uses it in general public spending. This share of returns to capital taken by the government is exactly equal to the risk premium. A high tax on capital reflects a high region risk.

We use data available from the OECD (2006a) for region specific risk q which rely upon the Knaepen Package methodology. The Knaepen Package is a system for assessing country credit risk and classifies countries into eight country risk categories (0 - 7), from no risk (0) to high risk (7). It basically measures the country credit risk, i.e. the likelihood that a country will service its external debt. To compute the risk classification per region, we take an arithmetic mean of ratings of the available countries. For the Advanced Countries, North-America and Japan the risk is nil, it corresponds to 3,4 for the Eastern Countries, to 3,95 for the Mediterranean World, 5,19 for Latin America, to 6,40 for Sub-Saharan Africa, to 6,17 for the Russian World, 3,18 for the Chinese World and to 4,89 for the Indian World.

A.1.3 Equilibrium conditions

Maximizing utility (3) under the households budget constraint (4) w.r.t. the levels of consumption determines the optimal (contingent) levels of consumption for both types of households:

$$c^j_{a+1,t+a+1} = \beta R_{t+a+1} c^j_{a,t+a}, \qquad j = s, u \tag{21}$$

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

$$w^j_t = (1-\alpha) K^\alpha_t A^{1-\alpha}_t L^{-\alpha}_t \frac{\partial L_t}{\partial L^j_t}, \tag{22}$$

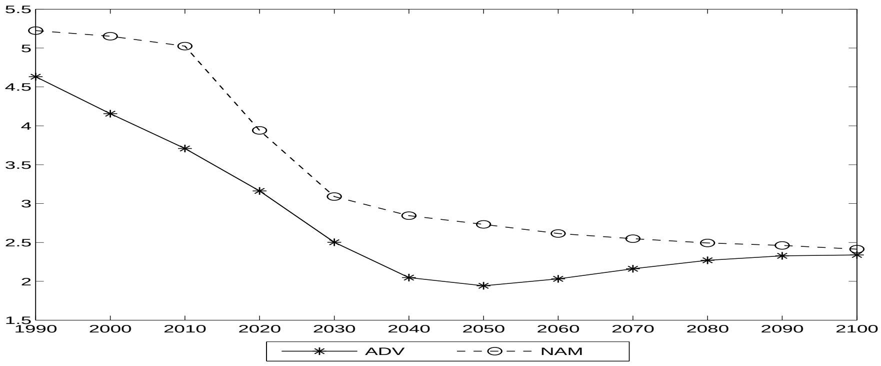
$$1 + \alpha K^{\alpha-1}_t (A_t L_t)^{1-\alpha} - \delta = R_t, \tag{23}$$

where δ represents the depreciation rate of capital.

A.2 Support ratio and immigration

Figure 4 depicts the support ratio (number of people of working age for one pensioner) in the Advanced Countries and in North-America over the 21^{st} century. The ageing process is stronger in the former region than in the latter one.

Figure 4: Support ratios in North-America and in the Advanced Countries



Throughout the paper, migration refers to migrants from the developing regions going or living in the North. In order to calibrate these migration stocks and flows for the baseline, we explicitly track migrants from the seven developing regions into the North-America and the Advanced Countries. North-to-North and South-to-South migrants are implicitly dealt with through the U.N. population data and forecasts. To introduce migration flows in the model, we make 3 assumptions. First, migrants are directly assimilated to natives, i.e. they acquire the same characteristics (e.g. productivity) as natives as soon as they enter the destination region. A second assumption is that there is no return migration. Finally, all the migrants arrive at the age of 15 (i.e. without any assets).[21]

Each of these two receiving regions experiences two different policies of increased immigration between 2010 and 2050. Instead of simulating two radical policies of increased immigration (e.g. an arrival of 100% of unskilled versus 100% of skilled immigrants), we prefer to compare the effects of two more "realistic" immigration policies: 70% of skilled / 30% of unskilled versus 30% of skilled / 70% of unskilled migrants. We argue that when a country chooses to adopt a selective immigration policy, it can never "attract" 100% of skilled migrants, because for example a migrant may arrive with his family members, who are probably not highly skilled.

In the following step we need to determine the "additional" number of migrants arriving to North-America and to the Advanced Countries between 2010 and 2050. According to the projections of the U.N. Population Division, 64’375 respectively 39’104 thousands of migrants will arrive to North-America respectively to the Advanced Countries between 2010 and 2050. From this number we subtract the number of 0 to 14 years old migrants. In the United States, 8% of the immigrants are aged between 0 to 14 years (U.S. Census Bureau). We apply this share also to the migrants of the Advanced Countries. Next, we only want to consider migrants from the seven developing to North-America and the Advanced Countries. Thus we subtract from the migrants aged 15 and more, all the migrants coming from the countries belonging to these two developed

[21] These assumptions are necessary in order not to increase the heterogeneity of agents in the model, which would further complicate the computation of the transitory path. In fact, in our model we have individuals with 2 different educational attainments of 8 different age classes and belonging to 10 different regions. If there was for example return migration in the model (no permanent immigration), migrants would go back to their region(s) of origin after some periods with different characteristics than the individuals that did not emigrate from their home region. Agent heterogeneity in the region(s) of origin would then increase. For the same reason we have to assume that migrants arrive at the age of 15 years. When migrants arrive later, they will come with different characteristics than natives and the heterogeneity of households in the destination country will also change.

regions and from Japan. Using the data available in the World Bank sponsored study of Docquier & Marfouk (2006), we obtain that 79.02% respectively 58.44% of the total immigrants in NAM respectively ADV come from the 7 developing regions in 2000. We assume that in the periods following 2000 the share of migrants coming from the seven developing regions will be more and more important in NAM and ADV. We assume that the share of migrants coming from the seven developing regions will increase progressively from 79.02% in 2000 to 85% in 2050 in North-America and from 58.44% to 70.13% in the Advanced Countries.[22] To determine from which developing region the additional migrants will arrive we assume that they will be split up according to the region of origin of the 2000 stock of migrants in North-America and in the Advanced Countries again by making use of the data available in the World Bank sponsored study of Docquier & Marfouk (2006). Table 3 indicates that the additional migrants to North-America and the Advanced Countries have quite different origins. While most of the additional migrants to North-America originate from Latin America and the Caribbean (54%) and from the Chinese World (22%), the Advanced Countries experience most of their additional immigration from the Middle East and North Africa (33%) and from the Eastern European Countries (22%).

Table 3: Additional Migrants to NAM and ADV by region of origin

Source region	EAS	MEN	LAC	JAP	SSA	RUS	CHI	IND
Host region								
NAM	6.19%	5.03%	53.58%	0%	2.81%	2.97%	21.76%	7.66%
ADV	21.61%	33.10%	8.86%	0%	11.19%	2.90%	9.68%	12.66%

Source: Docquier & Marfouk (2006) and own calculations

Table 4 shows the evolution in the proportion of international migrants under different scenarios. The share of immigrants is much higher in North-America than in the Advanced Countries. When migration inflows are increased by 25%, there are around 2.5% more migrants in North-America and almost 1.5% in the Advanced Countries in 2050.

Table 4: International migrants as a proportion of the population

Region and scenario	2010	2030	2050	2070	2090	2110	2130
ADV: Baseline	6.15%	7.36%	8.33%	9.07%	9.50%	9.66%	9.67%
ADV: +25% of migrants	6.43%	8.15%	9.67%	10.43%	10.44%	10.01%	9.67%
NAM: Baseline	12.39%	14.38%	15.68%	16.41%	16.48%	16.45%	16.45%
NAM: +25% of migrants	13.11%	16.07%	18.21%	18.70%	17.97%	16.99%	16.45%

Source: Docquier & Marfouk (2006) and own calculations

A.3 Baseline scenario

In the baseline scenario, the distance of the TFP of each region to the TFP of the leading economy is assumed to be constant after 2000, except for three developing regions of the model: the Eastern Countries, the Chinese World and the Indian World. In line with the recent accession of the majority of Eastern European countries to the European Union and with the last years' increased

[22] The value of 85% for North-America is fixed arbitrarily and 70.13% corresponds to an arbitrary 20% increase in the value of 2000.

growth pace of India and China, we assume that these three regions will experience a TFP catch-up with the leader over the 21^{st} century. The Eastern Countries will have increased their TFP compared to the leader's TFP by 25% in 2100. Moreover, we follow Ingenue (2005) in considering that both the Chinese and Indian regions will have doubled their TFP compared to the leader's TFP by 2100.

Furthermore, like the policies conducted in many developing countries, we consider that pension systems will be less generous in the near future because of population ageing. Because we anticipate such pensions reforms in the near future, we provide two changes in our initial assumptions concerning the pension systems over the first half of the 21^{st} century in our baseline scenario. First, between 2000 and 2040, the age of retirement is gradually increased by one year for both unskilled and skilled individuals. More formally, for the age group 55-64, λ^u (respectively λ^s) passes steadily from 0.5 to 0.6 (respectively from 0.7 to 0.8) over the period 2000-2040 in Japan, the Advanced Countries and North-America. Second, between 2000 and 2050, the replacement rate, χ_t, decreases in developed regions: from 41.5% to 36% in North-America, from 42.5% to 37% in the Advanced Countries and from 27.5% to 22% in Japan.

A.4 Evolution of the tax-to-GDP ratio

Figure 5: Tax-to-GDP ratio under the baseline scenario

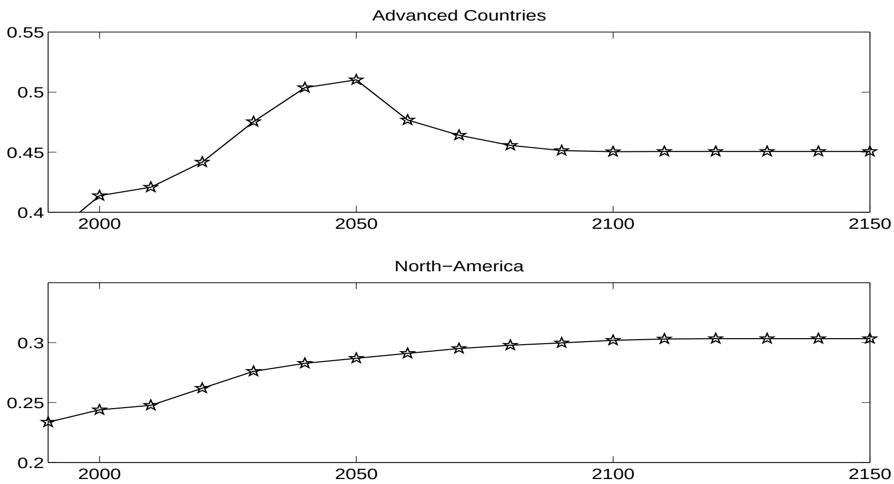
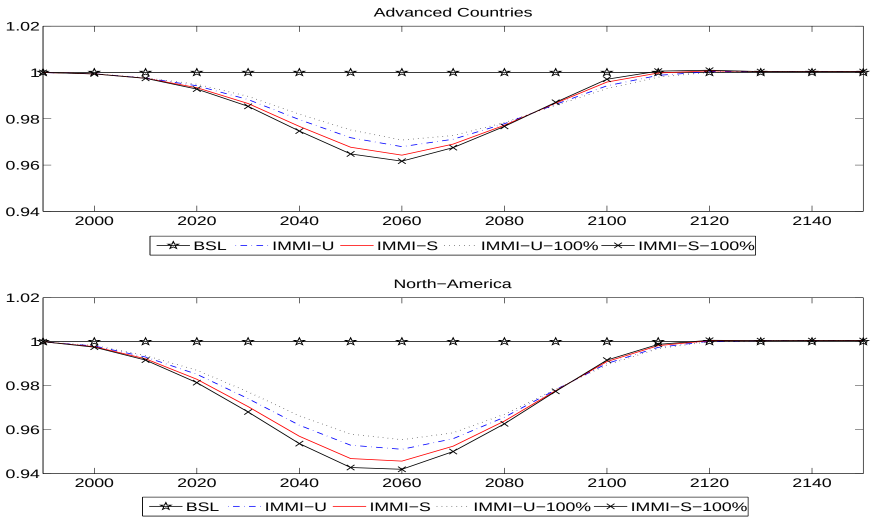


Figure 5 shows the evolution of the tax-to-GDP ratio in the Advanced Countries and in North-America. In both regions, the evolution of the tax-to-GDP ratio is strongly influenced by the specific ageing path of their populations (cf. appendix for the evolution of the support ratio of these two regions during the 21^{st} century). The Advanced Countries experience a rapid rise in the tax-to-GDP ratio between 2000 and 2050 (from 41.2% to 50.9%). After 2050, they decrease steadily to attain a stable value of 45% in the 22^nd century. Typically, the long-run "structural" increase from 41.2% to 50.9% is related to the trends in mortality and fertility rates. The short-run transitory overshooting bump is due to the timing of fertility and mortality changes (especially the succession of baby-boom and baby-bust periods). In North-America the ageing of the population is less striking, probably because of high immigration. The rise in the tax-to-GDP ratio is thus less strong, of around 4 percentage points (from 24.3% in 2000 to 28.7% in 2050) and continues to increase over the whole 21^{st} century. It stabilizes at the long-run value of 30.3%.

A.5 Tax-to-GDP ratio and immigration policies in the benchmark case

Figure 6 depicts the effects of different increased immigration policies on the tax-to-GDP ratio. It compares moderate selective (70%/30% of additional migrants are skilled/unskilled) and non-selective (30%/70%) immigration policies with extreme selective (100%/0% of additional immigrants are skilled/unskilled) and non-selective (0%/100%) immigration policies. In Europe, moderate selective ('IMMI-S') and moderate non-selective ('IMMI-U') immigration policies decrease the tax-to-GDP ratio by respectively 2.82% and 3.23%. The difference in the reduction of the tax-to-GDP ratio is more marked between a radical selective ('IMMI-S-100') and a non-selective ('IMMI-U-100') policy: a decline of 2.48% respectively 3.52%. In North-America, moderate selective ('IMMI-S') and non-selective ('IMMI-U') policies decrease taxes by 4.71% and 5.32%, radical ones by 4.20% and 5.72% in 2050.

Figure 6: Tax-to-GDP ratio under extreme immigration policies

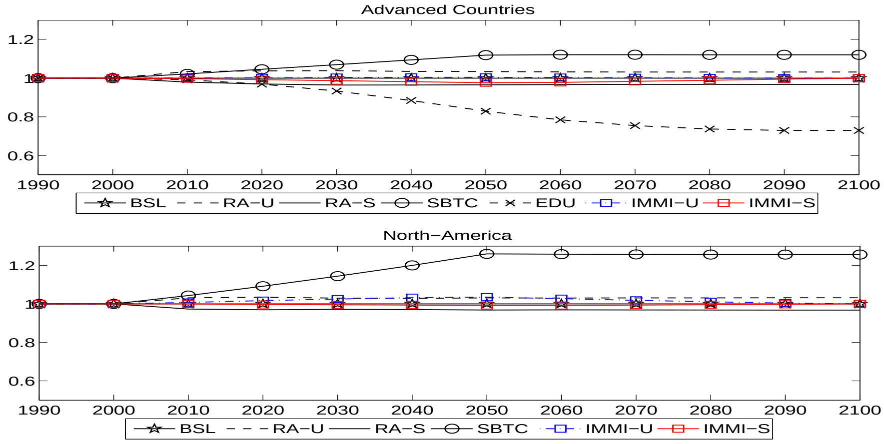


BSL is the baseline, IMMI-U, IMMI-S, IMMI-U-100 and IMMI-S-100 stand for the scenarios of increased immigration when respectively 30%, 70%, 0% and 100% of the additional migrants are skilled.

A.6 Skill premium in the benchmark model

The skill premium is defined as the skilled to unskilled wage ratio. An acceleration in skill-biased technical change increases the wage inequality among skill groups, while a rise in the supply of skills (Advanced Countries) reduces it (figure 7).

Figure 7: Skill premium with respect to the baseline

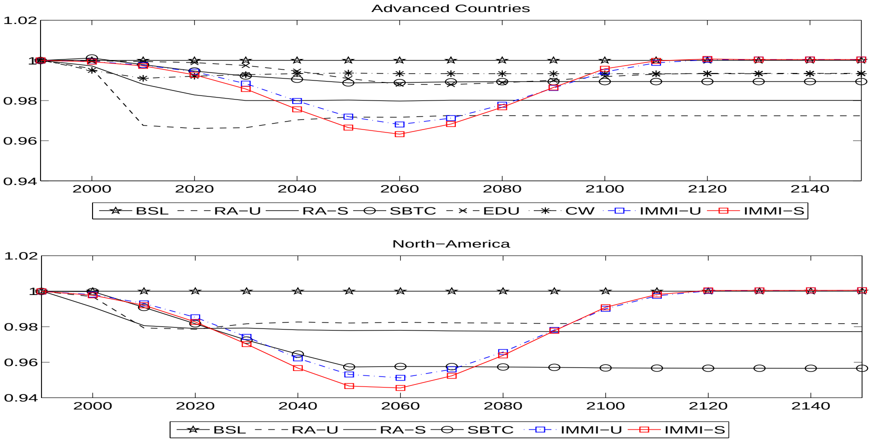


BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase.

A.7 Results under the variant model

In both regions and under both specifications of the model, the delay in retirement age (for skilled and unskilled) and higher skill-biased technical change have similar effects on the tax-to-GDP ratio and per capita GDP. However, with the "unemployment variant", the effect of a higher supply of skills on the tax-to-GDP ratio and on per capita GDP is more pronounced. It will decrease the tax-to-GDP ratio by slightly more than with the competitive model (0.8% against 0.1% compared to the baseline), but it raises per capita GDP by 8.9% instead of 7% with the benchmark model (see figures 8 and 9 in appendix). In addition, rendering the wage of unskilled workers more competitive doesn't affect very much taxes and per capita GDP. It will reduce the tax-to-GDP ratio by only 0.67% compared to the baseline and increase per capita GDP by only 1.7% in the long run.

Figure 8: Tax-to-GDP ratio w.r.t. the baseline with the variant model



BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase. CW is the additional scenario under the variant model, in which the unskilled wage is rendered more competitive.

Figure 9: Per capita GDP w.r.t. the baseline with the variant model

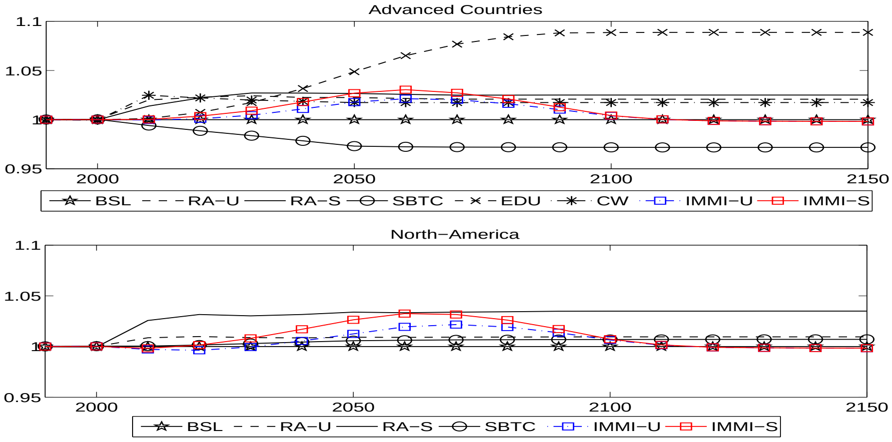


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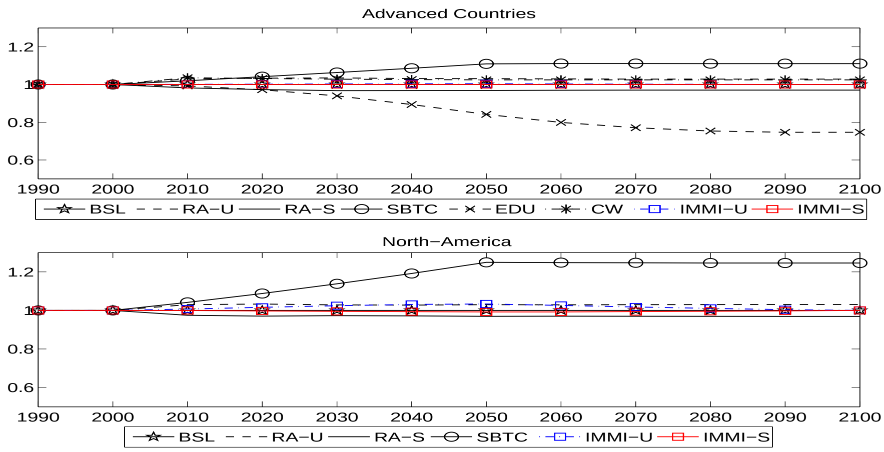
Figure 10: Skill premium w.r.t. the baseline with the variant model



BSL is the baseline, RA-S and RA-U stand for the scenarios of postponement in retirement age of skilled respectively unskilled individuals, SBTC and EDU are respectively the scenarios in which skill-biased technical change and education levels increase. CW is the additional scenario under the variant model, in which the unskilled wage is rendered more competitive.

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