ChinAfrica :
How can the Sino-African cooperation be beneficial for Africa ?

L. Marchiori

Discussion Paper 2007-14

Département des Sciences Économiques
de l'Université catholique de Louvain

ChinAfrica*:
How can the Sino-African cooperation be beneficial for Africa?

Luca Marchiori†

April 24, 2007

Abstract

In this paper, different scenarios of increased cooperation between China and African countries are simulated. Recent intensification of political and economic ties between China and Sub-Saharan African countries may give hope that an economic improvement in Sub-Saharan Africa (SSA) is possible. Three channels may lead to a catching-up of Africa with China: a reduction in Africa's investment risk, an increase in its total factor productivity (TFP) and an improvement of its worker skills. A computable general equilibrium model of the world economy is used, that shares the world in 10 regions, among which Sub-Saharan Africa and China. Three scenarios are considered in which, by 2100, Africa will have reduced simultaneously its gaps in investment risk, TFP and education to China by either 20% (scenario 1), 40% (scenario 2) or 60% (scenario 3). The effects on the Sub-Saharan African economy are very promising. The results show that, already in 2050, Africa will have increased its per capita Gross Domestic Product (GDP) by 50% with scenario 1, by 80% with scenario 2 and by 125% with scenario 3.

Key words: OLG-CGE Model, catching-up, simulations, Africa, China
JEL classification: E27, J11, O47, O55, O57

*"ChinAfrica" is a monthly Chinese magazine which targets African readers, covers among other subjects Sino-African cooperation, highlights affairs in China and Africa and is issued in several languages (http://www.chinafrica.cn/).

†I am highly indebted to Frédéric Docquier for his efficient supervision, ideas and comments. I am grateful to Raouf Boucekkine for comments on an earlier draft. I also thank Antonio Minniti, Matteo Picchio, Antoine Stevens and Alfonso Valdesogo. The usual disclaimers apply. I acknowledge the financial support from the Belgian French-speaking Community's programme "Action de recherches concertées" (ARC 03/08 -302) and from the Luxembourgish Ministry of Culture, Higher Education and Research. Correspondance address: IRES, Université catholique de Louvain, 3 Place Montesquieu, 1348 Louvain-la-Neuve, Belgium. E-mail: marchiori@ires.ucl.ac.be

1 Introduction

Since the first Ministerial Conference "Forum on China-Africa Cooperation" held in Beijing in 2000, Sino-African economic and trade cooperation has been boosted. In 1999, the total Sino-African trade volume was US$6.5 billion. By 2005, total Sino-African trade has reached US$39.7 billion and is expected to reach US$50 billion by 2006[1]. Today, China has become one of the top three largest trading partners of Africa. In 2003, the 2000 Forum has been followed by a second forum held in Addis Ababa. More recently, in November 2006, a third forum held again in Beijing, was attended by more than 40 African heads of state to promote co-operation in a wide range of fields between China and African countries. Critics say China needs Africa's rich supplies of natural resources and raw materials to fuel its surging economy. However, there may be some hope that overall, China's growing economic ties to Africa are benefiting the region.

The aim of this paper is to simulate different scenarios explaining how the recent strengthening of the Sino-African cooperation may turn out beneficial for Sub-Saharan Africa (SSA). I do not analyse the effects of an increase in capital flows from China to Africa, at least not directly. However, *three* indirect channels are considered through which the recent intensification of the Sino-African relations may improve the economic performance of African countries. In fact, the Sino-African cooperation is not only focused on trade, but covers a wide range of fields from education, healthcare and culture to the strengthening of political ties.

Thus the first channel through which the Sub-Saharan African economy may profit of its collaboration with China could pass through the Sino-African *political* relationship. The establishment of political consultation mechanisms between the two sides may lead African governments to raise the quality of their investment environments by adopting laws that reduce investment risk. Creating trust and a safer investment environment may attract more capital inflows to Africa and may eventually be equivalent to an increase in capital inflows to Africa. Secondly, *economic* agreements may enhance Sub-Saharan African adoption of Chinese technologies. In fact, the creation of joint committees on science and technology as well as on economic cooperation and trade between China and some African countries favor higher technological adoption. This higher adoption will lead to an increase of Africa's total factor productivity and eventually to a catching-up of Africa's economy to the one of China. Finally, China's Africa 2006 summit encourages cooperation in *education* between China and Sub-Saharan Africa, a topic already

[1]Source: the official site of the Forum on China-Africa Cooperation (FOCAC) http://www.focac.org and the site of the Chinese embassy in Zimbabwe http://zw.chineseembassy.org

discussed during the 2005 Sino-African Education Minister Forum[2]. Around fifty African countries established agreements in education with China[3]. Thus a third beneficial channel for Africa may consist in the approaching of the skill levels of its population to the ones of the Chinese population.

The analysis builds on an open-economy multi-region computable general equilibrium (CGE) dynamic overlapping generations (OLG) model. The world is split into 10 regions (or groups of countries): three developed regions and seven developing regions, among which Sub-Saharan Africa and the Chinese World. This study covers the analysis of the Sub-Saharan African economy over the 21^{st} century.

Under the scenarios of increased Sino-African cooperation, Sub-Saharan Africa will experience a constant improvement in its risk premium, TFP and education levels all over the 21^{st} century. Three scenarios are considered in this paper. In the first scenario, henceforth labelled as "SSA 20%" (or scenario 1), SSA's gaps in risk rating, TFP and skill levels to China will be reduced by 20% in 2100. In the second and third scenarios, labelled as "SSA 40%" (or scenario 2) and "SSA 60%" (or scenario 3), these gaps are reduced by respectively 40% and 60% in 2100. The results show that, already in 2050, Africa will have increased its per capita GDP by 50% under scenario 1, by 80% under scenario 2 or by 125% under scenario 3.

The paper is organized as follows. A short review of the literature is provided in section 2. Section 3 describes the 10 regions of the world and presents the model. The calibration of the baseline scenario is explained in section 4. Finally, section 5 provides the results of the study. Section 6 concludes.

2 Literature review

To my knowledge, no study makes assumptions on what could be the consequences of a Sino-African cooperation on the Sub-Saharan African economy over the first half of the 21^{st} century. The contribution of this paper is to undertake the analysis of these possible consequences in a multi-region world model, in which Sub-Saharan Africa (SSA) and China (CHI) are calibrated as two separate regions. This model

[2]During the Sino-African Education Minister Forum that took place in Beijing in November 2005, existing problems in educational development and implementation of educational strategies for developing countries were already discussed.

[3]In fact, according to the Chinese Minister of Education, China offers every year around 1200 scholarships to African students as well as 1000 training programs for African government officials. Moreover, China has also established several Confucius Institutes in Africa to spread Chinese language and culture and has sent professors to teach in African secondary schools and universities.

is close to world models in the vain of Ingenue (2005), which shares the world in developed and developing regions. One aim of these models is to analyse the effects of a demographic transition on capital flows (Börsch-Supan et al. 2001 and 2005, Feroli 2003, Ingenue 2001a, 2001b, 2004, Williamson 2001). However, they do not model a risk premium or heterogeneous agents and may therefore not analyse a catch-up of Sub-Saharan Africa to China via these two channels. Similarly to all these studies, the present model also evolves in a context of demographic transition.

The first channel through which Sub-Saharan countries may catch-up or approach Chinese levels of economic performance is a reduction in the risk premium. The risk premium is defined as a bonus on the rate of return to capital to ensure a risk-adjusted rate of return. In this paper, a high risk premium in a region reflects a high degree of investment risk. Political instability and corruption are often seen as determinants of investment risk and act as deterrents of economic growth[4]. Here the risk premium is modelled as a tax levied by a corrupt or politically instable government. A decrease in a region's risk premium may therefore reduce investment risk in a particular region and increase capital inflows (or decrease capital flights from a region) and thereby economic performance. The aim of the present model is not to explain all the effects of corruption on economic growth[5]. Nevertheless it manages to deal with a specific kind of corruption in a fully-specified *computable* dynamic general equilibrium setting and only few studies, as De la Croix and Delavallade (2006) or Blackburn et al. (2004), analyse this issue. As the latter authors put it: "much less research has been directed towards analysing the joint determination of corruption activities and economic outcomes within the context of fully-specified dynamic general equilibrium models. This is particularly notable given that the macroeconomic consequences of corruption have become an increasing concern to both economists and policy makers who have shared a deepening belief that a fundamental requirement for economic development is high quality governance".

Moreover, this paper touches another strand of literature focusing on technological adoption and economic growth. Adoption of technologies and innovation in research and development (R&D) are two main determinants of total factor productivity (see Nelson and Phelps 1970, Benhabib and Spiegel 1998). In general, imitation and adoption of foreign technologies are often viewed as means for developing countries to catch-up with countries at the technological frontier, while R&D is more concentrated in developed countries. Thus in this paper, a rise in

[4]See Acemoglu et al. (2002) for a study of the effects of political instability on growth and for corruption Mauro (1997) and Shleifer and Vishny (1993)

[5]See Jain (2002) and Aidt (2003) for a review on the different effects of corruption on the economy.

African total factor productivity comes through an increase in technological imitation, motivated by the fact that economic agreements between Africa and China may result in higher adoption of Chinese technologies by African countries.

Finally, vaguely related is the literature on the relationship of economic growth to the education levels of the labor force. In this paper, economic growth is exogenous. However, it is widely accepted in endogenous growth theory that human capital is one of the major determinants of economic growth and the well-known contributions by Lucas (1988) and by Mankiw, Romer and Weil (1992) document this view.

3 The Model

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

As in de la Croix and Docquier (2006), the existence of an insurance mechanism à la Arrow-Debreu is postulated. Each time an individual dies, her/his assets will be equally distributed among individuals belonging to the same age class. In other words, individuals do not leave any bequests to their children (or to next generations). Furthermore, there is only one consumption good and its price is the numeraire of the model. There is one leading economy (North-America), in the sense that the TFP of each region is expressed in terms of the TFP of the leading economy. The leader is always ahead in terms of TFP compared to the other regions. Besides, the evolution of the TFP is exogenous.

Finally, the economy has three agents: households, firms and public sector. In this section, the regional decomposition of the world, agents' behavior as well as the equilibrium of the model are described.

3.1 Regions

The model shares the world in 10 regions. Sub-Saharan Africa (SSA) and the Chinese world (CHI) together with Eastern Europe (EAS), the Middle East and North Africa (MEN), Latin America and Caribbean (LAC), the Former Soviet Union (RUS) and the Indian world with the Pacific Islands (IND), belong to the 7 regions which are composed by developing countries. The three other regions comprise developed countries: North America (NAM) with the United-States and Canada, Japan (JAP) and the Advanced Countries (ADV), which include Western European Countries plus Australia and New-Zealand (cf. Appendix for more details).

3.2 Demography

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

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

where $N_{0,t}$ measures the initial size of generation t and m_{t-1} is one plus the demographic growth rate, including both fertility and migration. Each household lives a maximum of 8 periods ($a = 0, ..., 7$) but faces a cumulative survival probability decreasing with age[6]. The size of each generation declines deterministically through time.

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

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

[6] To avoid agent heterogeneity, migration flows are allowed only among individuals of the first age class. Population is calibrated in order to match the projections of the United Nations' Population Division Prospects (United Nations, 2006).

3.3 Preferences

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

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

where $c_{a,t+a}^j$ is the consumption of age class a at time $t + a$[7].

The budget constraint for skilled and unskilled individuals requires equality between the expected value of expenditures, i.e. consumption plus consumption taxes, and the expected value of income, which consists of net labor income, pension benefits and other welfare transfers (see appendix).

Individuals are born with no assets at time t, or in other words there are no bequests. At time $t + a$ with $a > 0$, assets of skilled and unskilled individuals depend on their assets in the previous period $t + a - 1$ plus an interest rate as well as on current expenditures (consumption) and income (labor income, pension benefits and other welfare transfers).

3.4 Firms

At each period of time, a representative firm uses efficient labor (L_t) and physical capital (K_t) to produce a composite good (Y_t). A Cobb-Douglas production function with constant returns to scale describes tha production process:

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \tag{4}$$

where α measures the share of wage income in the national product, and A_t is an exogenous process representing total factor productivity.

[7] A more general expected utility function would be:

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

where β is the time preference factor. However, the psychological discount factor β can be set to 1 as in equation 3, because the probabilities of being alive $P_{a,t+a}$ suffice to match the life-time assets profiles of the individuals.

The total efficient labor force is the sum of skilled and unskilled efficient labor forces:

$$L_t = \sum_{a=0}^{7} \phi_{t-a} N_{a,t} (1 - e_t^s) \lambda_{a,t}^s h_t^s$$
$$+ \sum_{a=0}^{7} (1 - \phi_{t-a}) N_{a,t} (1 - e_t^u) \lambda_{a,t}^u h_t^u, \quad (5)$$

where h^j measures the stock of education for a worker of type j (assuming $h^u = 1$ and $h^s > 1$), ϕ_t is the proportion of skilled individuals among generation t and $\lambda_{a,t+a}^j$ is the labor participation rate for a j type individual of age class a (determining if he receives a labor income or if he is entitled of pension benefits, see appendix).

3.5 Government

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

$$\pi = \frac{q}{q^o} \pi^o, \quad (6)$$

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

The risk premium π is modelled here as a government tax on investment. In a risky region, a part of an investor's return to capital is levied by the government, who uses it in general public spending. This share of returns to capital taken by the government is exactly equal to the risk premium. The government also issues bonds and pays interests on public debt. Thus the government's budget constraint may be written as:

$$d_{t+1} Y_{t+1} = R_t^* d_t Y_t - S_t, \quad (7)$$

where d represents the debt-to-GDP ratio, R^* is one plus the international interest rate and S is the government's surplus. Equation 7 says that public debt in $t+1$ depends on past debt in t and its interests minus taxes on capital and minus the government's surplus S. This last one corresponds to the difference between the government's income (taxes on labor earnings and on consumption) and its expenditures (pension benefits, other welfare transfers, general public spending and general redistribution of earnings on capital taxes).

Finally, the pension system is modelled in order to allow for either a Bismarckian, a Beveridgian or a hybrid pension systems in each region (cf Appendix section A.1.3).

3.6 Equilibrium

A competitive equilibrium of the economy with perfect capital mobility is characterized by

- *the optimal solutions to the household's maximization problem*
- *the optimal solutions to the firm's maximization problem*
- *the equilibrium on the labor market*
- *the equilibrium on the goods market*
- *a balanced budget constraint of the government*
- *the equality between the aggregate value of world assets and the market value of the world-wide capital stock plus the sum of the debts of all regions*
- *and finally the arbitrage condition of the rates of return to capital*

The government's budget constraint (7) is satisfied each period by adjusting the wage tax rate. The labor market equilibrium equalizes the demand for labor from firms to the labor supply i.e. when (5) is satisfied.

In an economy with perfect capital mobility, the aggregate value of world assets equals the market value of the world-wide capital stock plus the sum of the debts of all regions:

$$\sum_{x \in X} \Omega_t^x = \sum_{x \in X} (K_t^x + d_t^x Y_t^x), \tag{8}$$

where $X = \{NAM, ADV, JAP, SSA, MEN, LAC, IND, CHI, EAS, RUS\}$, K_t^x is the sum of the capital stock of region x at time t, Ω_t^x is the sum of the assets of all the cohorts of region x at time t, $d_t^x Y_t^x$ is the level of region x's debt at time t. A last equilibrium condition of an economy with perfect capital mobility is the arbitrage condition of the returns to capital. The domestic interest rate of region x (R^x) should be equal to the international interest rate (R^*) up to the risk premium of region x (π^x):

$$R_t^x = R_t^*(1 + \pi^x), \tag{9}$$

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

4 Calibration of the baseline scenario

This section first describes the data and explains the calibration of the main parameters as well as the main observed and unobserved exogenous variables, while a more detailed description of parameters and variables can be found in appendix. Then, in a second subsection, the baseline scenario and the assumptions on the future are defined. Finally, a third subsection illustrates the scenarios for Sub-Saharan Africa.

To forecast the evolution of the Sub-Saharan African economy in a world characterized by global aging, the model economies of ten world regions are calibrated. This calibration is achieved by fixing some constant parameters, using data for observed exogenous variables and choosing (arbitrary) values for unobserved exogenous variables in order to match a series of characteristics.

The period of interest is 2000-2100. The model is then calibrated in such a way that it matches the economic characteristics of each region and world disparities over the period 1950-2000. The initial steady-state is in 1870 and the analysis focuses on the transitional path of the world economy until it reaches the final steady-state in 2200.

4.1 Parameters and exogenous variables

Parameters are set a priori and are identical in all the regions. The capital share in output α is set to 0.33.

Observed exogenous variables comprise public debt d_t, the share of skilled individuals among one generation ϕ_t, growth rate of the 15-24 years age class m_t, probability of being alive $P_{a,t+a}$ and the region's risk ranking q. Public debt d_t is computed from the World Development Indicator Database (2006). Exceptions are the public debt of the Advanced Countries and Japan, which are obtained from OECD data (Gross Financial Liabilities). The share of skilled individuals among one generation ϕ_t is computed from the Barro-Lee Data Set, which gives the share of skilled individuals aged 25 to 74 for the years 1950 to 2000. The probability of being alive at time $t + a$ for an individual of generation t, $P_{a,t+a}$, and the growth rate of the 15-24 years old, m_t, are computed from the projections of the U.N. Population Division (United Nations, 2006) for the years 1950 to 2050 (medium variant). After 2050, the probability of being alive is hold constant and the growth rate of the 15-24 years old is set to 1. The calibration of all these variables is explained in detail in appendix.

Finally, region specific risk q is calibrated by using the data available from the OECD (2006), which rely upon the Knaepen Package methodology. The Knaepen Package is a system for assessing country credit risk and classifies countries into eight country risk categories (0 - 7), from no risk (0) to high risk (7). It basically measures the country credit risk, i.e. the likelihood that a country will service its external debt. An arithmetic mean of ratings of the available countries is taken to compute the risk classification per region. Table 1 lists the regions in an increasing risk order. For the Advanced Countries, North-America and Japan the risk is nil. The classification is assumed to be time-constant as the average *per region* is quite stable over the period 2000-2006. Moreover, if country risk is also an evaluation of corruption, I can rely on Arvind Jain (2001), who lists various sources of methodologies that measure corruption and concludes that "there appears to be a high degree of stability of corruption over years as measured by these sources".

Table 1: Investment risk rating q per region in the Baseline Scenario

	NAM	ADV	JAP	CHI	EAS	MEN	IND	LAC	RUS	SSA
2000-2100	0	0	0	3.18	3.40	3.95	4.89	5.19	6.17	6.40

Source: OCDE rating classification and own computations

Remark: ratings go from 0 (no risk) to 7 (high risk)

Main **unobserved exogenous variables** include total factor productivity A_t, the growth rate g_t of the leading economy and the maximum risk premium π^o. To obtain total factor productivity A_t, the GDP ratio (Y_t/Y_t^*) is used, where Y_t^* is the leader's GDP. As in de la Croix and Docquier (2004), TFP is calibrated via a backsolving identification method. It consists in swapping the exogenous variable A_t for the endogenous variable Y_t/Y_t^* and solving the identification step with the

Dynare algorithm (Juillard, 1995). The ratio of GDP's is computed by employing the data of the GDP per purchasing power parity from the World Development Indicators (2006) for the three years 1980, 1990 and 2000. The value of 1980 (respectively 2000) is hold constant for the years preceding 1980 (respectively following 2000). TFP growth of the leader, $g_t = A^*_{t+1}/A^*_t$, where A^* is the leader's TFP, is calibrated on observations. The future growth rate of the North-American TFP is calibrated to 1.2, which means that the annual growth rate is equal to 1.84%. The stock of education of an unskilled individual, h^u_t, is normalized to 1, whereas the one of skilled individuals is set to the arbitrary value of 2.35 in all the regions. Thus a skilled individual earns a 2.35 times higher wage than an unskilled individual. Finally, the maximum risk premium (π^o) is fixed to the arbitrary value of 0.5.

4.2 Baseline and assumptions on the future

In the baseline scenario (BSL), the distance of the TFP of each region to the TFP of the leading economy is assumed to be constant after 2000, except for the Eastern Countries, the Chinese World and the Indian World. In line with the recent accession of the majority of Eastern European countries to the European Union and with the last years' increased growth pace of India and China, it is assumed that these three regions will experience a TFP catch-up with the leader over the 21^{st} century. Table 2 shows the TFP of each region in percentage of the leader's economy (North-America) for the years 2000 and 2100 (from highest to lowest). In the baseline scenario the Eastern Countries will have increased their TFP compared to the leader's TFP by 25% in 2100. Moreover, I follow Ingenue (2005) in assuming that both the Chinese and Indian regions will have doubled their TFP compared to the leader's TFP by 2100. Hence, Chinese and Indian TFP's will pass from respectively 18.8% and 11.4% in 2000 to respectively 37.6% and 22.8% of the Northern American TFP in 2100.

In addition, the proportion of skilled individuals among each new generation as well as each region's risk ratings is hold constant from 2000 onwards. A minor assumption of the baseline scenario considers, in line with the policies conducted in many developed countries, that pension systems will be less generous in the near future because of population aging.

Finally, during the 21^{st} century the world economy is characterized by global aging. In general, the population of all the regions decreases in the long-run, but the aging process differs among the regions. In some regions, the population ages later or at a different pace than others. In general, this process is very strong

Table 2: TFP in % to the leader's TFP in the Baseline

Rank	Region	2000	Region	2100
1	NAM	100%	NAM	100%
2	JAP	98.5%	JAP	98.5%
3	ADV	95.4%	ADV	95.4%
4	EAS	42.6%	**EAS**	**53.2%**
5	LAC	31.8%	**CHI**	**37.6%**
6	RUS	24.8%	LAC	31.8%
7	MEN	23.5%	RUS	24.8%
8	CHI	18.8%	MEN	23.5%
9	IND	11.4%	**IND**	**22.8%**
10	SSA	8.4%	SSA	8.4%

Source: Own calibration

between 1980 and 2050 to reach a minimum level, the support ratio (number of people of working age for one pensioner) reaches its minimum level in the middle of the 21^{st} century and then starts to stabilize. The exception is Sub-Saharan Africa where the support ratio decreases only after 2050 and stabilizes at a higher long-run value than the other regions after 2100 (see figure 6 in appendix).

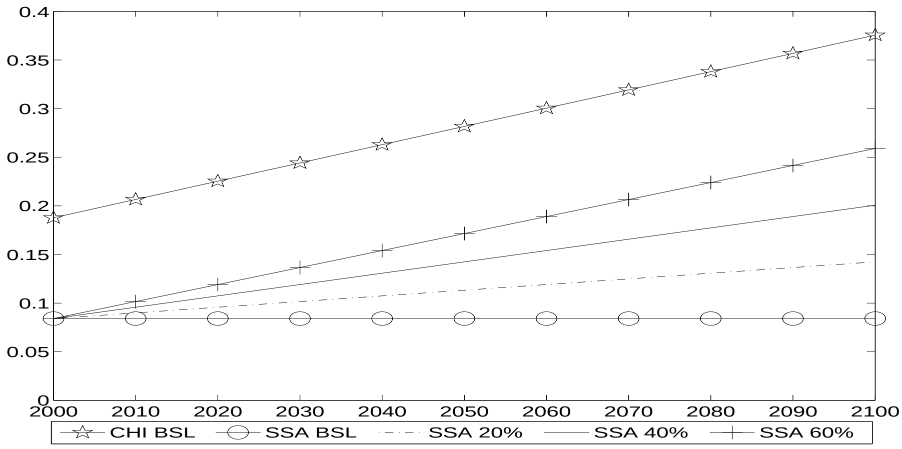
4.3 Three scenarios for Sub-Saharan Africa

The baseline scenario is compared to three optimistic scenarios in which the Sub-Saharan African economy experiences three structural changes during the 21^{st} century: a decrease in its risk rating, q, as well as an increase in its TFP, A_t, and in its worker skills, ϕ_t.

In the first scenario, labelled as "SSA 20%", the gaps in risk rating, TFP and worker skills of Sub-Saharan Africa to China are reduced by 20% in 2100. In scenarios 2 and 3, labelled as "SSA 40%" and "SSA 60%", these three gaps are reduced by respectively 40% and 60%. Figures 1 to 3 illustrate the evolution of these three variables in Sub-Saharan Africa under the different scenarios and compare it to the one in the Chinese World under the baseline scenario ("CHI BSL"). Sub-Saharan Africa's TFP A will pass from 8.4% under the baseline scenario in 2100 ("SSA BSL") to respectively 14.2%, 20% and 26% under respectively the "SSA 20%", "SSA 40%" and "SSA 60%" scenarios.

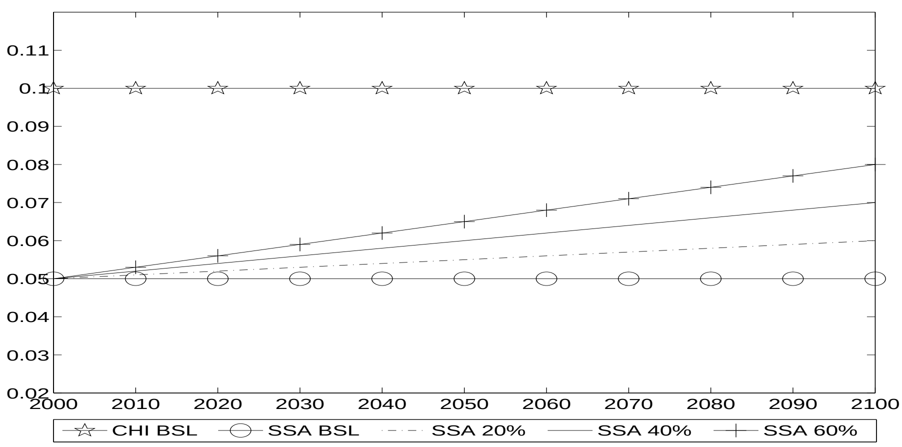
Similarly, the proportion of skilled among a new-born generation will attain 6%, 7% and 8% in 2100 under the "SSA 20%", "SSA 40%" and "SSA 60%" scenarios starting from 5% in the beginning of the century, whereas the risk rating

Figure 1: TFP A_t under three scenarios of increased Sino-African cooperation



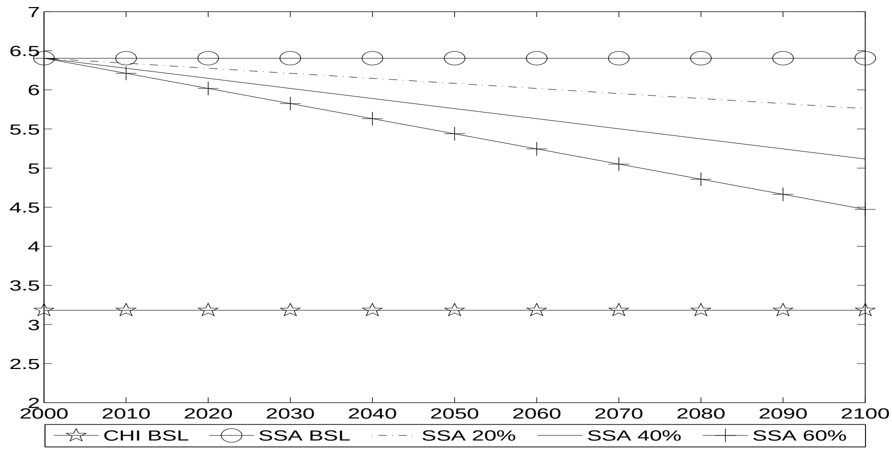
Own calibration and assumptions

Figure 2: Worker skills ϕ_t under three scenarios of increased Sino-African cooperation



will constantly improve from 6.40 in 2000 to respectively 5.76, 5.12 and 4.47 in 2100.

Figure 3: Risk rating q under three scenarios of increased Sino-African cooperation



Finally, it is assumed that there exists an inverse relationship between education and fertility (Becker and Lewis, 1973). Hence, the higher the increase in the proportion of skilled individuals among each generation in each of the three scenarios, the stronger the decrease in growth rate of the 15-24 years old m in Sub-Saharan Africa (cf Appendix A.2.5). After 2100, no region will experience any change in its economy.

5 Results

This section presents the effects of an improvement in three structural components of the Sub-Saharan African economy. How large are the benefits of a contemporaneous reduction in investment risk as well as increases in TFP and worker skills for the Sub-Saharan African economy? What are the effects of these shocks on North-South inequalities and on the world interest rate? First, the results of how the "SSA 20%", "SSA 40%" and "SSA 60%" scenarios affect per capita GDP in Africa are explained and then the effects on North-South inequalities and on the international interest rate are illustrated.

5.1 Effects on the African economy

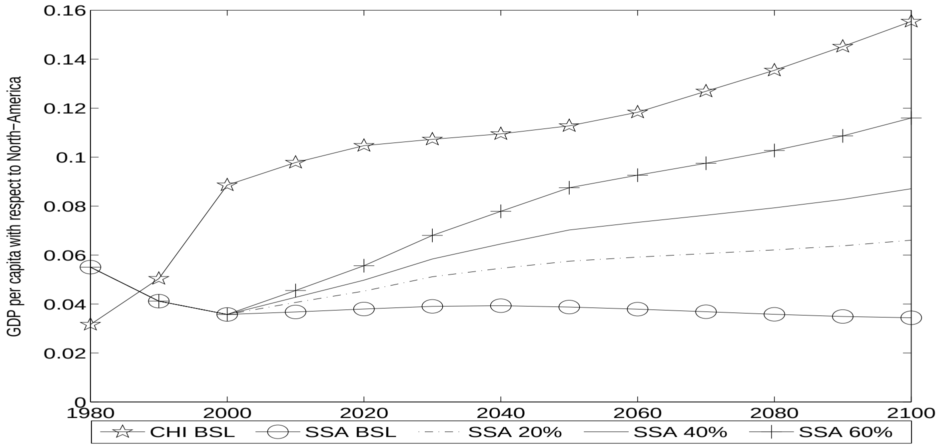
Figure 4 shows how per capita GDP evolves in the Chinese region ("CHI Bsl") and in Sub-Saharan Africa under the baseline scenario ("SSA BSL") and contrasts it with the scenarios of increased Sino-African cooperation "SSA 20%", "SSA 40%" and "SSA 60%". Africa's and China's per capita GDP correspond to 3.6% and 8.9% of North-America's per capita GDP in 2000. Under the three scenarios of increased cooperation, Africa's per capita GDP increases all over the 21^{st} century and its gap to the leading economy, North-America, shrinks. This continuous increase is due to the assumption that the Chinese economy steadily grows throughout the 21^{st} century and that Sub-Saharan Africa reduces its gaps to China in the three scenarios[8]. More importantly, we see that even a slight improvement in TFP, worker skills and risk environment (20% scenario) will almost double per capita GDP in Sub-Saharan Africa by 2050. When the three sources of economic improvement (in TFP, worker skills and risk environment) are taken separately, the increase in per capita GDP due to the increase in TFP explains the biggest part of the total increase in per capita GDP under each scenario[9]. Under scenarios "SSA 20%", "SSA 40%" and "SSA 60%", Sub-Saharan Africa's per capita GDP will have increased by 48%, 81% and 126% in 2050 and by 92%, 254% and 338% in 2100 compared to the baseline scenario. In these three scenarios the catch-up to China's per capita GDP is very strong until the mid-century.

Basically, these optimistic results rely upon Africa's demographic advantage over other regions during the first half of the 21^{st} century. During this period, Africa has still a steady supply in working force, while the population of the other regions start the aging process or are completing it. Thus, compared to other regions, Africa will have a greater potential in terms of working force over the first half of the 21^{st} century (see figure 6 in appendix). After 2050, even though per capita GDP continues to rise in the three scenarios, there is no more catch-up with China. While the ratio working force to total population is stabilized in China, the aging process in Sub-Saharan Africa begins in the second half of the 21^{st} century, because of the assumption of a constant growth rate of 15-24 years

[8] I assume a much lower growth rate in per capita GDP for the Chinese World from 2000 onwards than the trend during period 1980-2000 would predict. Nevertheless, Chinese per capita GDP grows continuously throughout the whole 21^{st} century and the perhaps weak TFP growth rate assumption for the early 21^{st} century maybe compensated by a steady long term TFP growth.

[9] In 2050 (respectively 2100), 89% (93.9%) of the increase in per capita GDP under scenario "SSA 20%" is due to the rise in TFP, 2.3% (2.4%) of it to the higher proportion of skilled individuals and 0.5% (0.77%) of it to the improvement in the risk environment. The residual effect of 8% (2.8%) is due to general equilibrium and interdependent effects.

Figure 4: Per capita GDP of SSA and CHI under three scenarios of increased Sino-African cooperation



old after 2050 in all regions. I have to observe that the present analysis does not take into account the impact of the AIDS epidemic on the African economy. In fact, the AIDS epidemic may considerably alter human capital accumulation, educational attainment and labor supply (Alvin Young, 2004). The present study relies on the fact that the reduction of the (young) population due to the AIDS epidemic is already taken into account by the Population projections of the UN (United Nations, 2006).

5.2 North-South inequalities

Table 3 classifies the regions according to their per capita GDP (with respect to North-America) for the years 2000, 2050 and 2100. We see that under the baseline scenario Sub-Saharan Africa remains the poorest region all over the $21st$ century, but its per capita GDP slightly increases compared to the leader because of its demographic advantage. Sub-Saharan Africa remains the poorest region also under the scenarios "SSA 20%" and "SSA 40%", but world inequalities decrease between the richest region and the poorest region by 5.1% $(= 1 - (1 - 0.079)/(1 - 0.029))$ under scenario 1 and by 7.6% under scenario 2. Under the most optimistic scenario, "SSA 60%", Sub-Saharan Africa manages to surpass the Indian World by 2100, even though India's per capita GDP more than doubles between 2000 and 2100. India's per capita GDP rises because of the baseline assumption that India's TFP

Table 3: World Ranking in per capita GDP (in % of North-America)

Rank	Region	2000	Region	2050	Region	2100
1	NAM	100%	NAM	100%	NAM	100%
2	JAP	96.4%	JAP	97%	JAP	93.2%
3	ADV	86.9%	ADV	83.1%	ADV	86.6%
4	EAS	26.6%	EAS	37.4%	EAS	35.9%
5	LAC	14.9%	LAC	18.8%	**CHI**	**23.3%**
6	RUS	14.2%	**CHI**	**18.7%**	LAC	18.8%
7	MEN	10.9%	RUS	17%	RUS	15.1%
8	CHI	9.4%	MEN	13.8%	MEN	14.9%
9	IND	4.7%	IND	9.6%	**SSA 60%**	**13.8%**
10	SSA 60%	2.9%	SSA 60%	7.1%	IND	13.2%
11	SSA 40%	2.9%	SSA 40%	5.7%	SSA 40%	10.4%
12	SSA 20%	2.9%	SSA 20%	4.7%	SSA 20%	7.9%
13	SSA BSL	2.9%	SSA BSL	3.2%	SSA BSL	4.1%

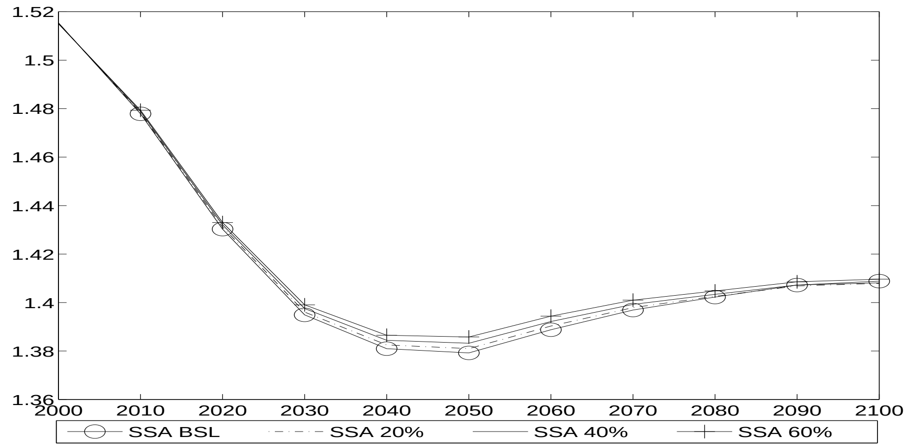
Note: SSA 60%, SSA 40%, SSA 20% and SSA BSL is the position of Sub-Saharan Africa under the different scenarios of increased Sino-African cooperation and under the baseline. In bold font, the regions that gained some position (s) compared to previous time column.

will double between 2000 and 2100, but also because India will experience a slower aging of its population compared to North-America according to U.N. population prospects (see figure 6 in appendix). Besides, China passes from the $8th$ position in 2000 to the $5th$ in 2100, benefiting from a rise in its TFP during the $21st$ century and from its slower demographic aging.

5.3 World interest rate

The evolution of the world interest rate is depicted in figure 5. In the reference case (as well as in the scenarios of increased Sino-African cooperation), the interest rate is declining strongly until mid-century to attain an annual interest rate of 3.26% in 2050 ($= 1.378^{1/10} - 1$). This can be explained by the strong aging of the world population during the first half of the 21^{st} century. It leads to a decrease in the labor force and to an increase in the capital-efficient labor ratio. Thus marginal productivity of labor increases whereas marginal productivity of capital decreases. From 2050 onwards the interest rate slightly increases again with the stabilization of the world population. In this paper, the international interest rate is equal to the rate of return to the leader's capital. Under the scenarios of increased Sino-African cooperation capital increases in Sub-Saharan Africa, thus more investment in Africa leads to a slight decrease in the capital stock of the other regions. Consequently, the international interest rate will slightly rise in response to the small drop in North-America's capital stock.

Figure 5: World interest rate under three scenarios of increased Sino-African cooperation



6 Conclusion

This paper analyses the (possible) beneficial effects of a Sino-African cooperation on Sub-Saharan countries over the 21^{st} century. I run scenarios in which Sino-African relations result *by hypothesis* in improvements of structural variables of Africa's economy over the 21^{st} century. The paper shows that a better investment environment, higher TFP and education levels of Africa's population lead to large increases in welfare levels in Sub-Saharan Africa in terms of per capita GDP.

However, improvements in these structural parameters of Africa's economy are introduced in a complete ad hoc manner and this paper has not the ambition to explain Africa's slow growth during the 20^{th} century only by its risky investment environment and its low TFP and education levels. Its aim is moreover not to give reasons for Africa's shortcomings in these three growth factors. Easterly and Levine (1997) as well as Artadi and Sala-i-Martin (2003) are good examples of studies exploring precisely the determinants of Africa's growth tragedy. This paper simply analyses scenarios in which governments of the black continent seize the opportunity of China's concern in their economies to overcome economic growth deterrents by exploiting their demographic advantage (slower population aging).

Several extensions may undoubtedly enrich this model. It would be interesting to endogenize the educational choice (i.e. the time spent in education) of the individuals. Besides, endogenizing total factor productivity would considerably improve the quality of the model. Ultimately, including foreign aid would provide a better framework to study more extensively capital inflows to Africa and its future economic performance. These issues are left for future research.

References

1. Aidt T.S. (2003), "Economic analysis of corruption: a survey", The Economic Journal, vol. 113, F632-F652

2. Artadi V. and X. Sala-i-Martin, (2003) "The Economic Tragedy of the XXth Century: Growth in Africa," NBER Working Papers 9865, National Bureau of Economic Research, Inc.

3. Becker, G.S., Lewis, H.G., 1973. On the interaction between the quantity and quality of children. Journal of Political Economy 81, S279 S288

4. Blackburn K., Bose N. and M. E. Haque (2004), "Endogenous Corruption and Economic Dvelopment", University of Nottingham, GEP Research Paper No. 2004/16

5. Börsch-Supan A., Ludwig A. and J. Winter (2005)"Aging, pension reform, and capital flows: A multi-country simulation model", NBER Working Paper No. 11850

6. Börsch-Supan A., Ludwig A. and J. Winter (2001) "Ageing and International Capital Flows", NBER Working Paper No. 8553

7. De la Croix, D. and F. Docquier (2003), "Diverging patterns of education premium and school attendance in France and the US; a Walrasian view", IRES Discussion Paper, n 10-2003

8. Easterly, W. and R. Levine, (1997), "Africa's Growth Tragedy: Policies and Ethnic Divisions," The Quarterly Journal of Economics, MIT Press, vol. 112(4), pages 1203-50, November .

9. Feroli M.(2003), "Capital Flows Among the G-7 Nations : A Demographic Perspective", Federal Reserve Bank, Finance and Economics Discussion Series Papers 54-2003

10. Ingenue Team (2001a), "Vieillissement démographique et transferts internationaux d'épargne : Premiers enseignements du modèle INGENUE", Revue d'économie politique, avril 2001, pp. 195-214

11. Ingenue Team (2001b), "Macroeconomic consequences of pension reforms in Europe : An investigation with the INGENUE World Model", working paper, Cepii-Cepremap-Ofce

12. Ingenue Team (2004), "Ingenue v.2: A world OLG-CGE Model with Imperfect Financial Markets, Exchange Rates and Stochastic Lifetime", working paper

13. Jain, A. K. (2001), "Corruption: a review", Journal of Economic Surveys, vol. 15(1), pp. 71-121

14. Juillard, M. (1995) "DYNARE, a program for the resolution of non-linear models with forward-looking variables. Release 1.3", Paris: CEPREMAP.

15. Lucas, R. E. (1988): "On the Mechanics of Economic Development", Journal of Monetary Economics, 22, 3-42.

16. Mankiw, N. G., D. Romer, and D. N. Weil (1992): "A Contribution to the Empirics of Economic Growth", Quarterly Journal Of Economics, 107(2), 407-437.

17. Mauro P. (1995), "Corruption and growth", Quarterly Journal of Economics, vol. 110, pp. 681-712. Reprinted in Williams et al. (2000) vol. 1, chapter 14.

18. OECD (2006), Country Risk Classification

19. United Nations (2006), World Population Prospects: The 2006 Revision

20. Wei S. (1999),"Corruption in economic development - beneficial grease, minor annoyance, or major obstacle?," Policy Research Working Paper Series 2048, The World Bank

21. Shleifer A. and R. W. Vishny, (1993) "Corruption", Quarterly Journal of Economics, 108, 3, 99-617

22. Williamson J. (2001), "Demographic shocks and Global Factor Flows", Conference Series ; [Proceedings], Federal Reserve Bank of Boston

23. World Development Indicators (2006)

24. Young A. (2004), "The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations", NBER Working Paper, No. 10991

A Appendix

A.1 Model

A.1.1 Regions

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

1. **North America (NAM)**: United States and Canada.
2. **Advanced Countries (ADV)**: Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.
3. **Japan (JAP)**: Japan.
4. **Eastern Europe (EAS)**: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Poland, Romania, Serbia and Montenegro, Slovakia and Slovenia.
5. **Middle East and North Africa (MEN)**: Algeria, Bahrain, Cyprus, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Malta, Morocco, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates and Yemen.
6. **Latin America and Caribbean (LAC)**: Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela.
7. **Sub-Saharan Africa (SSA)**: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Congo Democratic Republic, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Ivory Coast, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and

Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

8. **Former Soviet Union (RUS)**: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

9. **Chinese world (CHI)**: Brunei, Burma, Cambodia, China, East Timor, Hong Kong, Korea, Lao People's Democratic Republic, Macau, Mongolia, Philippines, Singapore, Thailand and VietNam.

10. **Indian world and Pacific Islands (IND)**: Afghanistan, Bangladesh, Bhutan, Federated States of Micronesia, Fiji, India, Indonesia, Malaysia, Maldives, Nepal, Pakistan, Papua New Guinea, Samoa, Solomon Islands, Sri Lanka, Tonga and Vanuatu.

A.1.2 Households

The budget constraint of unskilled (u) and skilled (s) individuals requires equality between the expected value of expenditures and the expected value of income, which consists of labor income (w), pension benefits (b) and other welfare transfers (tr). It is written as follows:

$$\begin{aligned}
&\sum_{a=0}^{7} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}}(1+\tau^c_{t+a})c^j_{a,t+a} \\
&= \sum_{a=0}^{7} \lambda^j_{a,t+a} \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}}(1-e^j_{t+a})(1-\tau^w_{t+a})w_{t+a}h^j_{t+a} \\
&+ \sum_{a=0}^{7} (1-\lambda^j_{a,t+a}) \frac{P_{a,t+a}}{\prod_{v=1}^{a} R_{t+v}} b^j_{t+a} + \sum_{a=0}^{7} \psi_{t+a} tr^j_a w_{t+a} h^j_{t+a}, \qquad j=s,u \qquad (10)
\end{aligned}$$

where $\lambda^j_{a,t+a}$ is the labor participation rate for a j type individual of age class a, w_t is labor income, R_t is one plus the interest rate, τ^c_t is consumption tax, τ^w_t income tax, b^j_t (individual) pension benefits, tr^j_a are other welfare transfers received by an individual of type j and they are represented as a time-constant fraction of labor income, the generosity factor ψ_t is the factor by which these other welfare transfers are multiplied at time t and finally h^j measures the stock of education for a worker of type j (assuming $h^u = 1$ and $h^s > 1$). Education is exogenous and individuals spend a fraction e_t^j of their total time (which is only positive in the first period of life).

Individuals are born with no assets, or in other words there are no bequests. Formally, at the beginning of their first period of life (when $a = 0$), $Z_{0,t}^j = O$ for all t. For $a > 0$, aggregated assets of skilled (Z^s) and unskilled individuals (Z^u) are represented by the two following equations:

$$\begin{aligned} Z_{a+1,t+a+1}^s = R_{t+a} Z_{a,t+a}^s + \phi_t N_{a,t+a}[(1-\tau_{t+a}^w) \\ (1-e_{t+a}^s)\lambda_{a,t+a}^s w_t h_{t+a}^s \\ -(1+\tau_{t+a}^c)c_{a,t+a}^s + (1-\lambda_{a,t+a}^s)b_{t+a}^s] + \psi_t tr_a^s w_t h_{t+a}^s \end{aligned} \tag{11}$$

$$\begin{aligned} Z_{a+1,t+a+1}^u = R_{t+a} Z_{a,t+a}^u + (1-\phi_t) N_{a,t+a}[(1-\tau_{t+a}^w) \\ (1-e_{t+a}^u)\lambda_{a,t+a}^u w_t h_{t+a}^u \\ -(1+\tau_{t+a}^c)c_{a,t+a}^u + (1-\lambda_{a,t+a}^u)b_{t+a}^u] + \psi_t tr_a^u w_t h_{t+a}^u, \end{aligned} \tag{12}$$

where $N_{a,t}$ is the number of individuals of age class a living at time t, ϕ_t is the proportion of skilled individuals.

A.1.3 Government Surplus

The government levies taxes on labor earnings (t_t^w) and on consumption expenditures (t_t^c) to finance general public consumption (c_t^g), social security transfers (tr_{a+1}^j) and pension benefits (b_{a+1}^j). The government surplus (S_t) can be written as:

$$
\begin{aligned}
S_t &= \tau_t^w L_t w_t \\
&+\tau_t^c[\sum_{a=0}^{7}\phi_{t-a}N_{a,t}c_{a,t}^s + \sum_{a=0}^{7}(1-\phi_{t-a})N_{a,t}c_{a,t}^u] \\
&-b_t^s\sum_{a=0}^{7}\phi_{t-a}N_{a,t}(1-e_t^s)(1-\lambda_{a,t}^s) \\
&-b_t^u\sum_{a=0}^{7}(1-\phi_{t-a})N_{a,t}(1-e_t^u)(1-\lambda_{a,t}^u) \\
&-\psi_t w_t h_t^s\sum_{a=0}^{7}\phi_{t-a}N_{a,t}(1-e_t^s)tr_a^s \\
&-\psi_t w_t h_t^u\sum_{a=0}^{7}(1-\phi_{t-a})N_{a,t}(1-e_t^u)tr_a^u \\
&-c_t^g Y_t,
\end{aligned}
\tag{13}
$$

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

The regional pension systems are partly Bismarckian and Beveridgian depending on the value of ρ comprised between 0 and 1.

$$
b_t^j = \chi_t w_t(h_t^j\rho + 1 - \rho), \tag{14}
$$

where χ_t is the replacement rate (< 1).

A.1.4 Equilibrium conditions

Maximizing utility (3) under the households budget constraint (10) w.r.t. the levels of consumption determines the optimal (contingent) levels of consumption for both types of households:

$$
c_{a+1,t+a+1}^j = \beta_{t+a}^a R_{t+a+1} c_{a,t+a}^j, \qquad j = s, u \tag{15}
$$

where β is set to 1 (see text). The profit maximization by firms requires the equality of the marginal productivity of each factor to its rate of return:

$$
(1-\alpha)K_t^\alpha A_t^{1-\alpha}L_t^{-\alpha} \quad = \quad w_t, \tag{16}
$$

$$1 + \alpha K_t^{\alpha-1}(A_t L_t)^{1-\alpha} - \delta \quad = \quad R_t, \tag{17}$$

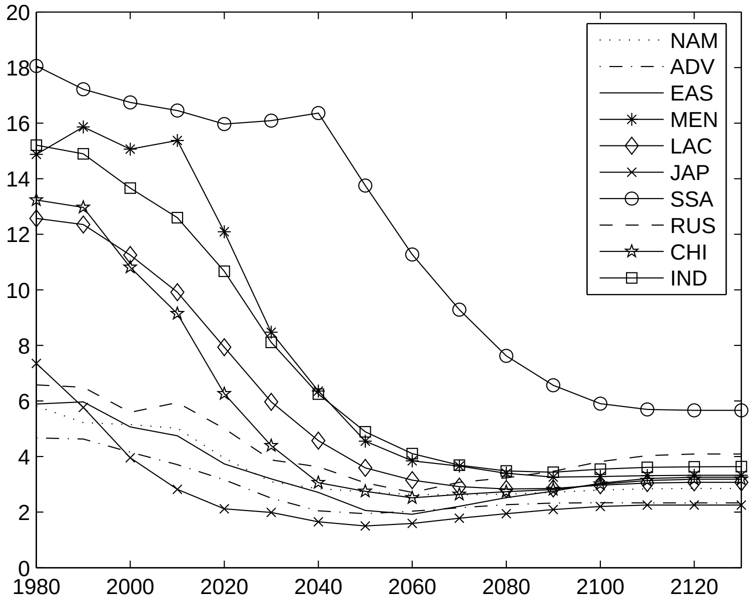
where δ represents the depreciation rate of capital.

A.2 Data and Calibration

A.2.1 Demographic Transition among world regions

Figure 6 illustrates the population aging process that occurs all over the world in the 21st century and more precisely the evolution of the support ratio of the 10 regions during the 21st century. The support ratio is a general indicator of the aging process and is defined as the number of people of working age for one pensioner.

Figure 6: Support ratios of the 10 world regions



Source: UN Population Prospects and own calibration

The support ratio decreases in the long-run for all the regions. However, the population of some regions ages later or at a different pace than others. Nevertheless there are some similarities in the evolution of the support ratio of all the regions. For almost all of them, the support ratio first strongly decreases between 1980 and 2050 to reach a minimum level between 2050 and 2090 and then it weakly recovers to stabilize at a long run value lying between 2 to 4 after 2100. The exception is the region of Sub-Saharan Africa where the support ratio only slowly decreases between 1980 and 2020, then weakly recovers until 2040, but then strongly decreases until 2100 (due to the assumption of zero growth of the 15-24 years age class after 2050) and then reaches a stable value around 5,66 after 2100.

A.2.2 Parameters

Five parameters are set a priori, of which two are identical (δ and α) for all the regions. The depreciation rate of capital, δ, equals 0.4. This value implies an annual depreciation rate of capital of about 5.5%. The capital share in output, α, is 0.33.

The pension scheme parameter, ρ, is specific to each region. For North-America it equals 0.2, for the Advanced Countries it corresponds to 0.6 and for Japan it equals 0.8. In all the other regions, the pension systems are supposed to be Beveridgian and the parameter is thus set to 0.

Finally, the data for the social security transfer profiles (tr_a^j) come from a US and European generational accounting study (Chojnicki, 2005). For the Advanced Countries and for Japan the time-constant transfer profiles are the same. The transfers of unskilled (skilled) individuals amount to 10% (3%) when aged 15 to 24 years, to 18% (6%) between 25 and 64 years, to 20% (10%) when aged 65 to 74 and 22% (15%) when they are above 75. The transfers in the other regions are in most cases less generous. Unskilled (skilled) individuals obtain transfers equal to 7% (0.5%), 12% (1%), 20% (6%) and 25% (12%) of their labor income when they belong respectively to the age classes 1, 2 to 5, 6, and 7 to 8.

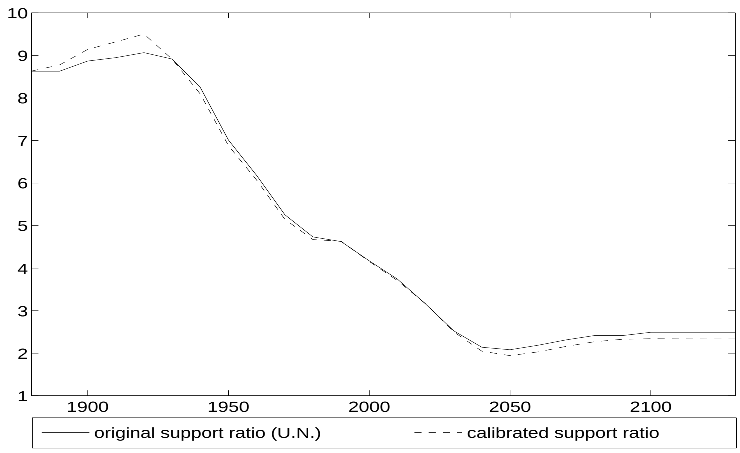
A.2.3 Observed Exogenous Variables

Public debt, d_t, and public spending, c_t^g. Public debt and public spending are computed from the World Development Indicator Database. Exceptions are the public debt of the Advanced Countries and Japan, which are obtained from the data of the OECD (Gross Financial Liabilities).

Demography. The growth rates of the 15-24 years old m_t and probabilities of being alive $P_{a,t+a}$ for the period 1870-2200 are obtained in two steps. In the first step, the probabilities of being alive at each period and the growth rates of the 15-24 years old *directly* are computed from the U.N. Population Division dataset. It gives the population per age group from 1950 to 2050 for almost every country in the world. Past and future growth rates of the 15-24 years old as well as the probabilities of being alive per age group for the period 1950 to 2050 are obtained directly from the population per age group. By applying the probabilities of being alive of 1950 to the years 1880 to 1940, the growth rate of the 15-24 years old is derived until 1880. The age groups beyond the year 2050 are created by applying the probabilities of being alive of 2050 to the years 2060-2130 and fixing the growth rate of the 15-24 years old to 1, except for the region of North-America, where the growth rate is set to 1.05 to take into account of the large volume of migration to the US. Then from 2190 on, the growth rate of the population is set to one for all the regions. However, the some of the so obtained probabilities to survive appear to be larger than 1 for some of the regions and for some age classes (i.e. regions ADV, NAM and JAP). If a age class in of the 10 regions has a probability of being alive above 1, it means that the region experienced an immigration inflow from other regions. Thus I have to make several assumptions in order to avoid problems of agent heterogeneity in the model, because migrants may have different characteristics than natives (e.g. human capital differences, different savings behaviour, different assets etc). In fact, if individuals are allowed to migrate in the model, there will be more than 2 types of individuals. This would complicate by much the computation of the steady-states and of the transition. Hence in a second step, migration during lifetime is excluded. Figure 7, which compares the support ratios (defined as the number of people of working age for one pensioner) obtained with the original data from the U.N population and with the calibrated data for the Advanced Countries. Note that as the probabilities of being alive and the growth rates of the 15-24 years old are hold constant from 2050 onwards, the population in each region will be constant since 2130 (except for North-America).

Share of skilled individuals, ϕ_t. The Barro-Lee Data Set is used to compute the share of skilled individual. It gives the share of skilled individuals aged 25 to 74 for the years 1950 to 2000. This data has to be disaggregated to obtain the share of skilled individuals per age group. It is not unreasonable to think that at each period the share of skilled individuals is highest among the youngest age classes. In particular, the share of skilled individuals aged 65 to 74 corresponds arbitrarily to 80% of the share of skilled aged 55 to 64, which in turn is equal to 80% of that of the 45-54, which finally corresponds to 80% of that of the 35-44, and which finally equals 80% of the share of skilled aged 25-34. The share of skilled of the older age classes, 75-84 and 85-94, is also determined by this "80%" assumption. As all the shares of skilled per age class depend on the share of skilled

Figure 7: Original and calibrated support ratios in the Advanced Countries



Source: UN Population Prospects and own calibration

aged 25-34, I compute this share in order that it matches the total share of skilled of 1950 given by the Barro-Lee Dataset. The values of the shares of the age classes 25-34 to 65-74 are then reported to the following years. For example, the share of skilled aged 35-44 in 1960 is equal to the share of skilled aged 25-34 in 1950 (as skilled and unskilled individuals are assumed to have the same probability to be alive at the beginning of each period). For all the following years, the share of skilled aged 25-34 is computed in the same way than for the year 1950. The share of skilled aged 15 to 24 in 1950 is simply equal to the share of skilled aged 25-34 in 1960.

A.2.4 Unobserved Exogenous Variables

Labor participation, λ_t^u and λ_t^s. The skilled and unskilled labor participation rates (respectively λ_t^s and λ_t^u) are set to 1 for the age groups 15-24, 25-34, 35-44 and 45-54. For the individuals aged 55-64, the participation rates equal 0.5 for all the regions, except for the participation rate of the *skilled* individuals of North-America, Japan and the Advanced countries that is set to 0.7. The participation rate for the three last age groups equals 0 for all the regions.

Time spent in education, e^s and e^u. Time spent in education is set to 0.6 for skilled individuals. Time spent in education for unskilled individuals equals

0.2 in North-America, Japan and the Advanced countries, whereas it is set to 0 for the other regions.

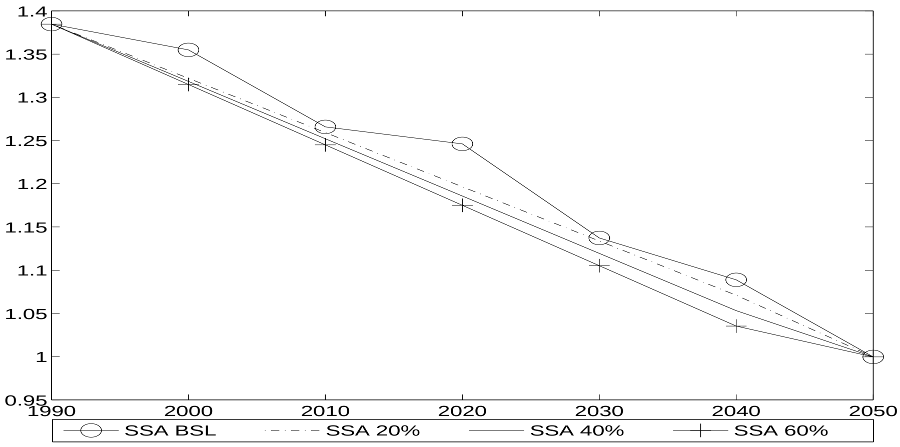
Replacement rate, θ_t. The replacement rate is calibrated in order to match the share of public pension spending to GDP of the year 1990. The data for this last variable come from Table A.5 of Palacios (1994) and the World Bank (1994). The replacement rate of 1950 is assumed to correspond to 3/4 of the one of 1990. The replacement rates of 1960, 1970 and 1980 are chosen in order to build an linear upward trend between 1950 and 1990. The ones before 1950 are kept identically to the value of 1950, whereas the replacement rates after 1990 correspond to the value of 1990.

Generosity factor of the social security transfers, ψ_t. This factor is set arbitrarily by assuming that the generosity factor increased during the period 1950-2000. It is thus set to 0.25 in 1950 and the years before and to 0.4 in 1960, to 0.55 in 1970, to 0.7 in 1980, to 0.95 in 1990 and to 1 in 2000 and afterwards.

A.2.5 Scenarios for Africa

An inverse relationship between education and fertility is assumed following the line of Becker and Lewis (1973). Hence, the higher the increase in the proportion of skilled individuals among each generation in each of the three scenarios, the stronger the decrease in the growth rate of the 15-24 years old m_t in Sub-Saharan Africa. Under the baseline scenario, the Sub-Saharan African growth rate of the 15-24 years old decreases over the first half of the 21_{st} century following the projections of the UN Population Division (Figure 8). Moreover, after 2050, it s assumed that population does not grow anymore and thus the growth rate of the 15-24 years old m_t is equal to 1 for $t \geq 2050$ (and m_t represents the growth rate of the 15-24 years old between N_{t+1} and N_t). Under the scenarios of increased Sino-African cooperation, the gap of the growth rates of the 15-24 years old in 2040 and 2050 is assumed to be reduced by 20% in scenario 1, by 40% in scenario 2 and by 60% in scenario 3. In Figure 8 the decrease in the growth rate of the 15-24 years old is faster, the higher the catching-up in the proportion of skilled African individuals among one generation ϕ^{SSA} with the Chinese proportion ϕ^{CHI}. Also for scenarios 1, 2 and 3, the growth rate of the 15-24 years old is assumed to be equal to one after 2050.

Figure 8: Growth rate of the 15-24 years old m under three scenarios of increased Sino-African cooperation



Source: UN Population Prospects and own calibration

Département des Sciences Économiques
de l'Université catholique de Louvain
Institut de Recherches Économiques et Sociales

Place Montesquieu, 3
1348 Louvain-la-Neuve, Belgique

ISSN 1379-244X D/2007/3082/014