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Macroeconomic Consequences of Global Endogenous Migration: A General Equilibrium Analysis

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Abstract

In this paper, we analyze the demographic and economic consequences of endogenous migrations flows over the coming decades in a multi-regions overlapping generations general equilibrium model (INGENUE 2) in which the world is divided in ten regions. Our analysis offers a global perspective on the consequences of international migration flows. The value-added of the INGENUE 2 model is that it enables us to analyze the effects of international migration on both the destination and the origin regions. A further innovation of our analysis is that international migration is treated as endogenous.

In a first step, we estimate the determinants of migration in an econometric model. We show, in particular, that the income differential is one of the key variables explaining migration flows. In a second step, we endogenize migration flows in the INGENUE 2 model. In order to do so, we use the econometrically estimated relationships between demographic and income developments in the INGENUE model, which enables us to project long-run migration flows and to improve on projections of purely demographic models.

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1 Introduction

In the XXIst century, the world economy is facing three major challenges. First, the demographic transition and the associated population ageing are putting the pay-as-you-go (PAYG) pension systems of OECD countries under pressure and are leading to various reforms. Second, the world economy is becoming increasingly interdependent. The deepening of the globalization process is reflected in increased levels of international trade, financial integration and international labour mobility. Third, the deepening globalization process may lead to changes in the world income distribution and, in particular, to an increase in North-South income inequalities. In the context of these 3 phenomena, we use an applied international general equilibrium model to study the long-term macroeconomic and demographic prospects of the world economy when international migration flows and economic developments are mutually interdependent. Along with international capital flows, international migration is a key feature in the process of income convergence between countries. At the same time, economic factors play an important role in migration choices since workers move mainly for higher incomes, better job opportunities and a better quality of life. Future trends in migration may have substantial demographic consequences. Firstly, as fertility is now below replacement in most OECD countries, policies to encourage immigration may become an important means for ageing countries to moderate the increase of the dependency ratio and the contribution rate. Secondly, workers in countries with a growing labor force have an incentive to move to ageing countries if the pace of GDP growth does not keep up with population growth. The difference in demographic change between their home countries and their potential host countries implies a decreasing return to labour in the former and an increasing return to labour and thus increasing income opportunities in the latter. Consequently, migration flows are driven by several political, demographic and economic factors, that need to be carefully evaluated to assess migration potential at the world level

In order to analyze these questions of ageing, migration and inter-regional inequalities, we use the Ingenue2 model[1]. The model describes a multi-region, world model in the spirit of those developed by Obstfeld & Rogoff (1996) in which the structure of each regional economy is similar to that of other applied overlapping generations (OLG) general equilibrium models (such as Auerbach & Kotlikoff (1987)) except that labour supply is exogenous. The world is divided into ten regions according to geographical and demographic criteria. The GDP growth rate of each region depends mainly on its demographic evolution and on the assumptions regarding catch up of total factor productivity.

With this general equilibrium model, we can have useful insights on the impact of the asynchronous ageing processes on international capital flows and interest rates. Current population structures and demographic projections for the various regions of the world show that the ageing process is not synchronous. This difference in time profiles of demographic changes suggests that one mechanism through which the pressure on pension systems could be eased is inter-temporal trade in the form of international capital flows. The 'triangular' relationship between population aging, pension reform, and international capital markets receives increasing attention in the academic literature, Brooks (2003), Börsch-Supan, Ludwig & Winter (2006), Aglietta et al. (2007) and Krueger & Ludwig (2007).

To the best of our knowledge, none of these world general equilibrium analyzes includes an explicit modeling of international migration. Storesletten (2000) and Chojnicki, Docquier & Ragot (2005) investigate whether a reform of immigration policies could attenuate the fiscal burden of ageing in the coming decades in a closed economy framework. Only two studies (Fehr, Jokisch & Kotlikoff (2003, 2004)) have treated international migration in multi-country open-economy CGE-OLG models. These studies develop a three country model (US, Europe and Japan) to study the macroeconomic

[1]The INGENUE 2 model was developed at CEPII, CEPREMAP and OFCE by Michel Aglietta (CEPII), Vladimir Borgy (CEPII), Jean Chateau (OECD), Michel Juillard (CEPREMAP), Jacques Le Cacheux (OFCE), Gilles Le Garrec (OFCE) and Vincent Touzé (OFCE).

effects of increased immigration on the three countries' pension systems. Even if they use an open economy framework, the impact of immigration on the sending countries and on inter-country inequalities are not treated. Compared to these studies, our paper offers a global perspective on the consequences of international migration. Indeed, the value-added of the INGENUE 2 model is that it is able to analyze the effects of international migration on both the destination and the origin regions.[2] The three major challenges facing the world economy, the sustainability of the public pension system, growth perspectives, income inequalities can thus be analyzed taking explicitly into account prospective international migration flows. Consequently, the following questions are addressed: what is the impact of migration on economic growth, capital accumulation, consumption, pension schemes and the current accounts of sending and receiving countries? Can immigration help mitigate the adverse effects of population ageing in OECD countries?

A further innovation of our world general equilibrium OLG model is that international migration is treated as endogenous. Indeed, some of the endogenous variables in this type of model are likely to affect the size of international migration flows (GDP per capita differential, demographic structure in the origin countries, poverty in the origin countries, stock of migrants in the destination countries). Nevertheless, existing world general equilibrium models assume exogenous migration scenarios (no migration, trend migration, increase of migration by a fixed proportion with respect to current levels). To endogenize international migration in Ingenue, we develop a two-step strategy. In a first step, we draw on the literature on the estimation of the determinants of international migration (Clark, Hatton & Williamson (2007), Mayda (2006), Zaiceva (2006)) to estimate the determinants of international migrations. Our econometric results are close to the ones of Clark et al. (2007) except that our estimations are done in a multi destination countries framework. In a second step, we introduce the estimated elasticities into INGENUE 2 and model the interdependence between these determinants (as GDP, GDP per capita, distance, common language, demographic structure, inequality and poverty indicators) and international flows explicitly.

With this interaction between the demographic part and the economic part of the world OLG model INGENUE 2, we are able to project dynamic endogenous migration flows. Compared to the United-Nations (2006) projections, our methodology induces important changes in the volume and the distribu-

[2] Docquier & Marchiori (2007) also develop such a unified framework to evaluate the impact of immigration policies on receiving and sending countries. However, their model is based on a more stylized framework and does not treat international migration as endogenous.

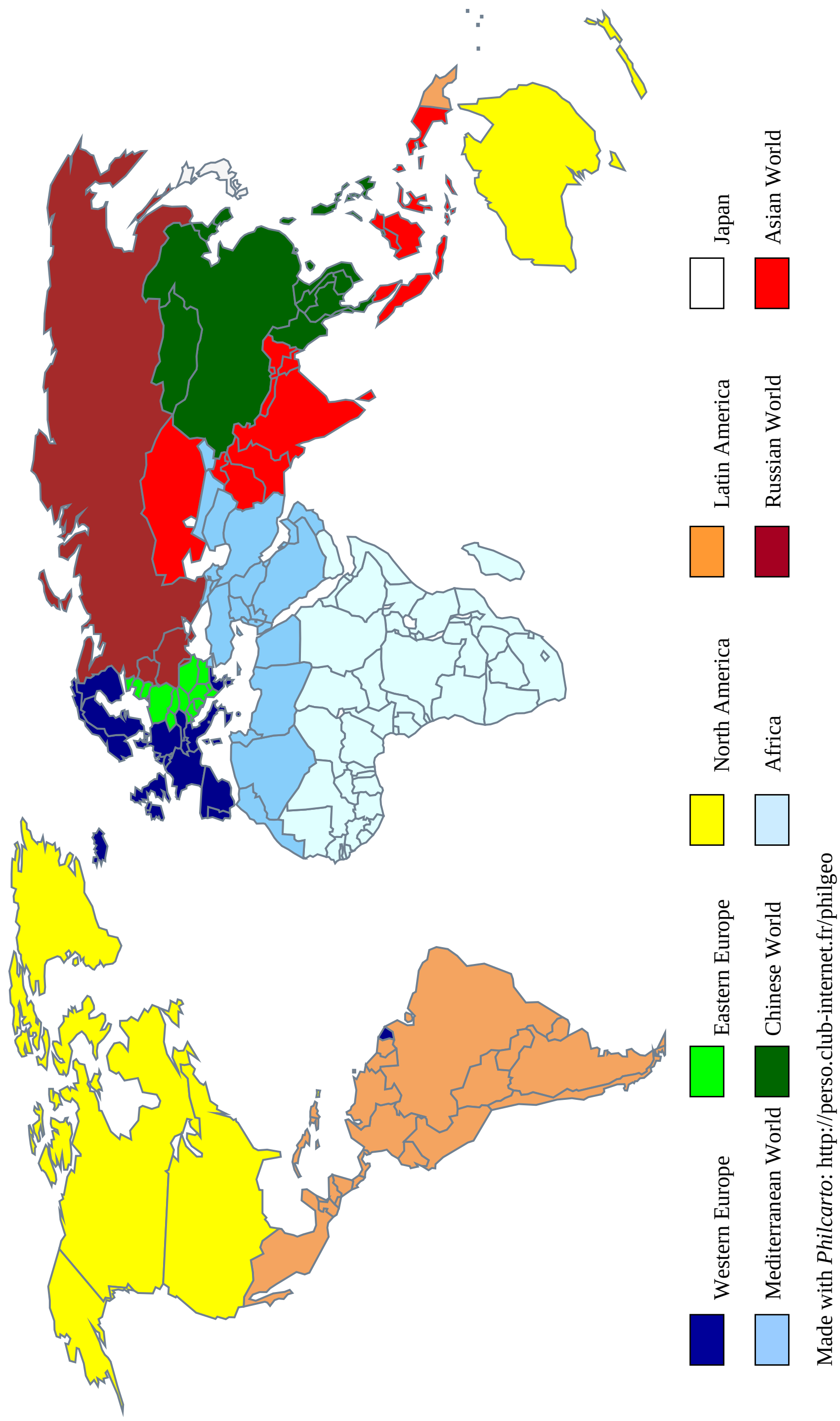
tion of the migration flows between regions. For example, net migration flows from Africa are almost four times higher compared to the United-Nations (2006) projections in 2050. Nevertheless, one must note that this realistic migration scenario, even if it induces a sharp increase in migration flows, does not totally offset the effect of ageing in the regions receiving the migrants: in this regard, pension reforms appear to be necessary in order to deal with the ageing problem that these regions will face in a near future. Concerning the regions losing migrants, the adverse consequences of emigration are more important the more the region is advanced in the ageing process (and is already suffering from a declining population). For example, the negative impact of emigration on contribution rates is two times higher in Eastern Europe than in the Mediterranean world even though the emigration rate is two times lower in Eastern Europe.

The rest of the paper is organized as follows. Section 2 describes our demographic model. The macroeconomic model is presented in Section 3. The calibration and the baseline results without migration are given in Section 4. Economic study of international migrations follows in Section 5. Section 6 endogenizes migration flows in the context of our world model. Finally, Section 7 concludes.

2 Demographics

The World is divided in 10 regions according mainly to geographical and demographic criteria. These regions are labeled: Western Europe, Eastern Europe, North America, Latin America, Japan, Mediterranean World, Chinese World, Africa, Russian World and Indian World. The content of each region is detailed in Appendix 1.

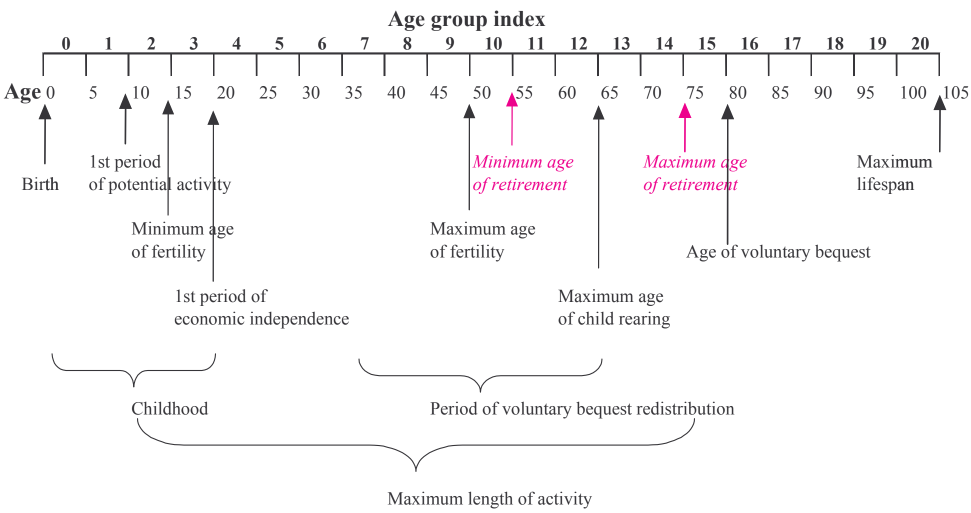
Figure 1: The ten regions of the Ingenue2 model



2.1 Population structure and projection method

The period of the model is set to five years. In each region z, the economy is populated by 21 overlapping generations who live up to a maximum age of 105. For notational purposes, age is denoted by $a \in [0, \ldots, 20]$. The number of people of age a at time t is denoted by $L_a^z(t)$. 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 $L^z(t) = \sum_{a=0}^{20} L_a^z(t)$. Between ages 15 and 50, women give birth to fraction of children at the beginning of each period (Figure 2). Our agents can die at any age and the probability of death is one at age 105.

Figure 2: The individual life cycle



Population evolution is calculated according to a standard population projection method on the basis of historical and prospective UN data. For that purpose, a simple demographic model has been developed, allowing us to generate projections that are consistent with United-Nations data. First, we aggregate the population structure across the countries of each region with the UN data from 1950 to 1995. Then we project fertility, net migration flows and mortality trends (for both sexes) at the 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. 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.

At each time, the number of births is equal to:

$$L_0^z(t) = \sum_{a=3}^{9} f_a^z(t) L_f a^z(t) \tag{1}$$

where $L_f a^z(t)$ is the female population of age a at time t and f_a^z is the average age-specific fertility rate. At each time, we calibrate f_a^z for the 10 geographical regions so that the number of births matches the UN figures until 2050.

Some people die before 105 years old ; if s_a denotes the conditional probability of surviving between age a and age $a+1$, the number of age $a-1$ individuals then follows :

$$L_a^z(t) = s_{a-1}^z(t-1) \cdot L_{a-1}^z(t-1) + \sum_{z*} M_a^{z*}(t) \quad \text{for all } a > 0 \tag{2}$$

with $M_a^{z*}(t)$ the number of net migrants that enter or leave the country to/from country $Z*$. We thus have $M_a^{z*}(t) > 0$ in case of immigration and $M_a^{z*}(t) < 0$ in case of emigration.

For population projections, we then need some process to describe the evolution of $\{s_{a-1}^z(t-1)\}_{a>0}$ for $t = 2000, \ldots, T$ (for both sexes). For this, we first have to set initial and final 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)). 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.

In the baseline scenario, we implicitly assume that there is no migration flows in the future ($M_a^{z*}(t) = 0$) so that the population evolution is only given by mortality and fertility assumptions. Our baseline population projection thus corresponds to the UN variant with no migration flows. Then, we build a comprehensive migratory scenario to analyze the demographic and economic consequences of international migration. Unlike fertility and mortality, which are in transition worldwide from high to low levels in a long historical process, there is much more uncertainty concerning net migration (see National-Research-Council (2000), Alho & Borgy (2008)). Therefore, migration projections have no strong and consistent trend that can serve as the backbone of credible projection assumptions for the future. For this reason, it is important to assess migration potential of these regions by analyzing the main driving forces of the past and recent trends. Assumptions related to migratory flows are then developed in details in Section 5 and 6. After 2050, the demographic model is calibrated in order for the population to converge towards a stationary level.

2.2 Main demographic features of the baseline scenario

Our baseline scenario reproduces UN projections with no migration through 2050. According to our demographic forecasts, the world population reaches 9.3 billions in 2050[3]. Population of the Asian world grows at a sustained pace and reaches 31% of the world population against 28.3% in 2000 (see Figure 3(a)). The population of the Chinese world increases at a very low pace between 2030 and its culmination in 2050. As a consequence, the share of the population of this region decreases during the first part of the 21st century (from 27% to 22%). The population of the African region grows at the highest pace in our projections given the high fertility rates that characterize the countries included in this region. The Mediterranean region is also characterized by a dynamic demography with a doubling population on the first half of the century. On the contrary, Western Europe population is relatively stable until 2020 and then clearly diminishes. This figure is even more pronounced for Eastern Europe and the Russian world with a total population that begins to decline immediately (respectively -15% and -30% between 2000 and 2050).

A sharp contrast arises in the rate of growth of the labor force (Figure 3(b)). Without migration, it declines throughout the half century in Russian world (very fast), Eastern Europe, Western Europe and Japan. It declines more moderately in North America (after 2010) and the Chinese world (after 2020). It decelerates but grows until 2050 in Latin America, Asia and the Mediterranean countries. The most atypical region is Africa where the labor force hardly decelerates at all. From an economic point of view, as a consequence of the dynamism of their working-age population, these regions will need a lot of capital to equip their numerous workers. As the leading OECD countries concentrate the largest part of world capital, the growth regime of the world economy will depend on international capital rather than labor mobility.

An intergenerational transfer of resources via capital export from the rich ageing countries to the labor force growing countries makes regions strongly interdependent. One can see on Figure 3(c) that the proportion of high

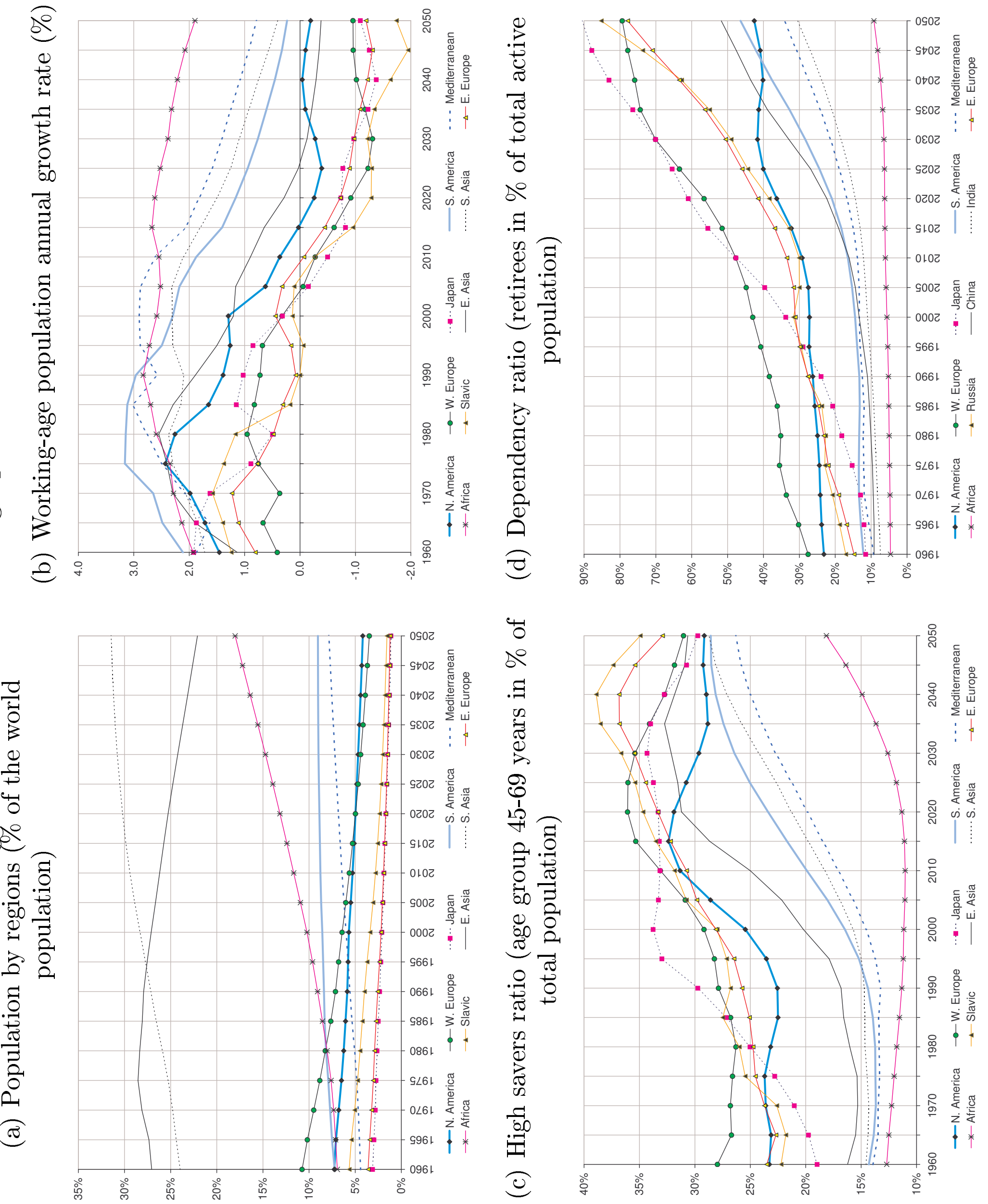
[3]The historical data (between 1950 and 2000) come from the UN database.

savers in total population[4] 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, Russian and Chinese world after this date. All are regions with declining labor force and thus hamper growth in the future. On the contrary, the regions found on Figure 3(b) 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.

Finally, this ageing phenomenon is summarized on figure 3(d) that presents the evolution of the old age dependency ratio (retirees in percentage of total working age population). While the fact of population ageing is common to all regions (except Africa), extent and timing differ substantially. For example, this ratio doubles in the case of Western Europe on the first half of the XXIst century and is expected to be almost 80% in 2050 when it is expected to be only around 35% in the same time in the Mediterranean world. It should be noted that Eastern Europe and the Russian World are more severely affected by ageing. The resulting asynchronous demographic ageing raises numerous issues for pension schemes concerning notably replacement migration. Indeed, developed countries have an incentive to increase legal immigration since this would alleviate the financial burden on the public retirement system by limiting the increase of the dependency ratio and the contribution rate.

[4]In this OLG model with life cycle behavior, the high saver populations are the cohorts aged between 45 and 69 years.

Figure 3: Benchmark demographic results



source: authors' calculation

3 INGENUE 2: A long term model for the world economy

Our economic simulations are performed with the computable, general equilibrium, multi-regional overlapping-generations model INGENUE 2[5]. Each of the ten regions is made of three categories of economic agents: households, firms and a Pay As You Go (PAYG) retirement pension system. Furthermore, we assume the existence of a fictive producer of a world intermediate good[6].

3.1 Household behavior

The individual life-cycle of a representative agent is described in Figure 2. Between ages 0 and 20, agents are children and are supported by their parents. Given the specificities of developing countries, we assume that children can begin to work at age 10 but their income is included in their parents' income. At age 21, agents become independent and start working. When becoming independent, individuals make economic decisions according to the life cycle hypothesis. A voluntary bequest is left to children at age 80 conditional on survival until 80.

In the budget constraint (see Equation 5 in Appendix 2), the expenditures consist of consumption (including costs of children) and saving in each age and each period. On the income side there is, first, the return on accumulated saving corrected by one-period survival probabilities. Second, there is non-financial income that depends on age: labor income (after social security taxes) adjusted by a region-specific age profile of labor force participation for people in full labor activity; a mix of labor income and pension benefits for people partially retired (reduced labor activity); full pension benefits for people entirely retired. The lifetime utility (Equation 4) is maximized under the intertemporal budget constraint, taking prices, social contributions and benefits as given (Modigliani (1986)). Like Fehr, Jokisch & Kotlikoff (2004), we do not distinguish between natives and immigrants in the model once the immigrants have joined the destination country.

[5]For technical features of the new INGENUE 2 model, as well as the baseline scenario and a sensitivity analysis of the main structural parameters, see Ingenue (2007).

[6]This presentation of the multi-region model is completed by a technical appendix. The equations mentioned in this section are presented in detail in Appendix 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 exogenous parameters are the retirement age and the replacement ratio. They are region-specific and the contribution rate is determined so as to balance the budget, period by period (Equation 7).

3.3 The production side and the world capital market

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 using labor and capital (Equation 8). In the spirit of Backus, Kehoe & Kydland (1995), we assume that the domestic composite final good of each region is produced according to a combination of the domestic intermediate good and an homogenous world good imported by the region from a world market (Equation 11). In order to simplify the exchanges of intermediate goods between regions of the world, this homogenous world good is "produced" by a fictive world producer as the output of a combination of all intermediate goods exported by the regions (Equation 12).

In each type of sector, firms act on competitive markets. They maximize their profit under their production constraint, taking prices as given. In the domestic intermediate good sector, the constraint is intertemporal since the production function depends on the stock of capital which is depreciated and accumulated. Intermediate goods producers thus maximize net present value of future cash flows, i.e. production values minus wage cost and capital cost. The latter depends on the depreciation rate which is itself affected by international capital market imperfection.

More precisely, the depreciation rate is asymmetrically dependent on the ownership ratio, defined as the ratio of the total wealth of households to the capital stock (see Equation 14). Indeed, firms located in countries that are indebted to the rest of the world borrow at a higher interest rate than the world interest rate and this "indebtedness premium" is proportional to its financial market exposure (measured by the ownership ratio). At equilibrium, the marginal return of capital thus depends on the net external position. In net debtor regions (ownership ratio less than one), the imperfection of international financial markets raises the cost of capital. It shows up in a higher rate of depreciation of the capital stock which in turns reduces the incentive to produce the intermediate good. In net creditor regions (ownership ratio above one), the rate of depreciation is a constant, thus independent from the financial position.

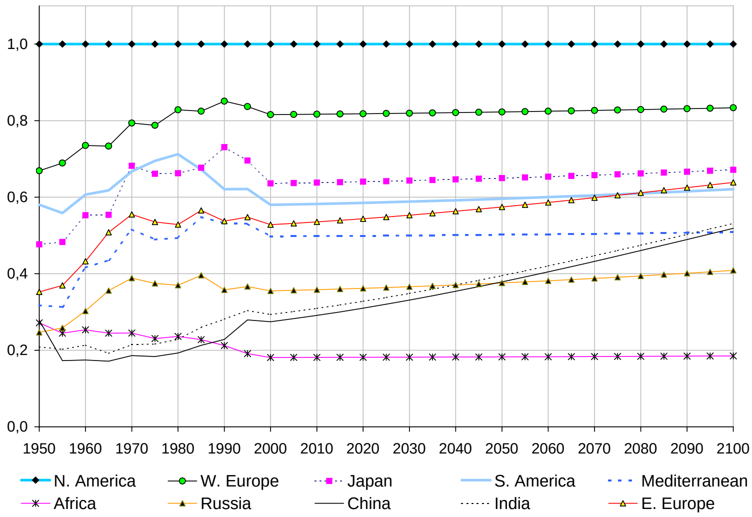
3.4 Technological catch-up

The basic trends that shape the future growth regime are demographic transition (assumptions on fertility, mortality and net migrations) and the diffusion of technological progress. These factors have always been prevalent in the rise of capitalism worldwide and they explain the current and future trends in term of convergence (or divergence) in real income per capita between countries.

All production functions are augmented by Total Factor Productivity (TFP) at constant prices which is a synthetic measure of technological progress for the whole economy. Estimating TFP is a difficult task for the ten world regions of the INGENUE 2 model. We define TFP as a Hicksian neutral technological progress in a Solow growth model. It means that there exits a production frontier that shifts over time. The level of 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 (Heston, Summers & Aten (2002)). After this date, the TFP growth rate is the result of a given, exogenous growth of 1.1% per annum in the North American region, supposed to be the technological leader, and a region-specific exogenous, catch-up factor, reflecting international diffusion of technological progress.

Figure 4 shows the profile of TFP in the ten regions of the INGENUE 2 model. Western Europe and Japan are assumed to resume their catch-up, meaning that they absorb the IT revolution after North America. Three regions have a sustained catch-up process: the takeoff in the Chinese world and the Indian world, which started in the 1990's is assumed to gain 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 catch-up in the level of TFP. Yet the rise in TFP at the same rate of the leading region, even if it entails no catch-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.

Figure 4: Total Factor Productivity: 1950-2100 (% of North American level)



sources: Heston et al. (2002), authors' calculation

4 Baseline path in the case without migration

4.1 Solving the model

The baseline scenario is the outcome of a long and weary process of calibration. To put the model on an acceptable track on the projection phase starting in 2000, the model computation shall begin at an initial date as far as in the past as the data permit it. The initialization begins in 1950 where initial stock of capital, household assets and an age distribution of savings are estimated. Exogenous variables and parameters are the demographic profiles in each region that are outputs of the demographic upstream model; the coefficients of the TFP determination in intermediary and final sector of each region; and the social security policy parameters in each region.

The competitive world equilibrium stems from five set of equations: intertemporal utility maximization of households; intertemporal profit maximization of firms in intermediate goods sectors; period profit maximization of firms in final goods sectors; period profit maximization of the world producer; and market clearing conditions. The markets for intermediate goods, final goods, labor in each region, and the market for the world intermediate good, are cleared in each period. These equations determine all relative equilibrium prices expressed in a common numeraire, which is the price of the intermediate good in North America. This convention allows us to express values in constant dollars. Finally, Walras' law implies that the world financial market equilibrium is the redundant equation.

4.2 The world economy's baseline transition path

We now turn to our simulated baseline policy transition paths for the 10 regions. Here, we only try to give the main intuitions necessary to understand how the model works (see Ingenue (2007, 2007b) for a complete description of the baseline). Results of the migration scenario will be presented with more details.

Regional growth

Growth in the world economy is shaped by secular trends in its most structural long-run determinants, i.e. the change in the demographic structure in the different parts of the world and the diffusion of technological progress. As previously detailed, 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 XXIst century. Therefore the pattern of the GDP regional growth rates largely follows that of the regional labor force growth rates.

Two characteristics stand out (see Figure 5(a)). Firstly, there is a general slowdown in growth because the working age population growth rate diminishes in all regions except 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 labor force of less-developed countries. Nevertheless convergence in total factor productivity has an impact since the dispersion in the growth rates of the labor force is substantially higher in 2050 than in 2000, while the dispersion in the GDP growth rates is slightly lower.

Investment and saving

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 labor force and high foreign indebtedness, raising markedly the rate of economic depreciation, the rate of gross investment to GDP increases until 2030.

Net saving in each region is the aggregate of individual savings in the life cycle. It depends on the demographic structure (high savers ratio and dependency ratio), on the expectation of future income and on the parameters of PAYG pension systems. Demographic determinants are prevalent. Regions with the fastest-increasing dependency ratios are the ones with the fastest-decreasing net saving rates, namely Japan, Western Europe, Eastern Europe and the Russian world (Figure 5(b)). Meanwhile, this gloomy demographic factor is compounded with a slow expected progression in income. In the Chinese World, the Indian World, South America and the Mediterranean world, the high saver ratio and the dependency ratio rise in tandem. In the early decades, while the population is still young, those regions grow faster than more demographically mature ones. It follows that young people expecting higher future income indulge in debt, reducing the overall saving rate.

Interest rates and capital flows

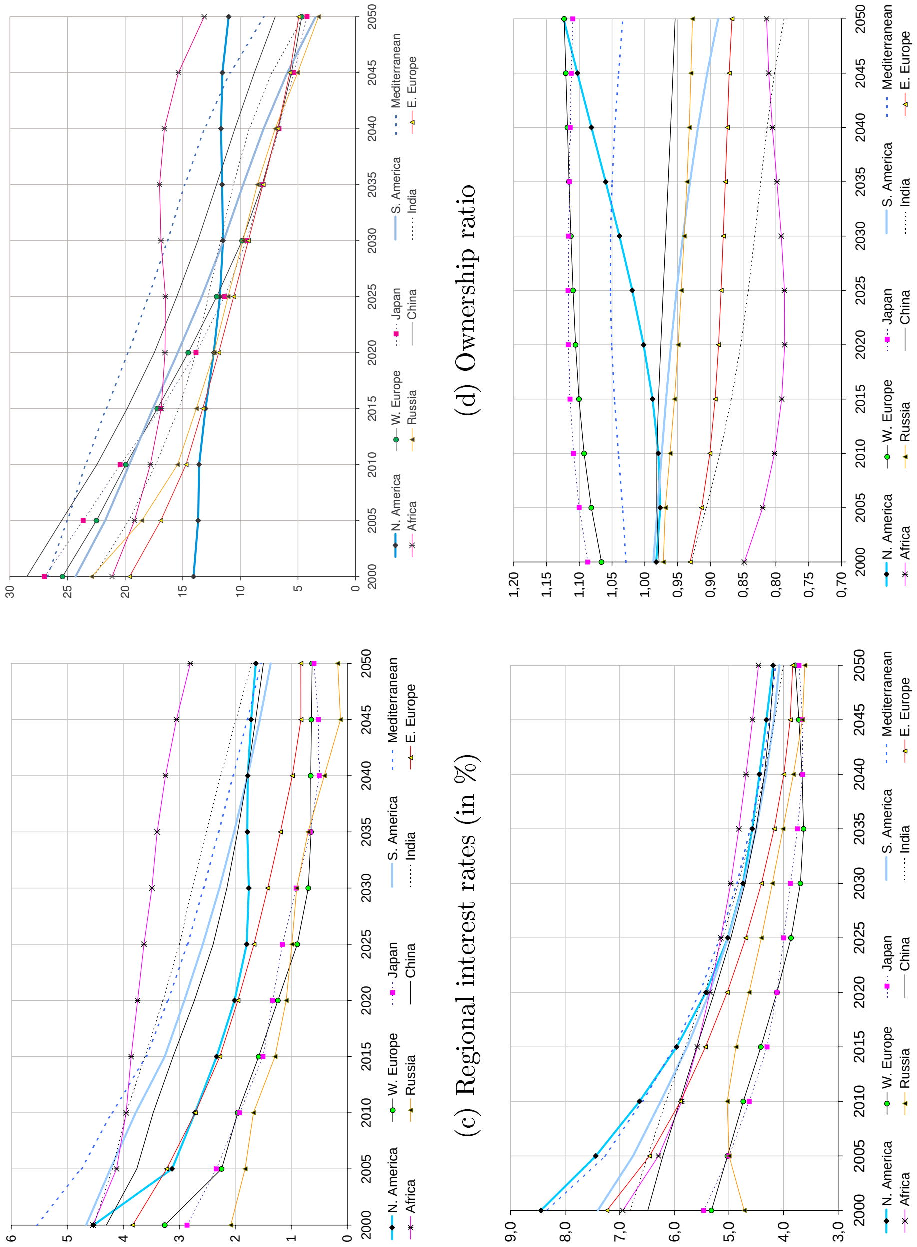
According to the model, the world real interest rate declines over the fifty years period. This is due to global ageing. Figures 3(b) and 3(c) show that the working age population decelerates while the age group of high savers is growing in one region after another. As a result, the world saving-investment 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(c)). The hierarchy of regional real interest rates is linked to the rate of change of the real exchange rates which regulate investment and saving flows. 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.

The world financial equilibrium allocates capital flows so as to finance current account imbalances. The magnitude of financial positions is measured by ownership ratios which are determined by cumulative current account balances. The most striking feature is the divergent profile of North America (see figure 5(d)). With a population consistently younger than in Japan and Europe, the rise in saving in North America is translated into a double improvement in the current account balance and the ownership ratio.

Figure 5: Benchmark macroeconomic results

(a) GDP growth rate (in %)

(b) Evolution of net saving (in % of GDP)



(c) Regional interest rates (in %)

(d) Ownership ratio

source: authors' calculation

5 Consequences of international migration flows

We now turn to analyzing demographic and economic consequences of international migration flows. We begin with a description of a traditional exogenous migration scenario that we compare with our baseline so as to understand the mechanisms related to the introduction of migration in such a world model.

For that purpose, an immigration shock is introduced into the model as an increase in the number of young adults (aged between 21 and 24, i.e. $M_a^{z*}(t) = 0$ if $a \neq 4$). After crossing the border, immigrants automatically become natives in an economic sense, i.e. they have the same preferences and fertility behavior as natives and adjust to the productivity of the host region. Furthermore, as in Storesletten (2000), we assume that immigrants move into receiving countries without any capital (Note that natives have no wealth at the same age).[7] However, this choice seems to play a minor part for the results since most immigrants actually move before the age of 30, i.e. at the beginning of the wealth accumulation process.

5.1 Calibration of migration flows compatible with UN projections

International migrants are unevenly distributed across world regions. By 2005, 47% of the stock of international migrants were resident in industrial countries and 53% in developing countries. The United-States, Canada and Australia (these 3 countries are regrouped the North America region in the INGENUE 2 framework) are the major traditional countries of permanent immigration. Over one quarter of immigrants live in one of these 3 countries. Western Europe has experienced net flows of immigration for four decades and represents the second major immigration area with 21% of the total immigrant stock. Eastern Europe and the former Soviet Union had around 15% of total immigrant stock in 2005. Migration in these regions follow a broad biaxial pattern: one axis has developed migration among the countries of Western, Central and Eastern Europe and the other one has arisen among the CIS countries (World-Bank (2006)). For example, Russia receives 75% of its immigrants from other CIS countries and over 70% of migrants from Western ECA (Europe and Central Asia regions) go to Western Europe. Finally, other regions are broadly characterized by a predominant labor migration

[7] These assumptions are necessary to avoid problems of agent heterogeneity that would complicate the computation of the transitory path.

through developed countries.

Following these facts and given data availability, our model essentially relies on migration flows toward the traditional countries of immigration. Thus, we distinguish 3 types of regions in the model:[8]

- pure immigration zones only face inward flows: Western Europe and North America;
- pure emigration zones only face outward flows: Latin America, Mediterranean World, Chinese World, Africa and Indian World;
- intermediate zones face simultaneously in- and outflows: Eastern Europe and Russian World.

We then adopt a calibration process that allows us to make actual net migration flows compatible with our multi-regions description of the world using different data sources. First, we aggregate net migration flows by countries used in the medium variant of 2006 UN population projections (United-Nations (2006)) to correspond to the INGENUE2 regional grouping. Then, we calibrate immigration flows to Western Europe, North America, Eastern Europe and the Russian World on UN figures removing intra-regional flows (for example German migration to France) as well as non pertinent flows for our analysis (for instance Western Europe migrations to North America). Given the world aspect of our model, immigration in host regions has to correspond to emigration in sending regions. Thus, we have to allocate immigration flows by origin regions. For that purpose, we use at first the emigration stocks and rates of 195 origin countries built by Docquier & Marfouk (2005) to allocate the immigration flows to Western Europe and North America.

However, Docquier & Marfouk (2005)'s database focuses on OECD countries as receiving countries and there is no information on migration flows to Eastern Europe and the Russian world. Thus, for the two intermediate regions, we complete with the World Bank report on Eastern Europe and the former Soviet Union (World-Bank (2006)) as well as with the data of Salt (2005). Table 1 gives the calibrated net migration flows by regions in 2005. Note that these calibrated flows appear lower than the UN official net flows given that we exclude intra-regional flows as well as many flows between developing countries. These flows thus represent almost 43% of the total net

[8] Given the weakness of official figures, we assume that Japan is isolated to international mobility of workers: there is thus neither immigration nor emigration to Japan.

flows following from the United-Nations (2006) study and correspond to the greater part of migration through OECD countries.

Table 1: Yearly net migration flows by origin and destination countries in 2005 (in thousand)

Origin Countries	Destination Countries: Western Europe	North America	Eastern Europe	Russian World	Total Emigration
Mediterranean World	256.8	86.1	0.9	53.2	397.0
Indian World	*58.5*	*107.0*	*0.3*	*54.6*	220.5
Chinese World	*41.7*	*316.7*	*1.2*	*0.0*	359.6
Eastern Europe	53.0	21.6	-	0.0	74.5
Russian World	36.7	46.5	21.9	-	105.0
Latin America	51.8	649.3	0.1	0.0	701.3
Africa	125.3	69.8	0.1	0.0	195.3
Total Immigration	623.8	1297.1	24.6	107.8	2053.3

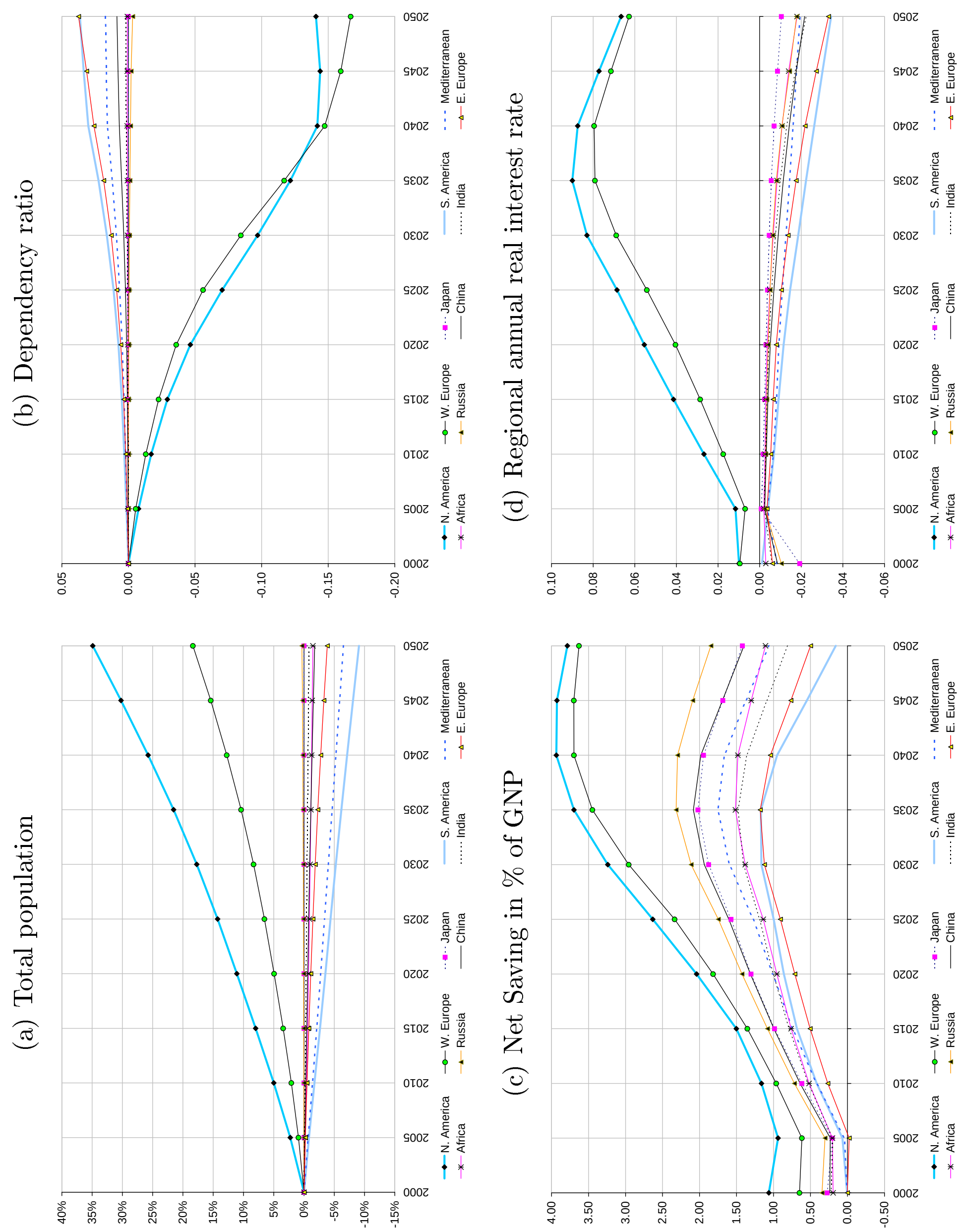
Sources : Docquier and Marfouk (2005), Salt (2005), United-Nations (2006), World Bank (2006); Authors' calculations

We have to reproduce this methodology for each five-year period in the future. Thus, we simply calibrate our migration flows to match the UN projections with migrations until 2050. Given the long run feature of INGENUE 2, we need to make some assumptions on migration flows far in the future. Between 2050 and 2100, we keep emigration rates constant at their 2050 values so that migration flows only evolve with the number of young workers in emigration area. After 2100, migration flows progressively reduce and are nil in 2150 in order for the population to converge towards a stationary level. This scenario is thus close to the United-Nations migration projection assuming that migration streams observed in lasting decades are durable and relatively predictable. Table 3 gives the dynamics of net migration flows until 2050.

5.2 Results of the conventional migration scenario

The results of our comprehensive migration scenario are compared to the benchmark with no migration. The effects of the shock on the main demographic and macroeconomic variables are presented in Figure 6 (expressed as deviations from the benchmark).

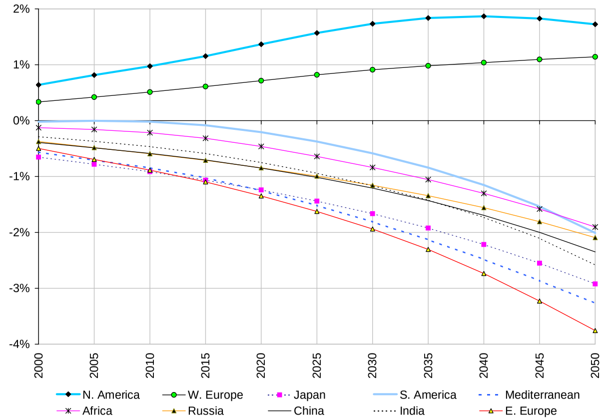
Figure 6: Results of the UN migration scenario (difference from baseline scenario): 2000-2050



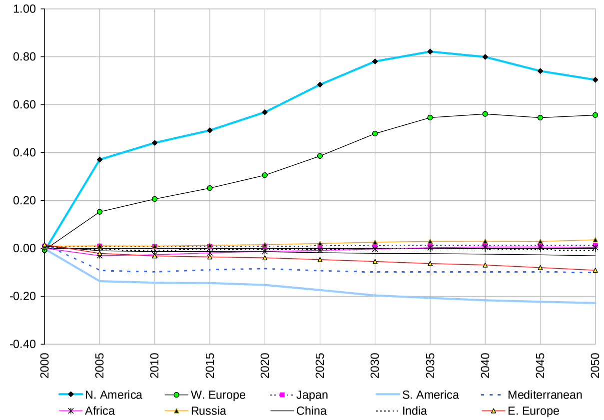
source: authors' calculation

Figure 6: Results of the UN migration scenario (difference from baseline scenario): 2000-2050

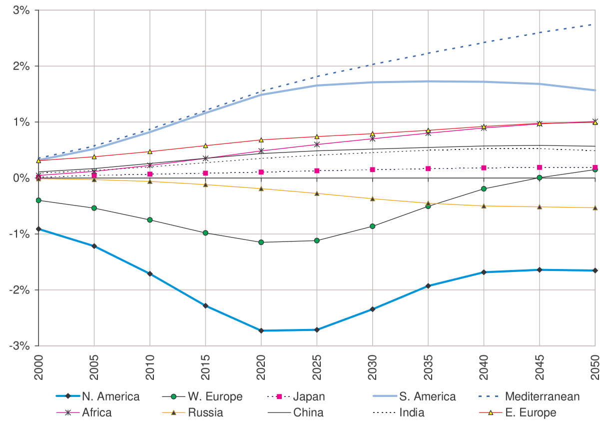
(e) Ownership Ratio



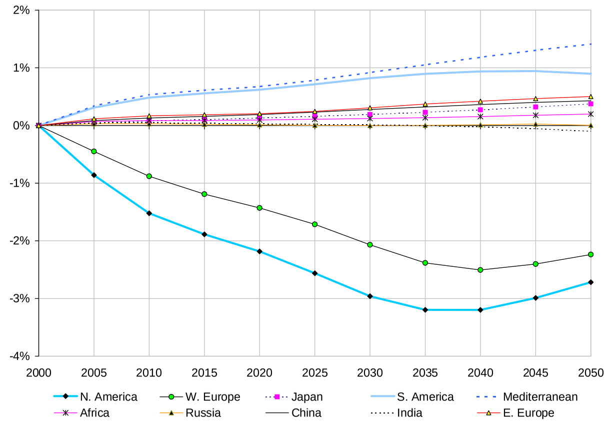
(f) GDP Growth rate



(g) Private consumption per capita (level)



(h) GDP per worker (level)



source: authors' calculation

The introduction of international migration in our demographic model strongly modifies the international distribution and the age structure of the world population for the concerned regions. North America and Western Europe are the only zone that faces up to large immigration flows (the Russian world also exhibits the features of an immigration zone on the whole period but to a lower extent) when other regions (except Japan) are net emigrations zones (Figure 6(a)). Thus, North America, Western Europe and the Russian world have a total population respectively 34.9%, 18.4% and 0.4% higher than in the baseline case in 2050. At the same time, the population of Latin America, Mediterranean world and Eastern Europe is respectively 9.1%, 6.5% and 3.9% lower. Other emigration regions are less affected by migration flows.

International migration flows also modify the age structure of the world population since migrants are assumed to be young workers (aged 20-24). In 2050, the dependency ratio is almost 17 points lower than in the baseline case in Western Europe (Figure 6(b)), 14.1 points in North America and 4.5 point lower in the Russian world. At this horizon, it increases by about 3.8 points in Eastern Europe and 1.7 points in Mediterranean World[9]. It follows that the financing of the PAYG pension system is substantially improved (resp. deteriorated) in North America, Western Europe and in the Russian world (resp. in sending regions) in line with the dependency ratio evolution. For example, the contribution rate reaches 28% in Western Europe in 2050 (compared to 31.9% in the baseline case) and 14.3% in North America (compared to 17.9% in the baseline case) because migrants contribute to its financing (Table 4).

The impact of international migratory flows on the GDP growth rate is far from being insignificant. The arrival of young workers progressively increases the GDP growth rate in North America and Western Europe. It is more than respectively 0.8 point and 0.5 point higher than in the baseline case in 2035 in North America and Western Europe and then stabilizes to this gap with the ageing of first migrant cohorts (see Figure 6(f)). The effect on the Russian world GDP growth rate follows the working age population evolution and is thus less marked. The mirror effect of the improving economic situation in immigration regions is a deterioration in the regions of emigration, and noticeably in Latin America and the Mediterranean world. Indeed, the mag-

[9]Note that the emigration rate in Eastern Europe is twice lower than in the Mediterranean world. Nevertheless, the negative impact on the dependency ratio is twice higher in Eastern Europe and is explained by the different demographic features between these two regions. The former is much advanced in the ageing process whereas the latter is still characterized by a more sustained growth of its working age population. The consequences of young workers emigration are thus more pronounced in the Eastern Europe case.

nitude of the deterioration depends on the loss of potential workers relative to the total labor force in the regions.

Nevertheless, the level of consumption per capita is less than in the baseline scenario in Western Europe until the very end of the half-century (see Figure 6(g)). The reason lies in the production sector : the inflow of workers reduces capital intensity relative to baseline. Indeed, immigration can be seen as a supply shock on the labor market, thus impacting on the productivity of factors supplied by natives. For a given stock of capital, an increase in labor supply reduces the capital by worker. The marginal productivity of capital is raised and the interest rate as well. Conversely, labor productivity is diminished with a lower capital intensity. As a consequence, GDP per worker is decreased in the regions receiving the migrants and, as a mirror effect, is increased in the regions sending the migrants (see Figure 6(h)). These migrations flows from regions with low level of TFP to regions with higher level of TFP thus induced a convergence process in terms of GDP per worker differential.

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 in receiving regions. It ensues that relatively to the baseline scenario, consumption is less augmented than total population ; hence consumption per capita is lower. Around 2035, when saving gains momentum (see Figure 6(c)) the interest rate recedes a bit because saving grows faster than investment. Therefore the growth of consumption per capita relative to baseline turns positive from 2020 onwards and the level moves overtake the baseline one in 2045. In North America and the Russian world, the level of consumption per capita is always lower than in the baseline given the net saving profile.

The opposite occurs in emigrating regions. But the impact is diffused over several regions and mitigated by the size of the labor force. The fall in the interest rate in these regions and the subsequent increase in productivity persists for almost the entire span of the fifty year period. Only Latin America and the Mediterranean world exhibit a non-negligible elevation of consumption per capita.

Saving increases in the regions receiving the migrants and reaches steadily high deviations from the baseline scenario (see Figure 6(c)). This comes from the fact that the stock of first generation migrants enters progressively the high saving stage of their life cycle. In the regions loosing the migrants, one must note also an increase of saving. Two effects have to be taken into consideration. On the one hand, from a demographic point of view, saving should decrease as a consequence of the fall of working age / saver population. On the other hand, households have a strong a incentive for increasing their saving as the world interest rate is substantially higher than in the baseline scenario. This latter adjustment dominates and reflects the adjustment one must observe in this specific world setting framework. Indeed, in the INGENUE 2 model, the world interest rate balances at each period the capital supply and the capital demand at a world level. In this case, the higher interest rate reflects noticeably the strong increase in investment (capital demand) in the two regions receiving the migrants.

The saving-investment balance is affected by the migrations flows. In particular, in the regions receiving the migrants, saving and investment increase simultaneously (as explained above). The current account balance is more in surplus in the Western Europe region compared to the baseline case. In North America, the current account switches from a deficit in the baseline to a surplus during the period 2010-2015. It follows from the improvement of the current account balance that North America and Western Europe reinforce their creditor position in the world economy during the period 2015-2050. The ownership ratio rises systematically above baseline (see Figure 6(e)). The regions of emigration with slightly appreciating exchange rates relative to baseline stay more in deficit and more in debt.

6 Endogenizing migration flows

Unlike fertility and mortality which are in transition worldwide from high to low levels in long historical process, migration projections have no strong and consistent trends that can serve as a backbone of credible projections for the future. Migration is usually treated as a residual factor in demographic projections and migration projections rely more on informed judgments than on systematic modeling. For example, United-Nations (2006) projections, used to build our exogenous migration scenario in Section 5, estimate future migration by some arbitrary assumptions, such as constant flows in the future or flows declining toward zero, according to the country considered. This methodology is somewhat unsatisfactory and involves substantial errors on projected population, not so at the global level but on specific countries or regions.

Nevertheless, the basic motivations for migration are now well known even if there is no complete migration theory that accounts for all the relevant factors. The main driving forces of the past and recent trends in migration flows thus have to be fully analyzed so as to be integrated in a dynamic framework where the demography and the economy interact one on the other. So as to endogenize international migration, we develop a two step strategy. In a first step, we estimate the dynamics of migration flows on the basis of selected variables (Section 6.1). In a second step (Section 6.2), we endogenize migration flows in the INGENUE 2 model: in order to do so, we relate demographic and macroeconomic dynamics between the regions through the econometric relation estimated in Section 6.1.

6.1 Estimation of the determinants of international migration

In order to endogenize migration flows in INGENUE 2, we first estimate the determinants of migration flows using an econometric model similar to Clark et al. (2007). For that purpose, we use data on international migration flows from the UN International Migration Flows to and from Selected Countries (IMSC) dataset that contains information on bilateral migration flows between the 15 main destination countries and approximately 200 origin countries between 1946 and 2004. We decide to restrict the empirical analysis to the time period 1985-2004 for two reasons. Firstly, our empirical model requires data on bilateral migrant stocks which, for some of the main destination countries, we are not able to construct before 1985. Secondly, we want to make sure that the estimated elasticities captures the current relationship between international migration flows and its determinants instead of historical relationships before 1985.

Data on PPP adjusted per worker GDP (constant 2000 international dollars) and population are from the Penn World Tables 6.2 (Heston & Summers, 2006). Average years of schooling are taken from Barro & Lee (2000), the share of population aged between 15 and 29 years from the International Labour Organisation Labour Force Statistics and measures of income inequality from the United Nations WIDER Institute that are in turn based on Deininger & Squire (1996). Data on the traditional gravity variables distance, common language and the existence of a colonial relationship are from CEPII's distance database[10].

Primary information on migrant stocks are from the Docquier & Marfouk (2005) database that reports migrant stocks for 30 destination countries and 192 origin countries for the years 1990 and 2000. In combination with the gross migration flows from the United Nations IMSC database, an interpo-

[10] http://www.cepii.fr/francgraph/bdd/distances.htm

lation procedure described in Appendix 3 allows us to obtain yearly migrant stocks for the years 1985-2004.

We estimate the elasticity of migration flows with respect to its main determinants using the following specification:

$$\begin{aligned} mig_{dot}/pop_{ot} &= \beta_0 + \beta_1(y_d/y_o)_{t-1} + \beta_2(syr_d/syr_o)_t + \beta_3 age_{ot} \\ &+\beta_4 ineq_{ot} + \beta_5(ineq_{ot})^2 + \beta_6 pov_{ot} + \beta_7 dist_{do} \\ &+\beta_8 comlang_{do} + \beta_9 colony_{do} + \beta_{10}(stock_{do,t-1}/pop_{d,t-1}) \\ &+\beta_{11}(stock_{do,t-1}/pop_{d,t-1})^2 + \kappa_{dt} + \kappa_t + \epsilon_{dot} \end{aligned} \tag{3}$$

where the d subscript points to the destination country, o for the origin and t for the year. Following the literature (Mayda, 2006 or Clark et al, 2007 among others) we choose the emigration rate, mig/pop, as the dependent variable of our empirical model.

Migration incentives are represented by the first five terms on the right-hand side of Equation (3). y_d/y_o is the (purchasing power parity adjusted) ratio of income per worker in the destination country relative to the origin country. This is our main variable of interest and we expect the estimated coefficient to be positive ($\beta_1 > 0$). syr_d/syr_o is the ratio of the average years of schooling in the destination country relative to the origin country. This variable adjusts the income per worker ratio for differences in human capital. For a given income per worker ratio, we expect the migration rate to be lower when human capital in the origin country is relatively higher relative to human capital in the destination country, since this would imply a relatively lower return to human capital in the origin country. We therefore expect the coefficient on the human capital ratio to be negative ($\beta_2 < 0$). age_{ot} is the share of the population aged between 15 and 29 years in the origin country and is supposed to capture the fact that, at a given level of the income per worker differential, the present value of migration is higher at younger ages. We therefore expect $\beta_3 > 0$. The variable $ineq_{ot}$ measures inequality in the origin country. Following Clark et al. (2007) and in line with the Roy model, we assume that the effect of inequality is nonlinear in the sense that increases in inequality have an upwards effect on the emigration rate at low levels of inequality but reduce it at high levels ($\beta_4 > 0$ and $\beta_5 < 0$).

Migration costs are represented by the remaining terms on the right-hand side of Equation (3). Poverty in the origin country, pov_{ot} can be considered as a constraint on emigration.[11] We therefore expect $\beta_6 < 0$. Geographical and cultural migration costs are proxied by the traditional gravity variables

[11]Since there are no data on poverty headcount available for the countries and years in

distance, $dist_{do}$, common language, $comlang_{do}$, and the presence of a colonial link, $colony_{do}$ ($\beta_7 < 0$, $\beta_8 > 0$, $\beta_9 > 0$). We further expect migration costs to decrease with the presence of an origin country migration network in period $t-1$ in the destination country, $stock_{do,t-1}/pop_{ot}$. To capture potential decreasing returns to network externalities we impose a quadratic structure of the network variable and expect $\beta_{10} > 0$ and $\beta_{11} < 0$.

We use panel estimation techniques to estimate Equation (3). This allows us to control for heterogeneity between countries that is not captured by our explanatory variables. The destination country times year specific effect κ_{dt} captures all unobserved characteristics of the destination country in a specific year, in particular the restrictiveness of its immigration policy. We do not include origin specific fixed effects since the reasons for including them are less apparent than for the destination country, where we want to control for unobserved migration policy and unobserved heterogeneity is partly absorbed in the migration network variables.[12] The year specific effect κ_t captures time specific effects that are common to all destination and origin countries.

We report four sets of estimation results in Table 2. Column (1) reports results for estimation of specification (3) with destination country fixed effects instead of destination country times year fixed effects. All the coefficients have the expected sign and are statistically significant at the 10% level, except for the share of the young population in the origin country. In particular the coefficient on the income per worker differential is positive and statistically significant at the 5% level. The marginal effect of the income per worker differential on the emigration rate is estimated at 0.003 meaning that an increase of one percentage point of the GDP per worker ratio implies an increase of 0.003 percentage point of the emigration rate. Column (2) reports results for estimation of specification (3) with destination country plus year fixed effects to account for changes in immigration policy in the destination country. The results do not change qualitatively and the estimated marginal effect of the income per worker differential on the emigration rate remains roughly constant at 0.004. Columns (3) and (4) repeat the estimations using the origin migration network in the destination country in period $t-5$ instead of period $t-1$ to reduce potential endogeneity of the network variable.[13] The

our sample, we follow Clark et al. (2007) and measure poverty by the inverse of income per capita squared. The rationale is that recent empirical studies find the poverty headcount to be negatively related to the inverse of income per capita squared (Ravallion (2004)).

[12]Note that this specification is the equivalent to the Clark et al. (2007) specification in a setting with multiple destination countries and multiple origin countries.

[13]Note that this reduces the size of the sample since the network variable cannot be constructed for the first five years.

Table 2: Main determinants of international migration

	(1)	(2)	(3)	(4)
Dependent variable		Emigration rate		
gdp per cap diff	0.003**	0.004***	0.003*	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
human cap diff	-0.007***	-0.010***	-0.006**	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)
origin share young pop	0.001	0.002	0.003**	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
gini origin	0.005**	0.005**	0.007***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
(gini origin)2	-0.000*	-0.000	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
origin pov	-0.002**	-0.002***	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
network	0.039***	0.041***	0.044***	0.046***
	(0.001)	(0.001)	(0.001)	(0.001)
(network)2	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
ln dist	-0.061***	-0.060***	-0.066***	-0.065***
	(0.005)	(0.005)	(0.005)	(0.005)
colonial link	0.046**	0.045**	0.064***	0.049**
	(0.018)	(0.018)	(0.021)	(0.021)
common language	0.110***	0.101***	0.132***	0.121***
	(0.010)	(0.010)	(0.012)	(0.012)
Destination FE	Yes	No	Yes	No
Destination-year FE	No	Yes	No	Yes
N	13295	13295	10274	10274
R2	0.52	0.55	0.51	0.55

Standard errors in parentheses
Significant at 10%; ** significant at 5%; *** significant at 1%
Source: Authors' calculations.

coefficient on the share of the young population in the origin country now turns significant at the 1% level and has the expected sign while the other results remain qualitatively unchanged.

Among the factors that have been highlighted by the econometric analysis are some endogenous variables of the INGENUE2 model. Three are retained to endogenize migration flows[14]. The first two one are related to economic factors and the third one accounts for network effects: (i) the GDP per worker differential captures the fact that many workers move mainly for higher income opportunities ; (ii) the poverty indicator measures a constraint to the migration in the origin country ; (iii) an accumulated stock of immigrants in a specific country encourages migration in direction of this country for future years. Then, estimated marginal effects presented in Table 2 allow us to back out a range for the elasticity of the emigration rate with respect to each of the three retained factors. For example, using $\sigma \equiv \beta_1 \frac{(y_d/y_o)}{(mig/pop)_{do}}$, at the sample median for $\frac{(y_d/y_o)}{(mig/pop)_{do}}$, this elasticity would range from 0.43 to 0.57 for the per worker income differentials. Given that a period is set to 5 years in the INGENUE 2 model, we choose specification 4 so as to endogenize migration flows and adopt an elasticity of 0.43 for the per worker income differentials. The interpretation is that a 10% increase of the per worker income ratio involves a 4.3% increase of the emigration rate. Following the same methodology, we infer elasticities of the emigration rate with respect to the poverty indicator and with respect to accumulated stock of immigrants, respectively equal to -0.03 and 0.43.

6.2 Results with endogenous migration

The INGENUE 2 model displays a number of endogenous variables, including GDP per worker for each period and each region of the model as well as the evolution of the stock of migrants in the receiving regions. As a consequence, we compute the endogenous migration flows using a dynamic feedback loop, in order to take into account the endogenous adjustments of the economic variables of the model that enter the econometric relation.

Some migration streams are durable, lasting decades, and relatively pre-

[14]We thus assume that the other determinants of emigration rates included in Equation 3 remain constant for the entire projection period. Even though it is naturally the case for some of them (ex: distance, common language, colonial link), we are aware of the limit of this partial integration of the migration determinants in our CGE framework. However, given the complexity of the task, we leave to further research a more complete integration of migration determinants in such a world model.

dictable. This is particularly the case of some types of migration such as labor migration or family reunification that tend to perpetuate themselves over time. Consequently, the migration flows that are strongest and most likely to endure are probably the flows toward the traditional countries of immigration. In this work, we only consider Western Europe and North America as the two only receiving regions that would be concerned by endogenous migration flows in the context of the Ingenue 2 model. Indeed, Eastern Europe and the Russian World, as potential receiving regions, are excluded from this endogenous migration process given that the recent period has been mainly marked by ethnic and conflict-driven migration that are by definition unpredictable.

The methodology to endogenize migration flows is relatively simple. The starting point for migration is still the year 2005 and the flows for the first period (2005-2009) thus remain the same as the one calibrated in the exogenous scenario. Then, the 14 bilateral emigration rates of the first period (2 destination regions and 7 origin regions) are modified on the basis of the endogenous evolution of the 3 determinants of international migration and of the 3 related elasticities following the econometric analysis of Section 6.1. We then obtain 14 new bilateral emigration rates for the period 2010-2014, which allows us to calibrate new migration flows for this period. These new migration flows then modify the macroeconomic dynamic of the INGENUE2 model, for example the GDP per worker evolution, and create a dynamic feedback loop between migration projections and the demographic and macroeconomic evolutions.[15] This methodology is replicated for each period until 2050. After this date, migration flows progressively decline and are nil in 2150 as in the exogenous scenario.

The results of the endogenous migrations scenario are presented in Table 3 where we compare exogenous migration flows of the United-Nations (2006) scenario (the one presented in Section 5) to endogenous migration flows for the period 2006-2050. Taking into account traditional economic and demographic determinants of migration flows (GDP per worker differential, poverty in origin countries and network effect) induces important changes in the volume and the distribution of the migration flows between regions com-

[15]Note that emigration rates are calibrated in a single step process at each period. Indeed, once emigration rates are fixed for a given year, endogenizing migration for future period slightly modifies the dynamic of macroeconomic variables such as the GDP per worker differential given the perfect foresight assumption of the INGENUE2 model. However, these changes are very marginal compared to the first order effect on emigration rates and we thus choose not to include these second order effects so as to simplify the simulation process.

pared to the United-Nations (2006) scenario. Indeed, some sending regions face substantial increase of their net migration flows on the mid-century horizon -for example, net migration flows from Africa and from the Mediterranean World are respectively almost four times and one time higher compared to the United-Nations (2006) projection- when other regions, such as the Chinese World are clearly less affected. Despite everything, the general evolution of migration flows for the five pure emigration regions is clearly on higher trends and logically transcripts into higher immigration for pure immigration regions. Western Europe, as a receiving region, is more concerned by this phenomenon than North America: the number of migrants in 2050 increases from 1.1 million to 1.9 million in North America (+63%); in Western Europe the number of migrants increase by 173%, reaching 1.5 million in 2050.

Table 3: Comparison of yearly net migration flows between the UN and the endogenous migration scenario (in thousand)

		2006-2010	2011-2015	2016-2020	2026-2030	2046-2050
Mediterranean World	UN 06	-397	-350	-341	-344	-344
	Endo. Flows	-397	-442	-491	-604	-867
Indian World	UN 06	-220	-205	-203	-204	-204
	Endo. Flows	-220	-237	-254	-287	-346
Chinese World	UN 06	-360	-333	-330	-331	-331
	Endo. Flows	-360	-368	-376	-382	-366
Latin America	UN 06	-701	-653	-648	-649	-649
	Endo. Flows	-701	-762	-816	-927	-1 120
Africa	UN 06	-195	-169	-165	-166	-166
	Endo. Flows	-195	-233	-278	-391	-715
Eastern Europe	UN 06	-50	-50	-50	-50	-50
	Endo. Flows	-50	-47	-44	-39	-26
Russian World	UN 06	3	5	5	5	5
	Endo. Flows	3	-1	-3	-4	-4
Western Europe	UN 06	654	564	546	551	551
	Endo. Flows	624	702	788	992	1 504
North America	UN 06	1 267	1 193	1 186	1 188	1 188
	Endo. Flows	1 297	1 390	1 474	1 643	1 936

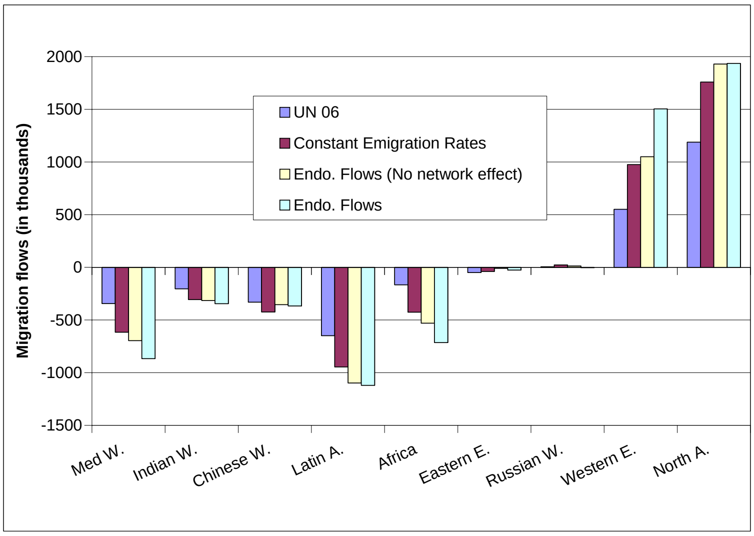
Sources:United-Nations (2006), Authors' calculations

So as to clarify the mechanism behind these results, Figure 7 displays the number of migrants in 2050 for the different regions of the model according to several intermediary scenarios: we decompose between constant emigration rates [16], endogenous flows without network effect and complete endogenous flows. We see that switching from the United-Nations (2006) scenario, that implies a net decrease of emigration rates for all sending regions, to the constant emigration rate induces an increase in migrations flows in all the regions. This result is logically linked to the total population evolution of each region (see Section 2.2). Africa, which is still characterized by high

[16]The constant emigration rate scenario is strictly the same as assuming that there is no evolution of the 3 determinants of migration flows over time since we simply project emigration rates changes based on the evolution of the 3 migration flows determinants in the complete endogenous scenario

fertility rates through 2050, has still a growing population and is thus the more affected region by the constant emigration rates scenario.

Figure 7: Disentangling the demographic and economic effects of endogenous flows



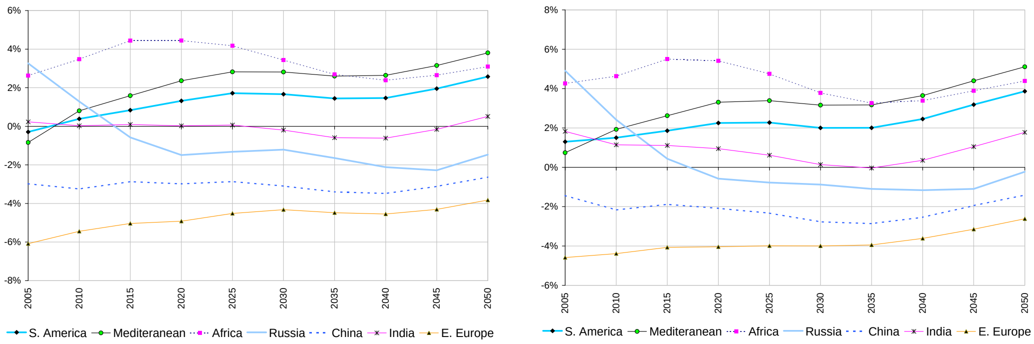
sources: United-Nations (2006), authors' calculation

Introducing the economic determinants of migration, i.e. GDP per worker differential and poverty in origin countries (endogenous scenario without network effects), induces additional flows from almost all sending regions (Figure 7). Indeed, the endogenous process of the INGENUE 2 model relies on two exogenous blocks : the catching up process and the demographic forecasts for the ten regions of the model. Given the relatively conservative assumptions regarding the evolution of TFP (see Section 4) and demographic evolutions, only the Chinese World and Eastern Europe (and to a lower extent the Russian world) are really acquainted with a catching-up process in term of GDP per worker compared to Western Europe and North America (Figure 8). However, as seen with the exogenous scenario (see Section 5), one should note that the migrations dynamics modifies the catching-up process through the decrease in the GDP per worker differential between the receiving and sending regions (figure 9(h)).

The comparison of the endogenous scenario without network effects with the complete endogenous scenario shows that migration flows are enhanced as we could expect (Figure 7). However, regarding the receiving regions,

Figure 8: Growth rate of the GDP per worker differential in the endogenous flows scenario

(a) Compared to Western Europe (b) Compared to North America



source: authors' calculation

one must note that the network effect does not add a lot of migrants for the North American region, contrary to the Western Europe region: with the introduction of the network effect, the number of migrants in 2050 is nearly the same in North America (+0.4%); in Western Europe the number of migrants increase by 43%. These differences on the number of migrants induced by the network effect could be explained by the fact that the initial value of installed migrants is already high in 2000: the share of migrants is equal to 6.2% in Western Europe compared to 13.6% in North America, according to the United-Nations. As a consequence, the estimated elasticity that we used applies to a stock of migrants that is substantially higher in the North American case: new migration flows after 2000 thus have a moderate impact on the migrants stock evolution. In 2050, the respective shares of migrants are respectively equal to 14.5% and 17.6%.

Finally, the macroeconomic and demographic consequences of the endogenous migration scenario are qualitatively the same as the exogenous migration one presented in Section 5 (see Figure 9). However, from a quantitative point of view, it appears that the economic consequences are enhanced for the Western Europe region in the case of the endogenous scenario. The main macroeconomic effects are enhanced for this region in 2050 as a consequence of the higher number of migrants compared to the exogenous case. In particular, the positive impact on saving is now more important in Western Europe than in the North American region.

Concerning the financing of PAYG pension schemes, the endogenous migration scenario lowers the financial needs even further compared to the UN06

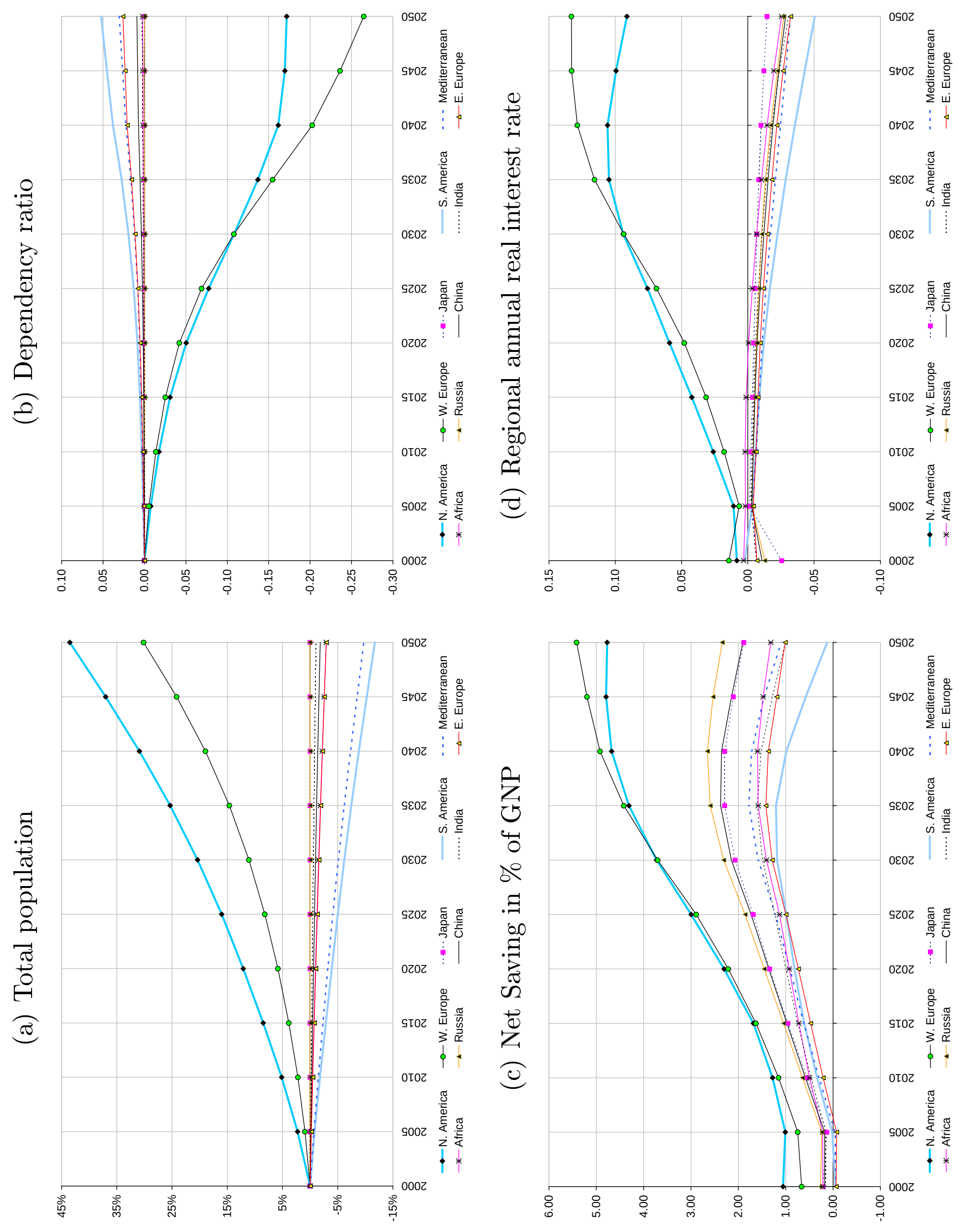
Table 4: Contribution rates evolution

		2000	2010	2020	2030	2040	2050
Western Europe	Baseline	17.1%	19.1%	22.5%	27.6%	30.7%	31.9%
	UN 06	17.1%	18.7%	21.5%	25.4%	27.1%	28.0%
	Endo. Flows	17.1%	18.7%	21.3%	24.8%	25.7%	25.5%
North America	Baseline	9.1%	10.4%	13.4%	16.5%	17.4%	17.9%
	UN 06	9.1%	9.9%	12.1%	13.9%	13.7%	14.3%
	Endo. Flows	9.1%	9.8%	12.0%	13.6%	13.1%	13.4%

Sources: Authors' calculations

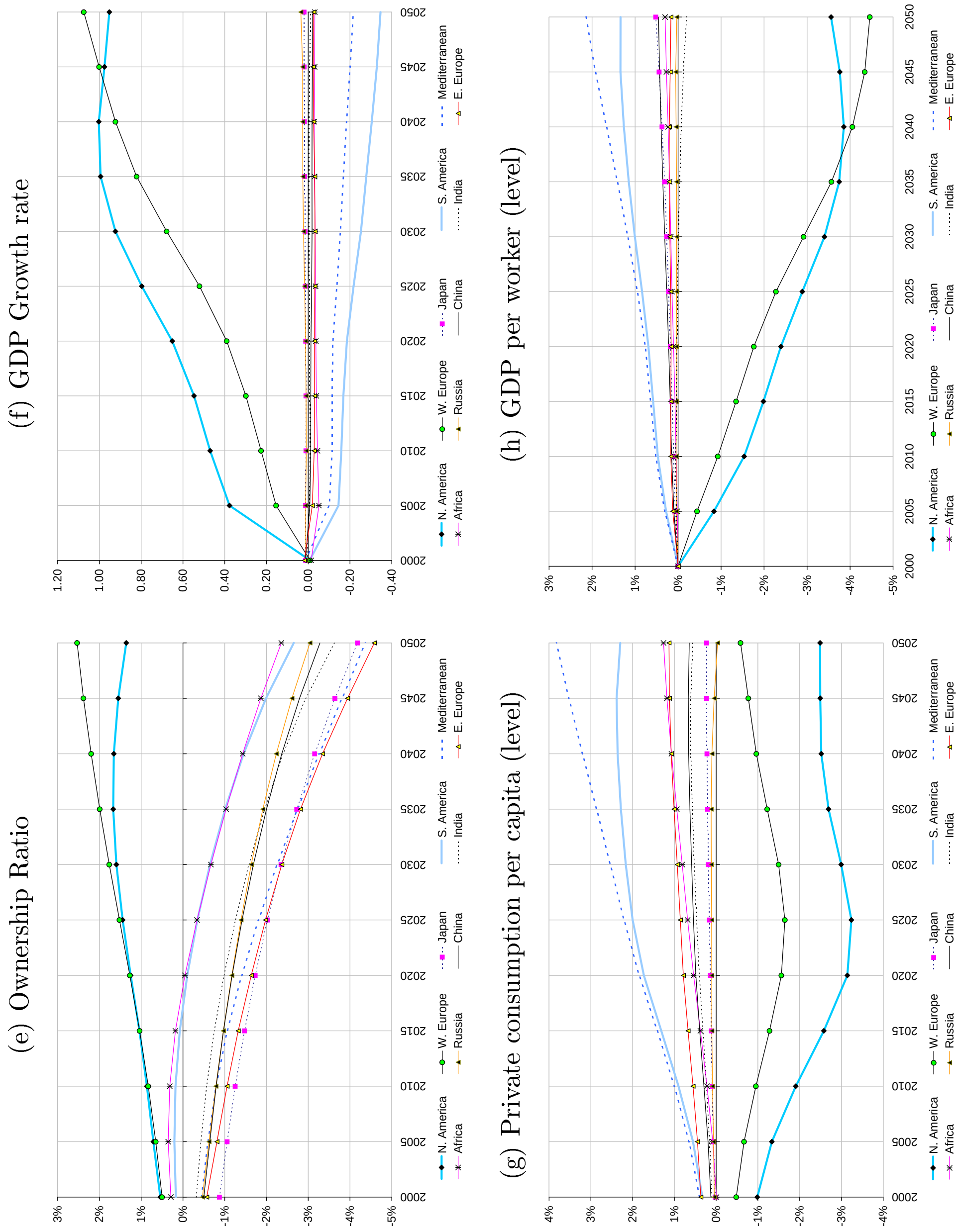
scenario, particularly in the Western Europe region (Table 4). For instance, in the European case, the contribution rate is 6.4 percentage points lower in the endogenous flows scenario in 2050 compared to the baseline without migration (2.5 percentage points lower than the UN06 scenario). Given that the contribution rate is likely to increase by 14.8 percentage points between 2000 and 2050 in Western Europe, introducing endogenous migration flows reduces by less than a half the financial burden arising from ageing. Consequently, even if it induces a sharp increase in migration flows, this scenario does not totally offset the effect of ageing and thus raises the question of pension reforms in a near future.

Figure 9: Results of the endogenous migration scenario (difference from baseline scenario): 2000-2050



source: authors' calculation

Figure 9: Results of the endogenous migration scenario (difference from baseline scenario): 2000-2050



source: authors' calculation

7 Conclusion

History teaches how the search of better living conditions and higher wages is a strong motive for emigration. From an economic perspective, migration flows around the world are first apprehended as a change in the geographic structure of the global labor force. In the arrival countries, the increase of the labor force, as long as most of the new comers work, entails an increase in the capital return which attracts capital flows. Of course, the reverse effect characterizes the leaving countries. As a consequence, migration flows change the geographic structure of the wages around the world. From this perspective, using a world general equilibrium model as INGENUE 2 in evaluating the migration flows for the next century has two main advantages. First, it allows studying simultaneously the impact of the migration flows on the arrival countries as well as on the leaving countries. Second, it allows evaluating the feedback effect of capital flows and wage changes on migration flows.

The introduction of endogenous migration flows into INGENUE 2 brings some lights on several important demographic and economic questions. First, migration could have substantial impact on GDP growth in the regions receiving the migrants (positive impact) but also on the regions sending the migrants (negative impact). According to our simulations, Western Europe and North America should benefit substantially from the arrival of cohorts of migrants in the next decades. Second, despite their sizes, these flows will not be sufficient to counteract the impact of population ageing in these regions: even when immigration flows are taken into account, pension reforms in these ageing regions (and in particular in Western Europe) will remain necessary. In order to quantify this result, we can note that taking endogenous migration flows into account leads to a decrease of 6.5 percentage points of the contribution rate in Western Europe in 2050 (4.5 percentage points in North America), compared to the baseline scenario without migrations.

With the interaction that we have modeled between the demographic part and the economic part of the world OLG model, we have been able to project dynamic migrations flows. Note that this corresponds to one of the research priorities defined by the National-Research-Council (2000) in order to improve the projections of international migration flows. According to us, this work constitutes a first step in this direction and we consider that future researches on projections of international migration flows could build on the methodology that we have developed. Our methodology has to be improved by further researches. On the one hand, immigrants are assumed to have exactly the same productivity as the native workers. The skill distribution of immigrants from developing regions suggests that they may be less skilled than the average European and North American worker. On the other hand, the remittances flows (associated with the migrations flows) are not modeled in our framework. Clearly, these flows could be of great importance, from a quantitative point of view, noticeably when we focus on some specific countries.

Furthermore, the general equilibrium multi-regions OLG model that we use has several assumptions that could limit the scope of our analysis. Firstly, the INGENUE 2 model assumes perfect flexibility in the labor and goods markets. Thus, immigration has no impact on unemployment and economic output is continuously at potential. Secondly, the age of migrants is limited to some specific cohort and we do not model return migration. Such demographic assumptions would be quite difficult to include in our multi-regions OLG framework. Despite the shortcomings that we mention, it appears that the main value-added of our analysis is the long term general equilibrium analysis of international migration flows that we propose.

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Appendix 1: Regional grouping

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

1. **"Western Europe" :** 'Channel Islands', 'Denmark', 'Finland', 'Iceland', 'Ireland', 'Norway', 'Sweden', 'United Kingdom', 'Greece', 'Italy', 'Malta', 'Portugal', 'Spain', 'Austria', 'Belgium', 'France', 'Germany' (East + West), 'Luxembourg', 'Netherlands', 'Switzerland'.
2. **"Eastern Europe" :** 'Estonia', 'Latvia', Lithuania', 'Bulgaria', 'Czech Republic', 'Hungary', 'Poland' 'Romania', 'Slovakia', 'Slovenia', 'Albania', 'Bosnia and Herzegovina', 'Croatia', 'Former Yugoslav Republic of Macedonia'.
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', 'Republic of Moldova',

10. **"Indian World" :** 'India', 'Afghanistan', 'Bangladesh', 'Bhutan', 'Maldives', 'Nepal', 'Pakistan', 'Sri Lanka', 'Tajikistan', 'Indonesia', 'Kazakhstan', 'Malaysia'.

Appendix 2: Description of the model

In this appendix, we provide a technical presentation of the economic part of the INGENUE 2 model. A complete presentation of the model could be found in Ingenue (2007).

Households

Economic choices of households concern consumption/saving and are made with perfect foresight at the beginning of their adult life. Labor supply is assumed to be exogenously given by the age-specific rate of participation to the labor market, noted : e_a^z. We take International Labor 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. Adults can (partially) retire from age $\underline{r}^z$ and they may not stay in the labor force after a legal maximal mandatory retirement age $\bar{r}^z$.

The intertemporal preferences of a new entrant in working life, native or migrant, 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)[17] :

[17] Usually in these kind of model the age T is the biological limit to life (here 105 years.)

$$
\begin{aligned}
U^z_{a_0}(t) &= \sum_{a=a_0}^{20} \rho^{a-a_0} \left[\prod_{i=a_0}^{a-1} s^z_i(t+i) \right] \frac{\eta}{\eta-1} c^z_a(t+a-a_0)^{\frac{\eta-1}{\eta}} \\
&+ \rho^{T-a_0} \prod_{i=a_0}^{T} s^z_T(t+T-a_0) V\left(H^z(t+T-a_0)\right) \qquad (4)
\end{aligned}
$$

where ρ is the psychological discount factor, 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).

At any given period, the budget constraint is :

$$
\begin{aligned}
&\tau^z_a(t) p^z_f(t) C^z_a(t) + p^z_f(t) S^z_a(t) = Y^z_a(t) + p^z_f(t) S^z_{a-1}(t-1) \frac{R^z(t)}{s_{a-1}(t-1)} \\
&+ \; p^z_f(t) h^z_a(t) - p^z_f(t) H^z(t) \Upsilon_T(t) \qquad (5)
\end{aligned}
$$

$$
Y^z_a(t) = \begin{cases} \zeta^z_a(t) + (1-\theta^z(t)) w^z(t) e_a(t) \vartheta_a & \text{for} \quad a < \underline{r}^a \\ (1-\theta^z(t)) w^z(t) e_a(t) \vartheta_a + (1-e_a(t)) P^z_a(t) & \text{for} \quad \underline{r}^a \le a < \bar{r}^a \\ P^z_a(t) & \text{for} \quad a \ge \bar{r}^a \end{cases}
$$

where S^z_a 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 $S_{20} \ge 0$ 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. $\tau^z_a(t) p^z_f(t) C^z_a(t)$ denotes the total consumption (that is the consumption of the parents and the one of their children). $p^z_f(t) S^z_a(t)$ represents the wealth at the end of date t. $p^z_f(t)$ denotes the price of the domestic final good (in terms of one foreign goods) 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, 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

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.

survival probability of the generation. Besides children receive inherited assets $h^z_a(t-1)$ 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 (5) $\Upsilon_T(t)$ 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 labor at time t. When the agent is partly retired ($a \in [\underline{r}^a, \bar{r}^a[$), she also receives a pension benefit P^z_a 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^z_a 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 use the age distribution of children for each parent (from their past fertility behavior) and a constant age equivalence scale of children.[18]. $\zeta^z_a(t)$ is the labor income that children bring to their parents resources during their childhood (calculated in the same spirit as costs of children-rearing).

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. We adopt Miles (1999) human capital profile's estimation and ϑ_a is normalized so that $\vartheta_{a_0} = 1$.

Voluntary bequests are distributed to children according to the fertility calendar of their deceased parents. At the equilibrium the sum of voluntary bequest will be equal to the inheritance received by children. We assume that bequests are distributed equally to all children, i.e. 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. The tradeoff between domestic and foreign assets is characterized by :

$$R^z(t) = R^\star(t)\frac{p^z_f(t-1)}{p^z_f(t)} \qquad \text{for all t} > 0 \tag{6}$$

[18]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.

where $R^\star(t)$ is the unique world interest factor (in terms of the world numéraire), the condition (6) 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.

The public sector

The pension $P_a^z(t)$ paid is a fraction $\kappa(t)$ of the current average (net of tax) wage $[1-\theta^z(t)]w^z(t)$. We assume a time-to-time balanced-budget rule :

$$\frac{\theta^z(t)}{1-\theta^z(t)} = \kappa(t)\cdot\frac{\sum_{a\geq \underline{r}^a}(1-e_a(t))L_a(t)}{\sum_{a\leq \bar{r}^a} e_a(t)L_a(t)} \tag{7}$$

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 (7).

Production side

Intermediate good sector

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

$$YI^z(t) = AI^z(t)\left(K^z(t-1)\right)^\alpha \left(N^z(t)\right)^{1-\alpha} \quad 0<\alpha<1 \tag{8}$$

The maximization of the firm value will imply that at the equilibrium ($\forall t$) :

$$\begin{aligned} R^\star(t+1)\frac{p_f^z(t)}{p_f^z(t+1)} + \delta^z(t+1) - 1 &= \frac{p_I^z(t+1)}{p_f^z(t+1)}\alpha AI^z(t+1)\left(k^z(t)\right)^{\alpha-1} && (9)\\ w^z(t) &= p_I^z(t)(1-\alpha)AI^z(t)\left(k^z(t-1)\right)^\alpha && (10)\end{aligned}$$

where p_I^z is the price of the domestic intermediate good, $\delta^z(t)$ is the rate of economic depreciation and $k^z(t-1) = K^z(t-1)/N^z(t)$ is the capital-labor ratio.

Final good production sector

The domestic composite final good of region z, YF^z, is produced according to a combination of two intermediate goods: a "domestic" intermediate good in quantities B^z and a "World" intermediate good in quantities M^z, according to the following CES technology, where $\sigma \geq 0$ denotes the elasticity of substitution, $\forall z$:

$$YF^z(t) = AF^z(t)\left[(\omega^z)^{\frac{1}{\sigma^z}}\left(B^z(t)\right)^{\frac{\sigma^z-1}{\sigma^z}} + (1-\omega^z)^{\frac{1}{\sigma^z}}\left(M^z(t)\right)^{\frac{\sigma^z-1}{\sigma^z}}\right]^{\frac{\sigma^z}{\sigma^z-1}} \quad (11)$$

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 behavior 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 (11), where p_I^z is the price of the home-specific intermediate good and $p^\star$ is the price of the world intermediate good.

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 :

$$Y^\star(t) = A^\star(t)\left[\sum_z \gamma^z(t)^{\frac{1}{\mu}} X^z(t)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \quad (12)$$

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 (12). This yields at the equilibrium the following factor demand function :

$$X^z(t) = \gamma^z(t)\left(E^z(t)\right)^{-\mu} Y^\star(t)A^\star(t)^{\mu-1} \qquad \text{for all z} \quad (13)$$

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 :

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

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 rigorous 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 $\varepsilon > 0$:

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

where $S^z(t) = \sum_{a=a_0}^{19} L_a(t)S_a(t)$ is the aggregate financial wealth across all cohorts in region z which 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.

Appendix 3: Interpolation procedure for annual foreign migrants stock

In order to obtain annual estimates of the stock of foreign migrants we adapt the interpolation procedure of Clark et al. (2007) to our purposes. More specifically, we interpolate between the 1990 and 2000 benchmarks obtained from Docquier & Marfouk (2005) using the following stock adjustment equation:

$$S_{dot+1} = M_{dot} + d_{do}S_{dot} \qquad (15)$$

where S_t is the stock at the beginning of year t and M_t is the flow during that year. We use the gross flows from the IMSC database to update the stock.

The parameter d reflects deaths, return migration, and illegal immigration, which subtract or add to the stock independently of the additions through gross immigration and hence $1-d$ is the rate at which the stock depreciates. This depreciation rate is calculated for the interval between 1990 and 2000 using an iterative procedure beginning with S_t, such that the value of S_{t+10} obtained by cumulating forward is reconciled with that of the next Census benchmark. Thus there is a different value of d for each destination-origin country pair. We then use this value of d and the gross migration flows from the IMSC database to extrapolate forward to 2004 and backward to 1985. Even if this methodology is somewhat questionable, it appears to reasonably reproduce the migration stocks evolution in destination countries. Indeed, our results have been gauged with success for the 6 main OECD receiving countries (United States, Canada, Australia, United-Kingdom, France and Germany) with the database of Defoort (2008).