Income disparities, population and migration flows over the 21st century*

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Abstract. This paper provides worldwide projections of population, educational attainment, international migration and income for the 21st century. We develop and parametrize a dynamic, stylized model of the world economy that accounts for the key interdependencies between demographic and economic variables. Our baseline scenario matches the 'high-fertility' population prospects of the United Nations, assumes constant education and migration policies, long-run absolute convergence in total factor productivity (TFP) between emerging and high-income countries, and absence of takeoff in Africa. It predicts a rise in the income share of Asia (from 38 to 59 percent of the world income) and in the demographic share of Africa (from 10 to 25 percent of the world population). However, over the 21st century, the worldwide proportion of adult migrants will only increase by one percentage point (from 3.5 to 4.5 percent). Half of this change is explained by the increased attractiveness of China and India; and the remaining part is explained by the increased migration pressure from Africa to Western Europe. Keeping its immigration policy unchanged, the European Union will see its average immigration rate increase from 7.5 to 17.2 percent. Then, we assess the sensitivity of our projections to changes in migration policies, TFP disparities, fertility and education. The evolution of productivity in emerging economies and in Africa will have a drastic impact on the worldwide population size, income disparities and the migration pressure to the European Union. Effects are magnified if TFP convergence is accompanied by a fall in immigration restrictions in emerging countries. *Keywords*: income and population prospects, migration, world economy, growth, inequality.

1. Introduction

Demographic and economic disparities between countries have intensified over the 20th century. The share of Western Europe and Western offshoots in the world population decreased from 20.5 to 11.4 percent between 1900 and 2010 (Maddison, 2007); and according to the United Nations (2014), the demographic share of the most developed countries decreased from 32.2 to 17.9 percent between 1950 and 2010. At the same time, the global distribution of income has shown extraordinarily large shifts,

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with a small group of rich countries growing much faster than the rest of the world. Over the 20th century, inflation-adjusted GDP per capita was multiplied by 6.5 and 6.8 in Western Europe and Western offshoots. It was multiplied by 5.3 in South America, by 3.1 in South-East Asia and by 2.4 only in Africa. Since the beginning of the 19th century, the world distribution of income has been more and more unequal: the level of the Theil index has increased from 0.45 to 0.80 and its across-country component has risen from 0.08 to 0.50 (see Bourguignon and Morrisson, 2002; Sala-i-Martin, 2006).

Changes in aggregate population and income levels as well as in their distribution across countries have drastic implications for the world economy. They affect the world's ability to manage its natural resources, the distribution of political power and political tensions, the development assistance from rich nations and international agencies. These effects are uncertain and hard to predict.[1] Importantly, in a world of increasingly porous boundaries, millions of workers seek to reduce the gap between their own position and that of people in other, wealthier, places. Increased disparities, in terms of population, wages, labor market opportunities or lifestyles, affect the size and structure of international migration flows as well as the location decisions of migrants (Grogger and Hanson, 2010; Belot and Hatton, 2008).

Predicting the evolution of income and population disparities across countries is important. In particular, it may help us understanding the forces governing the supply of migrants and the evolution of migration flows. Historically, the number of international migrants has increased from 92 to 211 million between 1960 and 2010, following the level of the world population. Hence, the worldwide average migration rate has been fairly stable at around 3 percent of the world population. However the proportion of foreign-born in the population of high-income OECD countries has increased from 4.6 to 10.9 percent over the same period, and the proportion of immigrants originating from developing countries has skyrocketed from 1.5 to 8.0 percent. Immigration has become a key policy issue in high-income countries and it is important to identify the factors that will govern future migration flows. Over the last three decades, the takeoff of China, India and other emerging countries has probably shaped the size and structure of migration flows, inducing a fall in the supply of migrants from these two countries to Western destinations. The evolution of the population, productivity and immigration policies in these transition economies is likely to have drastic effects on the future of the world economy and the allocation of international migrants, especially if these countries become increasingly attractive for foreign workers. In addition, the macroeconomic and demographic prospects for sub-Saharan African countries are other key determinants of future migration flows. Indeed, over the past

[1] For example, the relationship between economic growth and environmental quality is not fixed along the development path. It changes as a country reaches a level of income at which people can demand and afford a more efficient infrastructure and a cleaner environment. This may imply an inverted-U relationship between environmental degradation and economic growth, known as the Environmental Kuznets Curve (Grossman and Krueger, 1995). Recent evidence shows however, that developing countries are addressing environmental issues, sometimes adopting developed country standards with a short time lag and sometimes performing better than some wealthy countries (Stern, 2004; Dasgupta et al., 2002). As far as terrorism is concerned, exploratory evidence in Kruger and Maleckova (2003) suggests that neither poverty nor education has a direct, causal impact on terrorism. See also Milanovic (2005) on the political consequences of income and population disparities.

decades, the evolution of South-North migration flows has been governed by the evolution of the population size in developing countries. The migration pressure is likely to intensify as the share of this continent in the world population is expected to increase threefold in the course of the 21st century (United Nations, 2014). This could drastically affect Europe, the main destination of African emigrants. The evolution of the African economy will be another key determinant of the worldwide supply of migrants.

Predicting the distributions of income, population and migration is a complex task given the strong interdependencies between these variables. These interdependencies have rarely been accounted for in projection exercises. For example, the demographic projections of the United Nations do not anticipate the economic forces and policy reforms that shape demography (see Mountford and Rapoport, 2014). They assume long-run convergence toward low fertility and high life expectancy across countries, and constant immigration flows. The UN methodology disregards interdependencies between fertility, mortality and migration scenarios, and their interplay with the evolution of human capital and the world distribution of income. The recent IIASA projections include the educational dimension (see Samir et al, 2010), predicting the population of 120 countries by level of educational attainment, and accounting for differentials in fertility, mortality and migration by education. However assumptions about future educational development (e.g. partial convergence in enrolment rates) are also rather deterministic and seemingly disconnected from changes in the economic environment. Given the high correlation between economic and socio-demographic variables, assuming cross-country convergence in demographic indicators implicitly suggests that economic variables should also converge in the long-run. This is not what historical data reveal (see Sala-i-Martin, 2006).

The general premise of this paper is that the interdependencies between economic and demographic cannot be disregarded. We develop and parametrize a dynamic, stylized model of the world economy with endogenous income disparities, migration, fertility and education decisions. The model accounts for the links between (skill-biased) emigration prospects, investment in human capital and population growth. It distinguishes between 195 countries, populated by two types of adult worker and their offspring. Inevitably, our stylized model omits several important features of the real world. It does not account for all demographic variables (such as urbanization, mortality, network externalities, aging) and economic variables (such as trade, unemployment, redistribution, capital movements). However it accounts for the long-run interactions between human capital accumulation, migration and growth. We believe such a quantitative theory framework is an appropriate tool to identify the key factors governing the future of the world economy and migration flows. Using scenarios about the evolution of total factor productivity (TFP), education and fertility policies, and immigration barriers, we jointly predict the evolution of income inequality, population growth, and migration flows over the 21st century.

Overall, our results indicate that the trajectory of the world economy is highly sensitive to the technological environment. In particular, the evolution of productivity in transition economies and, to a lesser extent, in Africa will have a drastic impact on the worldwide population size, income level and inequality. If the takeoff of emerging countries is accompanied by a relaxation of migration costs to these countries, this will increase the world income, reduce inequality and reduce the migration pressure in the current main destination countries. In all scenarios, the migration pressure will intensify in Europe. Keeping immigration policy unchanged, the average immigration rates to the EU15 could increase from 7.5 to 17.2 percent. Changes in fertility and educational policies affect the world population and have limited macroeconomic effects; however they have drastic effects on European immigration rates. Our results show that the situation in Europe is closely connected to the demographic and economic futures of Africa. Aslow and partial convergence in TFP between Africa and high-income countries or a decrease in African birth rates could attenuate the rise in European immigration by 3 percentage points in the long-run.

The remainder of the paper is organized as following. Section 2 provides a non-technical description of our model (for a more detailed description, see Delogu et al., 2013). Section 3 describes its parametrization and the baseline projections for the 21st century. The sensitivity of our projections to migration policies, technological and demographic environments will be analyzed in Section 4. Finally, Section 5 concludes.

2. A dynamic model of the world economy

Our model covers the world economy over the period 2000-2100. It endogenizes income disparities between and within 195 countries ($k=1,...,K$), bilateral migration by education level, fertility and education decisions. It assumes one-period lived adult decision-makers and countries characterized by heterogeneous levels of TFP, education subsidy and country-specific attitude towards child labor. The trajectory of these country-specific characteristics determines individual decisions and the productive potential of nations.

Adults maximize their well-being and decide where to live, whether to invest in their own (higher or college) education, how much to consume, and how much to invest in the basic education of their children. We distinguish between college-educated adults and the less educated ($s=h,l$). We assume that preferences are represented by a two-level nested utility function. The outer utility function has a deterministic and a random components. For an individual of type s in cohort t, the utility moving from a country of origin k to a country destination i is denoted by $U_{ki,s,t}$ and depends on four terms: an endogenous destination-specific component, $v_{i,s,t}$, the effort to move from the origin to the destination country (reflecting the effort to obtain a visa and private migration costs), $m_{ki,s,t}$, the effort to acquire higher education (if acquired) in the origin country, $e_{k,s,t}$, and a migration taste shock reflecting heterogeneous preferences for alternative locations, $\varepsilon_{ki,s,t}$.

We use the following logarithmic specification:

(1) $U_{ki,s,t} = \log(v_{i,s,t}) + \log(1- m_{ki,s,t}) + \log(1- e_{k,s,t}) + \varepsilon_{ki,s,t}$.

The maximization of this outer utility function, which basically involves a comparison between discrete education and migration options, determines the education structure of the adult population, the number of bilateral migrants and the number of non-migrants. Indeed, the latter two components of outer utility function vary across individuals. The effort to acquire higher education ($e_{k,s,t}$) follows a Pareto distribution – the density of ability decreases with the level of ability – with country-specific parameters. The migration taste shock ($\varepsilon_{ki,s,t}$) follows an extreme-value distribution of type 1. Hence, as shown in McFadden (1984), the ratio of migrants to non-migrants is given by a logit expression. Hence, not everyone wants to acquire college education, wants to emigrate or choose the same location.

The inner utility function determines $v_{i,s,t}$, the destination-specific component of the outer utility function. It is assumed to be a Cobb-Douglas function of private consumption ($c_{i,s,t}$), fertility ($n_{i,s,t}$) and the proportion of children receiving basic education ($q_{i,s,t}$). In logs, we have:

(2) $\log(v_{i,s,t}) = (1-\theta) \log(c_{i,s,t}) + \theta \log(n_{i,s,t}) + \theta\lambda \log(q_{i,s,t})$,

where (θ,λ) are preference parameters.

After migration, adults maximize this inner utility function subject to a standard budget constraint, which include the time cost of raising children (τ per child), the cost of providing basic education and child labor. Fertility and basic-education decisions govern population growth and the proportion of children receiving basic education. Only those who received basic education when they are young will be able to invest in college education in the next period.

The outer and inner utility functions are interrelated. When deciding to emigrate or stay in their home country, individuals anticipate $\log(v_{i,s,t})$, the optimal level of (inner) utility attainable in all possible destinations, and $m_{ki,s,t}$, the effort required to emigrate. Hence, destination choices are governed by differences in income, (basic and higher) education policies, and migration costs. The sum of type-s adults deciding to live in country k is denoted by $N_{k,s,t}$: their labor supply is denoted by $L_{k,s,t}= N_{k,s,t}(1-\tau n_{i,s,t})$ as raising one child incurs a time cost τ.

The model also endogenizes income disparities between and within countries. Education and migration decisions affect the size and the structure of the labor force in all countries. This determines production and wages. In each country, production is the product of TFP by a Constant-Elasticity-of-Substitution (CES) combination of the low-skilled and high-skilled employment levels. We write:

(3) $Y_{k,t} = A_{k,t} [\phi_k (L_{k,h,t})^{\varphi} + (1-\phi_k) (L_{k,l,t})^{\varphi}]^{1/\varphi}$,

where $A_{k,t}$ measures the TFP, ϕ_k governs the relative productivity of college-educated workers, and φ is a transformation of the elasticity of substitution, $\sigma=1/(1-\varphi)$. The skill-specific wage rates are equal to the marginal productivity of workers. Given the CES structure in (3), changes in the composition of the labor force driven by migration or education decisions affect income levels and inequality within countries.

The mechanics and timing of the model are summarized on Figure 1. The set of exogenous variables include the TFP levels, basic and higher education costs and the relative wage that can be earned by uneducated children (as percentage of the low-skilled wage rate). The latter variable affects the opportunity cost of having children and is a key determinant of the fertility rate. At time *t*, the size of the native adult population and the proportion of adults who received basic education are pre-determined. The timing of decision is such that adults decide whether to acquire higher education or not before discovering their migration taste. At the beginning of the period, they educate if the expected benefits from college education exceed the training effort; adults who did not receive basic education have no access to higher education. The expected benefits from college education are affected by emigration prospects: if migration restrictions are skill-biased in the main destinations, individuals anticipate that acquiring education increases the probability to emigrate to a wealthier country. This is in line with recent literature on brain drain and brain gain (see Docquier and Rapoport, 2012).[2] This cost-benefit analysis determines the number of college-educated and less educated natives at time *t*. Then, natives discover their migration taste and decide to emigrate or to stay in their home country. This determines the number of college-educated and less educated residents at time *t*. Finally, after migration, each individual chooses the number of children and the proportion of them who receive basic education. The model is calibrated in such a way that college-educated adults provide each child with basic education. The structure of the resident labor force and fertility decisions determines the supply of labor in each country. In turn, this determines the equilibrium wage rates and the GDP level. In our general equilibrium framework, decisions about fertility, education, migration and the world distribution of income (i.e. wage disparities between and within countries) are interdependent.

[Insert Figure 1 about here]

This model is calibrated to match the characteristics of the world economy in the year 2000 or over the period 1975-2000, and to be compatible with the 'High fertility' demographic projections of the United Nations for the period 2000-2100 (United Nations, 2014) and the recent trends in TFP. Our baseline projections are presented in Section 3. Then, we will simulate the trajectory of the world

[2] We will not emphasize too much this mechanism since it has limited effects on the aggregate (as in Delogu at al., 2013).

economy under alternative sets of technological, socio-demographic and migratory assumptions in Section 4.

3. Parametrization and baseline projections for the 21st century

Most structural parameters of the utility function are assumed to be identical across countries and are calibrated in line with the empirical literature (for more details, see Delogu et al. 2013). The time-cost of having children is set to 15 percent of the parental time endowment. This means that the maximal (or biological) fertility rate equals 6.7 children per adult, or 13 per couple. The preference parameters for the quantity and quality of children, θ and λ, are set 0.3 and 0.6, respectively. Similarly, the elasticity of substitution in the production function equals 3.0, as in Docquier et al. (2014). The scale parameter of the distribution of the random component of the outer utility function ($\varepsilon_{i,s,t}$) is set to unity. This matches the empirically estimated level of the elasticity of migration to income (around 0.7, equal to 1-θ in our model). The slope of the Pareto distribution of higher education costs is equal to 0.4. This matches the empirically estimated levels of the average elasticity of college-education investment to high-skilled emigration prospects in developing countries. The other parameters (mainly TFP levels and policy variables, as depicted on Figure 1) are assumed to be country-specific and are calibrated as explained in Sections 3.1 to 3.3. Baseline simulation projections will be presented in Sections 3.4 to 3.6.

3.1. Total factor productivity (TFP)

To identify the trends in TFP, we construct panel data and regress the 5-year growth rate of TFP of all countries k, $\log(A_{k,t}/A_{k,t-5})$, on the 5-year lagged distance to the USA, $\log(A_{US,t-5}/A_{k,t-5})$, time fixed effects, a_t, income-group and geographic dummies, X_k, an indicator of lagged human capital, $\log(h_{k,t-5})$, and a constant, a_0. Our "convergence equation" writes as following:

(4) $$\log(A_{k,t}/A_{k,t-5}) = a_0 + a_t + b\log(A_{US,t-5}/A_{k,t-5}) + c\,X_k + d\log(h_{k,t-5}) + u_{k,t}$$

This equation determines the trajectory of TFP disparities across countries and is compatible with a long-run balanced-growth path. Indeed, differencing (4) with the same expression for the US yields:

(4') $$\log(A_{US,t}/A_{k,t}) = (1-b)\log(A_{US,t-5}/A_{k,t-5}) + c\,(X_{US}-X_k) + d\log(h_{US,t-5}/h_{k,t-5})$$

If b is comprised between 0 and 1, the long-run (LR) distance to the USA is given by:

(5) $$\log(A_{US,LR}/A_{k,LR}) = [c\,(X_{US}-X_k) + d\log(h_{US,LR}/h_{k,LR})] / b$$

We have collected data on GDP per capita, the size and education structure of the labor force for all the countries of the world in 5-year intervals over the period 1980-2010. To identify the TFP level, we use the CES production technology and assume an elasticity of substitution equal to 3 in all countries. The country-specific preference parameters for high-skilled and low-skilled workers, ϕ_k in (3), are calibrated to match data on skill premia in 2000. These parameters are assumed to be time invariant. We then identify the TFP levels of the 195 countries in 5-year intervals (denoted by $A_{k,t}$) as a residual of the production technology. As for the human capital proxy, we use the proportion of individuals aged 25 and over with college education completed (Barro and Lee, 2013). We estimate (1) using 1,365 observations (195 countries times 7 periods of 5 years, from 1980-85 to 2005-10). Empirical results are described in Table 1.

[Insert Table 1 about here]

In columns 1 and 2 (the most parsimonious specifications), we identified a slow process of absolute convergence. The speed of convergence is around 4 percent per 5 year; it is robust to the inclusion of time fixed effects. In column 3, we added income-group dummies (reference group = high-income countries) and show that (i) the constant is not significantly different from zero (i.e. absolute convergence in TFP among between the US and other high-income countries); (ii) the dummy for the BRICs (Brazil, Russia, India and China) is not significant, suggesting that emerging countries are also converging with high-income countries; and (iii) the dummy for middle-income and low-income countries are negative and significant. Contrary to the BRICs, the other developing countries will not catch up with high-income countries in the long-run. Adding human capital in column 5 does not improve the fit as human capital is weakly significant. In columns 5 and 6, the empirical models with geographical dummies have lower predictive power than models based on income groups. Multicollinearity issues arise when region and income group dummies are included in the same regression.

The regression in column 3 are used to define our baseline TFP scenario. It predicts that, in the very long-run, TFP levels in low-income and middle-income countries will be equal to 6.47 and 25.4 percent of the TFP level in the USA and other high-income countries, respectively. Indeed, in (2), the term cX_i is equal to -0.304 and -0.152 in low-income and middle-income countries respectively, b is equal to 0.111, and cX_{US} is equal to zero. In our baseline scenario, we assume an annual TFP growth rate of 1.5 percent for the USA and use the estimated coefficients to predict TFP levels of all countries until the year 2100. Figure 2.a depicts the trajectory of the unweighted TFP average level of each income group as percentage of the US level ($A_{k,t}$ /$A_{US,t}$). In the BRICs, the average TFP in 2000 amounted to 30.4 percent of the US level and is predicted to reach 87.7 percent of the US level in 2100. In high-income countries, the TFP level will increase from 76.8 to 96.9 percent of the US level. On the contrary, the technological distance to the US frontier will increase for middle-income and low-income countries, where the relative TFP level will decrease from 35.5 to 25.9 and from 11.0 to 6.7 percent, respectively. As a by-product of our projections, the average TFP level of sub-Saharan African countries will decrease from 23.6 to 15.6 percent.

[Insert Figure 2.a to 2.c about here]

3.2. Population

The evolution of the world population is governed by the fertility and education decisions of individuals. The children's wage rates (capturing attitude toward child labor) affect the opportunity cost of education. We calibrate its current and future levels to match the evolution of the working-age population between 1975 and 2000 and the 'High Fertility' population projections of the United Nations for the 21st century.[3] In the baseline, the world population aged 25 and over will increase from 3.2 billion to 10.4 billion between 2000 and 2100. This involves an average annual growth rate of 1.2 percent in the world population.

Nevertheless, what matters in the model is the relative share of each country or region in the total population. Figure 2.b depicts the evolution of the share of the six main regions of the world from 2000 to 2100. In line with the United Nations demographic projections (United Nations, 2014), our model predicts that the share of the African continent will drastically increase over the 21st century, with an average growth rate of 2.3 percent per year. In 2000, Africa represented about 10 percent of the world adult population. According to our projections, this share will reach 25 percent in 2100 and Africa will account for about one third of the world population growth. The share of North America will slightly increase from 6.3 to 6.7 percent. On the contrary, the shares of the other regions will decrease: from 60.9 to 51.7 percent in Asia, from 13.9 to 8.0 percent in Europe, from 7.9 to 7.8 percent in Latin America and the Caribbean. Still, the Asian continent will remain the largest one. Shocks that affect China or India or the African continent are likely to have serious effects on the world economy (Mountford and Rapoport, 2014).

3.3. Educational attainment

As far as the educational structure of the population is concerned, the country-specific parameters of the distribution of education costs are calibrated such that we perfectly match data on the skill composition of the native and resident working-age populations in 2000. Education costs, as percentage of the country-specific wage rate of college graduates, are assumed to be time-invariant in the baseline. Hence, the evolution of the skill structure of the world labor force will be governed by the change in the opportunity cost of having children.

Figure 2.c depicts the evolution of the proportion of college graduates in the labor force between 2000 and 2100. This share will increase from 50.6 to 55.3 percent in the United States (not reported on the figure), from 18.8 to 26.6 percent in Europe and from 30.1 to 39.1 percent in high-income countries. We also predict a drastic improvement in Latin America, from 11.4 to 22.0 percent, extrapolating the trends observed between 1975 and 2000. As far as other developing regions are concerned, this share will increase at a slow pace under our high-fertility variant, from 6.0 to 8.9 percent on average. In

[3] Note that the 'Constant Fertility' variant predicts a world population of 13.3 billion in 2100, and the medium fertility variant gives 7.6 billion (see United Nations, 2014).

particular, it will increase from 6.2 to 9.2 percent in Asia and from 4.6 to 5.8 in Africa. The bold line represents the world average, changing from 11.2 to 14.3 percent over the 21st century.

3.4. Income per worker

The evolution of TFP and the education structure of the labor force determines the time path of income per worker in all countries. In the United States, income per worker will be multiplied by 4.8 between 2000 and 2100, increasing from USD 52,141 to 250,333. Figure 3.a depicts the time path of income per worker in the other regions as percentage of the US level. The worldwide average income will converge towards the US level (from 27.3 to 48.2 percent, i.e. from USD 14,209 to 120,772). Convergence will be rapid in Europe (from 48.5 to 85.0 percent) and Asia (from 16.6 to 54.4 percent). The latter result is obviously driven by the takeoff of China and India, where income per worker will increase from USD 6,212 to 172,044 in our baseline scenario. Convergence will be slower in Latin America (from 27.6 to 38.8 percent) and absent in Africa (from 12.5 to 10.2 percent). In the latter region, economic growth will be relatively slower than in high-income countries, due to rising TFP disparities and slow progress in educational attainment. Income per worker will only increase from USD 4,610 to 20,109 in sub-Saharan Africa, and from 10,824 to 49,702 in the MENA (Middle East and Northern Africa).

Figure 3.b gives the evolution of the regional shares in the world aggregate income. The most perceptible change is the rise of Asia. Due to the takeoff of China and India, the income share of Asia will rise from 38.1 to 58.8 percent over the 21st century. Due to the increasing share of Africa in the world population, its share in the world income will slightly increase from 4.7 to 5.3 percent. The share of the other regions will decrease over time: from 8.0 to 6.2 percent in Latin America, from 24.6 to 14.1 percent in Europe, from 22.7 to 13.9 in North America, and from 1.8 to 1.6 percent in the mainland of Australia.

[Insert Figures 3.a and 3.b about here]

3.5. International migration

Migration costs in 2000 ($m_{ki,s,2000}$) are calibrated so as to match the observed size and structure of each migration corridor in 2000. They are treated as time-invariant over the period 2000-2100. Hence, future migration flows respond to changing income and population disparities, keeping migration policies unchanged.

Table 2 gives the rate or emigration of college-educated adults as percentage of the college-educated native population aged 25 and over. The worldwide average emigration rate of college graduates will increase from 8.1 to 9.9 percent over the 21st century. Slight increases are predicted for the US, Latin American countries and the rest of Asia. Slight decreases are obtained in the Canada and Australia, the EU15 and Persian Gulf countries. This is due to the fact that TFP in the latter countries will catch up with the US level. The two regions where the brain drain will drastically change over the 21st century are sub-Saharan Africa and the MENA. In the MENA, the emigration rate of college-educated workers will increase from 17.5 to 25.2 percent. In sub-Saharan Africa, the rise is even greater, from 15.8 to 26.8 percent. Europe is the main destination of the new emigrants from these two regions. Unsurprisingly, as explained below, the absence of economic take-off in the MENA and sub-Saharan Africa will affect the migration pressure to Europe. Similar emigration patterns are obtained for the less educated, although their emigration rates are smaller.

[Insert Table 2 about here]

As far as immigration is concerned, Table 3 presents the projections for the world and for selected receiving countries. Assuming unchanged immigration policies, the worldwide average proportion of adult migrants will increase from 3.5 to 4.5 percent over the 21st century. A slight increase in immigration rates will be observed in the United States, Japan, Switzerland or South Africa. Canada and Australia will see their immigration rates slightly decrease in the long-run. On the contrary, European and emerging countries will experience drastic changes in their immigration rates. In the EU15, the immigration rate will be 2.3 times as large in 2100 than in 2000. This is due to the combination of two factors. On the demand side, Europe will gradually become more attractive, due to the convergence in TFP and income with the United States. On the supply side, the EU15 is the main destination of African emigrants. Rising income disparities between Europe and sub-Saharan Africas or MENA (Middle-East and Northern Africa) countries will increase the migration pressure to Europe. The EU15 will represent about 6 percent of the world population in 2100. Hence, a 10 percentage-point change in the European immigration rate alone explains a 0.6 percentage-point change in the world proportion of migrants. In the BRICs, the average immigration rate will be more than twice as large (from 1.0 to 2.2 percent). A 1.2 percentage-point change in immigration seems a small number for a destination country. However the BRICs will represent about 40 of the population in 2100. Increased immigration to the BRICs alone explains a 0.5 percentage-point increase in the world proportion of migrants.

[Insert Table 3 about here]

4. Sensitivity to economic, demographic and policy environments

The main conclusions from our baseline experiment are that the economic weight of the BRICs (from 22.8 to 53.4 percent of the world income) and demographic weight of Africa (from 10.2 to 24.9 percent of the world population) will drastically increase over the 21st century. This will translate into a greater migration pressure to the EU15.

Economic and demographic shocks that affect the BRICs and Africa are likely to have drastic implications for the world economy and the structure of international migration. In this section, we simulate the trajectory of the world economy under six alternative scenarios about the evolution of TFP levels, fertility, education and migration policies. Figures 4, 5 and 6 show the deviations from the baseline and Table 4 gives the long-run immigration rates obtained for the world and for selected countries under each alternative scenario.

4.1. Technological variants

As shown on Figure 2.a, our baseline scenario assumes that the average TFP level of the BRICs will increase from 30.4 to 87.8 percent of the US level, and the average TFP level of sub-Saharan African countries will decrease from 23.6 to 15.6 percent of the US level. Two alternative technological scenarios are considered here:

- The first variant, labeled as '*Slower BRIC*', assumes a slower convergence for the BRICs. In (4), we set the fixed effect for the BRICs to X_{BRIC}=-0.075, rather than zero in Table 1. This level is roughly equivalent (in absolute value) to half of the fixed effect of other middle-income countries (equal to -0.152). Under this scenario, the BRICs will not catch up with high-income countries: on average, the average TFP of the BRICs will increase from 30.4 to 47.5 percent of the US level between 2000 and 2100 (rather than 87.7 percent in the baseline).
- The second variant, labeled *'Faster SSA'*, assumes a faster convergence for sub-Saharan African countries. In (4), we set the fixed effect for the SSA countries to X_{SSA}=-0.225, rather than -0.303 in the baseline. This represents a 0.075 shock in X_{SSA}, equivalent in size to the BRIC's drop in TFP considered in the first variant. Hence, while diverging in the baseline, the relative TFP level of sub-Saharan countries will partly converge towards the US level: on average, the average TFP of African countries will increase from 23.6 to 28.9 percent of the US level between 2000 and 2100 (rather than 15.6 percent in the baseline).

These two technological variants are as plausible as the baseline one. However, they drastically modify the economic and demographic projections of our model. Results are depicted on Figure 4.

[Insert Figure 4 about here]

Figure 4.a represents the trajectory of the world adult population over the 21st century, in perspective with historical data for the 19th and 20th centuries from the United Nations database. Figure 4.b gives the percentage of deviation from the baseline over the 21st century. Under the *'Slower BRIC'* scenario, the wage rate (i.e. the opportunity cost of education) increases less in emerging countries. Compared to the baseline, the fertility rate is greater and by 2100, the world population will be 29.9 percent larger than under the baseline and will reach 13.5 billion (instead of 10.4 billion under the baseline). This population size corresponds to the United Nations prediction with constant fertility. On the contrary, under the *'Faster SSA'* scenario, fertility decreases in Africa and the world population will be 16.2 percent smaller in 2100 (8.7 billion instead of 10.4 under the baseline). This population trajectory becomes similar to the United Nations prediction under the 'Medium Fertility' variant.

Figure 4.c represents the trajectory of the worldwide average level of income per worker in the 21st century, in perspective with historical data for the 19th and 20th centuries from Maddison (2007). Figure 4.b gives the percentage of deviation from the baseline. Under the *'Slower BRIC'* scenario, the worldwide average level of income per worker in 2100 will be 26.5 percent smaller than under the baseline (USD 86,161 instead of 120,772). The average level of income per worker in China and India will decrease from USD 172,044 in the baseline to USD 83,591 (i.e. -51.2 percent). On the contrary, under the '*Faster SSA*' scenario, the worldwide level of income per worker will be 14.9 percent greater (USD 139,965 instead of 120,772). By 2100, the average level of income per worker in sub-Saharan Africa will increase from USD 20,109 in the baseline to USD 44,293 (i.e. +120.3 percent).

Figure 4.e represents the trajectory of the world migration rate in the 21st century, in perspective with historical data for the 20th centuries from McKeown (2004). Figure 4.f gives the worldwide stock of adult migrants as percentage of deviation from the baseline. Under the '*Slower BRIC*' scenario, the worldwide stock of migrants will be slightly smaller than under the baseline from 2000 to 2075, and slightly greater after 2075. This results from two forces: the BRICs will be less attractive for international migrants, and will send more emigrants abroad. Given the rise in the world population, the world migrate rate will be smaller than in the baseline. However, Table 4 shows that the long-run immigration rates of the US, United Kingdom, Canada, Australia and Persian Gulf countries are about 0.5 percentage point greater under this variant. Under the '*Faster SSA*' scenario, the world migration stock will be 20.3 percent smaller than under the baseline. In the long-run, the brain drain from Africa will be 8.7 percentage points smaller than under the baseline (18.1 percent rather than 26.8). The implications for European countries are important: by 2100, faster TFP growth in Africa will reduce the European immigration rate from 17.7 to 14.2 percent. Table 4 shows the faster growth in Africa reduces the long-run immigration rate of European countries in general (by 3 percentage points), and of the United Kingdom in particular (by 10.5 percentage points). TFP growth in Africa is a key determinant of the migration pressure to Europe. As far as the world migration rate is concerned, it will remain comparable to the baseline level: the world migration stock follows the world population.

Finally, Figure 4.g represents the trajectory of the Theil index of income inequality in the 21st century, in perspective with historical data for the 19th and 20th centuries from Bourguignon and Morrisson (2002), complemented by Sala-I-Martin (2005) for the period 1980-2000. Figure 4.h gives the Theil index as percentage of deviation from the baseline. Under the '*Slower BRIC*' scenario, the Theil index will be smaller than under the baseline from 2050 on (24.4 percent smaller by 2100). Under the '*Faster SSA*' scenario, it will decrease more rapidly and will be 39.7 percent smaller by 2100.

These results illustrate the strong potential connections between the evolution of the world economy, income inequality and demographic changes, as well the strong sensitivity of population and economic projections to the technological environment. Helping emerging countries to converge slightly reduces the migration pressure; helping African countries to take off has a drastic impact on the European immigration rates.

4.2. Fertility and education variants

In our baseline scenario, the world population aged 25 and over will increase from 3.2 billion to 10.4 billion (as in the 'High Fertility' variant of the United Nations population prospects) and the share of college graduates will increase from 11.2 to 14.3 percent between 2000 and 2100. Two alternative socio-demographic scenarios are considered here:

- The first variant, labeled as '*Low Fert*', assumes smaller birth rates in all countries of the world. Compared to the baseline, we divide children's potential income by 1.2 (i.e. we decrease it by 16.7 percent) in all countries from 2025 on. This reduces the opportunity cost of basic education and the fertility rate.
- The second variant, labeled as '*High Educ*', assumes greater educational attainment in all countries of the world. Compared to the baseline, we divide the cost of basic education by 1.5 (i.e. decreases by 33.3 percent) in all countries from 2025 on. This increases the investment in basic education by low-skilled parents and the pool of adults eligible for higher education.

The demographic and macroeconomic implications of these two shocks are depicted on Figure 5. The scales of the axes and the baseline levels are identical to those of Figure 4.

[Insert Figure 5 about here]

In the '*Low Fert*' scenario, the world population aged 25 and over will reach 7.8 billion in 2100. This is 25 percent less than in the baseline (10.4 billion), and corresponds to the central variant of the United Nations projections. Compared to our baseline, the annual population growth rate will decrease by 0.4 percentage point in the MENA, 0.3 percentage point in sub-Saharan Africa and Latin America, and 0.2 percentage point in Europe. Due to the quality-quantity tradeoff, investment in human capital is larger and by 2100, the proportion of college-graduates in the labor force will be 2.2 percentage point greater than under the baseline. However, contrary to technological variants, the macroeconomic effects of the fertility variant are smaller. The worldwide average level of GDP per worker will be 9.8 percent greater and the Theil index will be 13.7 percent smaller in the long-run. As far as the migration is concerned, the number of international migrants will be 26 percent lower. In relative terms, this change is almost identical to that of the world population. Hence, the worldwide average migration rate will be roughly unaffected by the fertility variant. The only noticeable change is that the immigration rate to high-income countries will be smaller, as shown in Table 4. In the US and Europe, the long-run immigration rates will be 2 to 2.5 percentage point smaller compared to the baseline (from 12.5 to 10.5 for the US, and from 17.2 to 14.4 in Europe). Again, population growth in Africa is a key determinant of the migration pressure to Europe.

The '*High Educ*' variant has similar effect on the proportion of college graduates in the world labor force. By 2100, this proportion will be 2.4 percentage point greater than under the baseline. However, the macroeconomic and demographic effects are usually smaller than those of the fertility variant. In the long-run, the world population will be 4.3 percent greater (10.8 billion rather than 10.4 in the baseline). The worldwide average level of GDP per worker will be 4.3 percent greater and the Theil index will be 5.4 percent smaller. College-educated workers are more mobile than the less educated. Compared to the baseline, the rise in educational attainment increases the number of international migrants by 8.7 percent and the world migration rate by 0.2 percentage point.

4.3. Migration policy variants

Our baseline scenario assumes constant migration costs, i.e. constant moving costs and migration policies. Two alternative migration scenarios are considered here:

- The first one, labeled as '*Restrict USA*', assumes that greater immigration restrictions in the United States. Numerically, we divide the identified values for (1- $m_{kUS,s,t}$) by four for all origin countries.
- The second one, labeled as '*Open CHIND*', assumes that the costs of migrating to China and India fall. The new values for (1- $m_{ki,s,t}$), for i = China and India, equal 0.8 for college graduates from Asia, 0.96 for low-skilled workers from Asia, and (1- $m_{kUS,s,t}$) for migrants from other countries (except migrants from Latin America and the Caribbean).

The demographic and macroeconomic implications of these two shocks are depicted on Figure 6. The scales of the axes and the baseline levels are identical to those of Figure 4.

[Insert Figure 6 about here]

Changes in immigration policies have a limited impact on the world population. In the '*Restrict USA*' scenario, the long-run immigration rate of the US will fall from 12.5 to 5.2 percent. The world stock of migrants will decrease by 10.5 percent and the worldwide average migration rate will be 0.5 percentage point lower than in the baseline. Lower emigration prospects will slightly reduce investments in education and income per worker in developing regions. In addition, as potential migrants are forced to stay put, the worldwide average level of GDP per capita will be 3.1 smaller than under the baseline. Overall, increasing immigration restrictions to the US has a limited impact on the world economy and the level of inequality. It has minor effects on the migration pressure to Europe and to other industrialized countries (see Table 4).

On the contrary, if China and India becomes as attractive as the richest countries of the world, the effect on the world economy will be drastic. Under the '*Open CHIND*' scenario, the long-run immigration rates of China and India increase by 14.6 and 4.6 percentage points, respectively. Migration to other high-income countries are smaller, as shown in Table 4. The number of international migrants will be twice as large as under the baseline in 2050, and about 80 percent greater in the long-run. The worldwide level of GDP per worker will be 14.4 greater, as many new migrants from Asian countries increase their income by moving to China and India. Globally, increased migration to the BRICs can decrease the global level of inequality by about 15 percent in the long-run. Changes in the attractiveness of China and India has important effects on the migration pressure to Europe and to other industrialized countries: it reduces the immigration rate of the US and Europe by 2 percentage points.

5. Conclusion

This paper highlights the strong interdependencies between the evolution of the world economy, income inequality and demographic changes. Relying on a dynamic, stylized model of the world economy with endogenous income disparities, migration, fertility and education decisions, we assess the sensitivity of population and economic projections to the technological, socio-demographic and policy environments. We show that the evolution of productivity in emerging economies and in Africa will have a drastic impact on the worldwide level of population, income disparities and the migration pressure to high-income countries. This is particularly true if technological convergence is accompanied by a fall in immigration restrictions in emerging countries. Changes in fertility policies and educational attainment have more limited macroeconomic economic effects but drastically affect immigration rates. In particular, helping African countries to take off or to control their birth rates has a drastic impact on the European immigration rates.

6. References

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TABLES AND FIGURES

Table 1. Estimation of TFP trends, 1980-2010

Dep: $\log(A_{i,t}/A_{i,t-5})$	(1)	(2)	(3)	(4)	(5)	(6)
$\log(A_{US,t-5}/A_{i,t-5})$	0.043^{***}	0.040^{***}	0.111^{***}	0.116^{***}	0.061^{***}	0.075^{***}
	(0.007)	(0.007)	(0.012)	(0.012)	(0.008)	(0.010)
BRIC	-	-	0.029	0.023	-	-
			(0.042)	(0.043)		
Middle income	-	-	-0.152^{***}	-0.144^{***}	-	-
			(0.020)	(0.022)		
Low- income	-	-	-0.304^{***}	-0.283^{***}	-	-
			(0.020)	(0.039)		
$\log(h_{i,t-1})$	-	-	-	0.015^{*}	-	0.036^{***}
				(0.008)		(0.009)
Constant	-0.050^{***}	-0.051^{***}	-0.016	-0.060^{**}	-0.050^{***}	0.067^{*}
	(0.010)	(0.014)	(0.015)	(0.030)	(0.017)	(0.035)
Time FE	No	Yes	Yes	Yes	Yes	Yes
Region FE	No	No	No	No	Yes	Yes
Obs.	1,365	1,365	1,365	1,365	1,365	1,365
F(.)	35.15	10.32	13.32	13.17	10.70	10.59
R^2	0.033	0.056	0.143	0.146	0.110	0.120

Notes. T-stat between parentheses. Col. 2 and 3: reference group=high-income countries. Col. And 5: reference group=USA.

Table 2. Predicted emigration rates of college graduates in the baseline scenario

(As percentage of the college-educated native labor force, 2000-2100)

	2000	2025	2050	2075	2100
WORLD	8.1	8.6	9.4	9.9	9.9
USA	0.6	0.7	0.7	0.8	0.8
EU15	8.7	8.0	7.7	7.5	7.4
Canada & Australia	7.2	6.6	6.3	6.1	6.0
Gulf Cooperation Council	14.9	14.0	13.2	13.0	12.8
Middle-East & North. Africa	17.5	20.1	22.7	24.5	25.2
Sub-Saharan Africa	15.8	19.8	22.8	24.8	26.8
Commonwealth of Ind. States	16.1	17.7	17.7	16.0	13.7
China & India	5.7	2.7	1.9	1.6	1.4
Rest of Asia	8.6	10.0	11.3	11.9	11.8
Latin Am. & Caribbean	12.3	13.0	13.3	13.3	12.7
Others	18.0	16.6	16.5	16.2	15.2

Source: Own calculations.

Table 3. Predicted immigration rates in the baseline scenario

(As percentage of the resident labor force, 2000-2100)

	2000	2025	2050	2075	2100
World	3.5	4.0	4.4	4.5	4.4
USA	13.2	15.2	15.8	14.3	12.5
Australia	28.1	26.1	26.1	25.9	24.8
Canada	22.5	22.3	23.1	22.2	20.2
Japan	1.0	1.0	1.2	1.3	1.3
Switzerland	23.8	24.4	25.4	25.7	25.7
Saudi Arabia	33.9	21.2	16.4	13.4	10.9
South Africa	3.8	3.8	4.6	5.7	6.7
EU15	7.5	10.9	14.1	16.1	17.2
France	*9.3*	*14.3*	*18.6*	*20.2*	*20.4*
Germany	*7.8*	*11.4*	*14.5*	*14.8*	*14.6*
Italy	*2.2*	*3.5*	*4.9*	*6.1*	*7.1*
Spain	*5.5*	*8.5*	*11.0*	*12.2*	*12.6*
Sweden	*12.2*	*16.6*	*20.8*	*23.0*	*23.6*
United Kingdom	*8.8*	*13.2*	*18.7*	*24.6*	*28.1*
BRIC	1.0	2.0	2.6	2.6	2.2
Brazil	*0.3*	*0.3*	*0.3*	*0.4*	*0.3*
Russia	*9.4*	*13.8*	*13.8*	*11.7*	*9.6*
India	*1.1*	*2.8*	*4.0*	*3.9*	*3.2*
China	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*

Source: Own calculations.

Table 4. Long-run immigration rates under alternative scenarios

(As percentage of the resident labor force, year 2100)

	Baseline	Slower BRIC	Faster SSA	Low Fertility	High Education	Restrict USA	Open CHIND
World	4.4	3.5	4.1	4.3	4.5	3.9	7.9
USA	12.5	13.0	11.6	10.5	12.0	5.2	10.9
Australia	24.8	25.4	22.4	22.5	23.9	25.0	22.1
Canada	20.2	21.1	17.6	17.4	20.5	19.5	18.5
Japan	1.3	2.3	1.3	1.2	1.2	1.4	1.5
Switzerland	25.7	26.5	23.8	23.3	27.2	25.5	23.9
Saudi Arabia	10.9	12.3	10.5	9.6	9.7	11.0	8.2
South Africa	6.7	6.7	4.7	5.5	7.0	6.7	6.7
EU15	17.2	17.7	14.2	14.4	16.0	17.2	15.4
France	*20.4*	*20.5*	*18.2*	*17.2*	*20.9*	*20.5*	*19.4*
Germany	*14.6*	*14.8*	*13.8*	*11.8*	*11.4*	*14.5*	*10.6*
Italy	*7.1*	*7.5*	*5.5*	*5.8*	*7.4*	*7.1*	*6.7*
Spain	*12.6*	*13.0*	*11.8*	*11.4*	*13.1*	*13.3*	*12.4*
Sweden	*23.6*	*23.9*	*21.6*	*20.7*	*20.9*	*23.8*	*19.6*
United Kingdom	*28.1*	*29.2*	*17.6*	*23.2*	*25.3*	*27.7*	*27.1*
BRIC	2.2	1.0	2.2	2.2	2.4	2.3	10.2
Brazil	*0.3*	*0.1*	*0.3*	*0.4*	*0.4*	*0.4*	*0.3*
Russia	*9.6*	*7.3*	*9.5*	*9.2*	*9.2*	*9.7*	*9.3*
India	*3.2*	*1.3*	*3.2*	*3.1*	*3.2*	*3.2*	*7.8*
China	*0.1*	*0.0*	*0.1*	*0.1*	*0.1*	*0.1*	*14.7*

Source: Own calculations.

Figure 1. Mechanics of the model

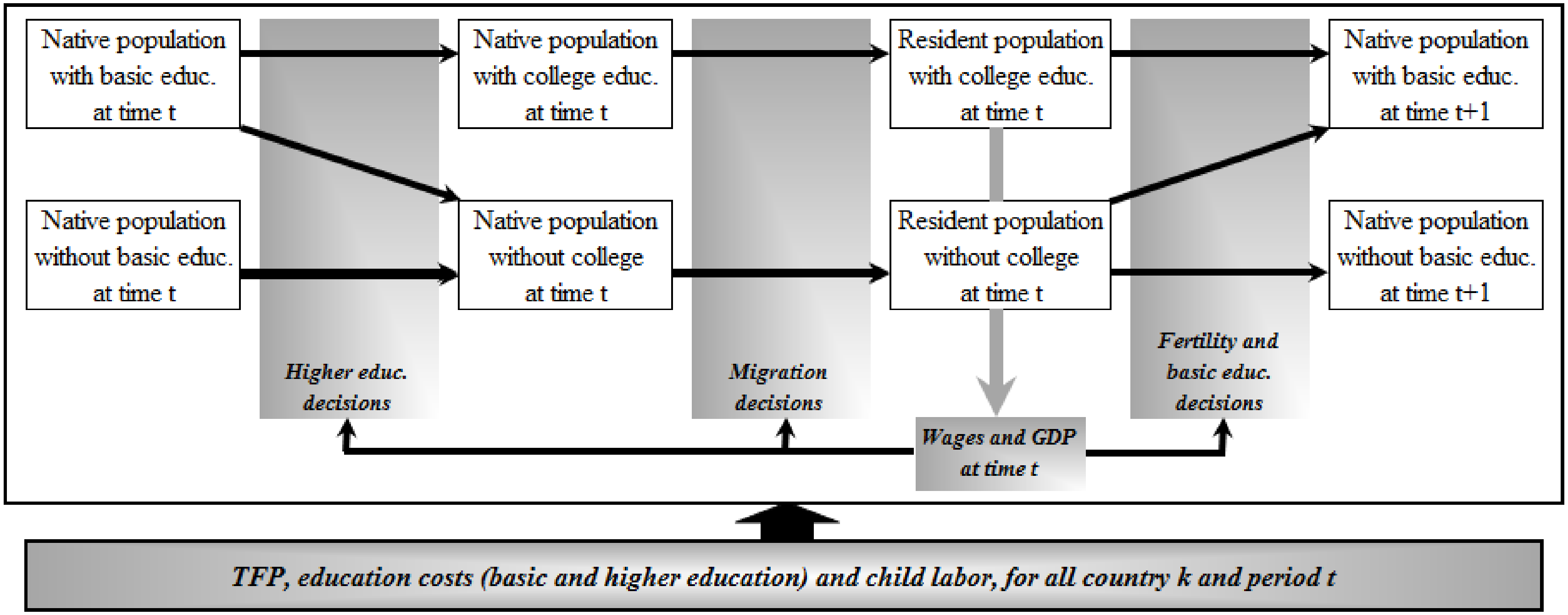
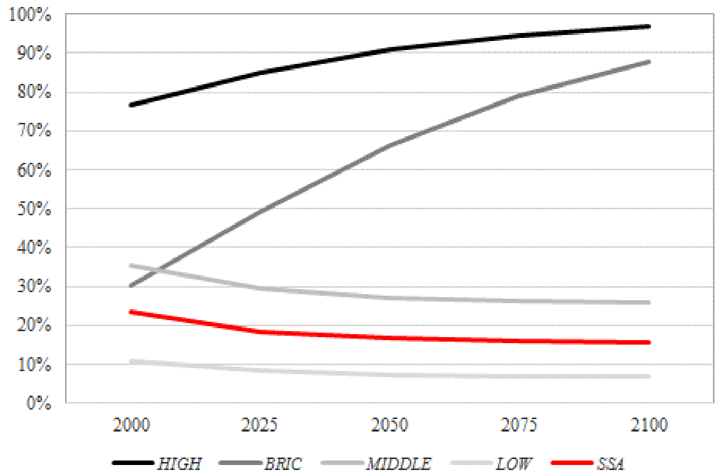
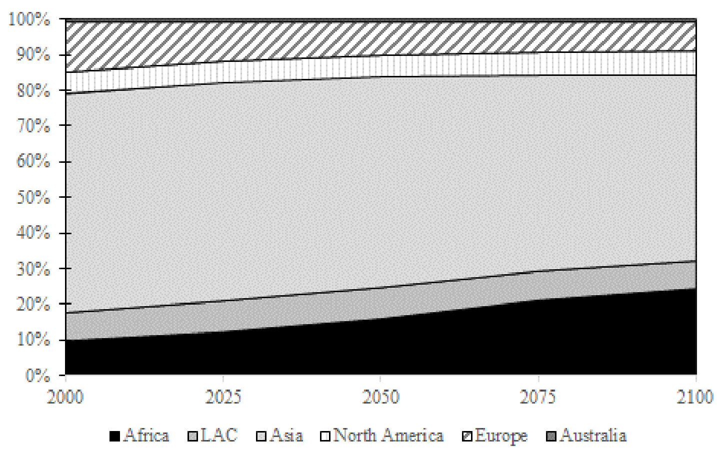


Figure 2. Parametrization of the model

2.a. TFP ratio with the United States by income group, 2000-2100



2.b. Regional shares in the world population aged 25+, 2000-2100



2.c. Proportion of college graduates in selected regions, 2000-2100

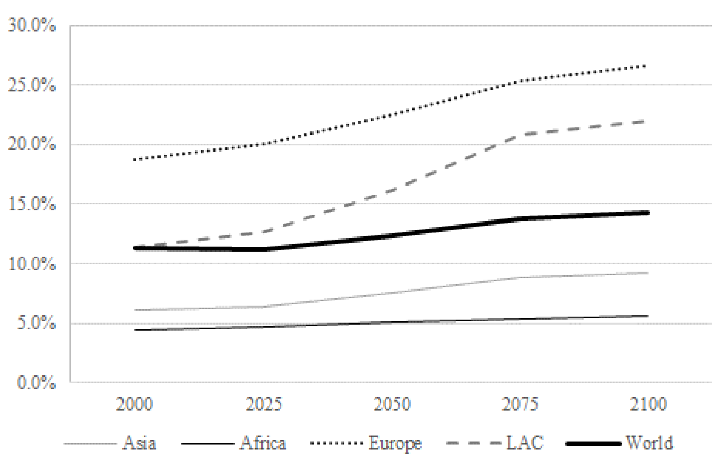
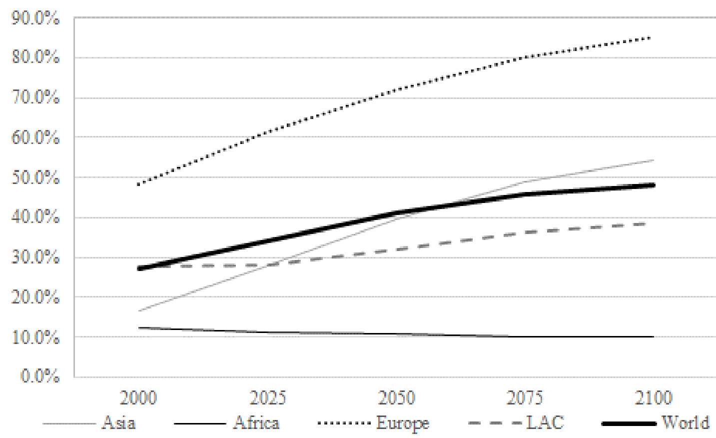


Figure 3. Income projections

3.a. Income per worker as percentage of the US level, 2000-2100



3.b. Regional shares in the world aggregate income, 2000-2100

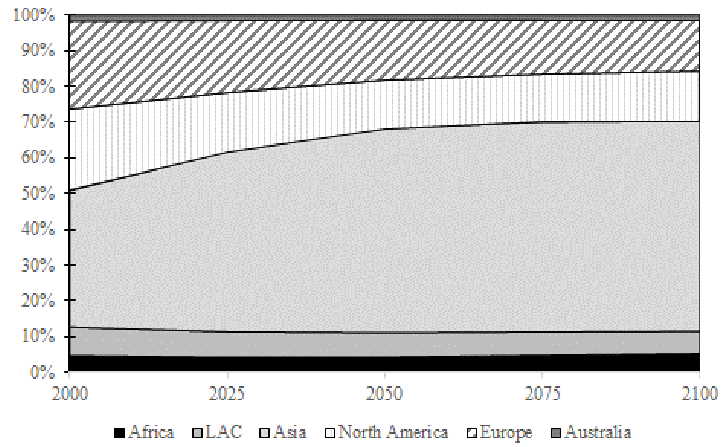
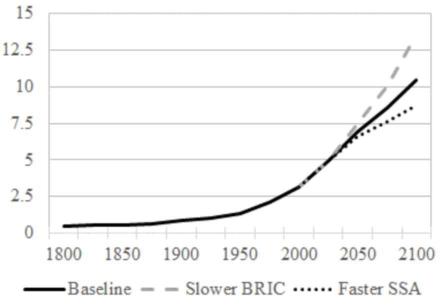
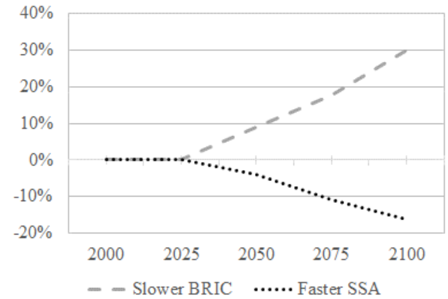


Figure 4. Projections under technological variants

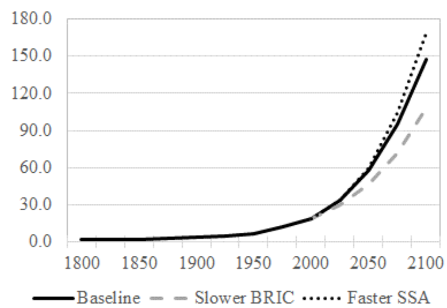
4.a. World population aged 25 and over
In 1E09 (1800-2100)



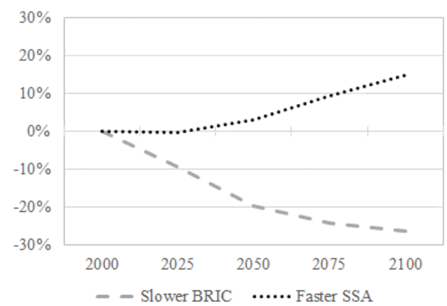
4.b. World population aged 25 and over
Percentage of deviation from baseline (2000-2100)



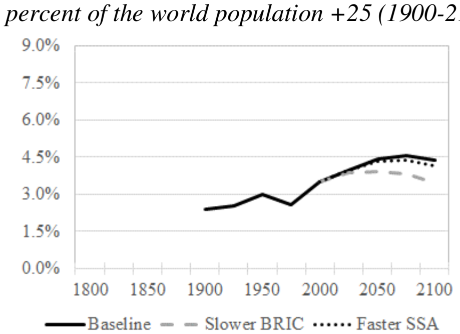
4.c. World GDP per worker
In USD 1E3 (1800-2100)



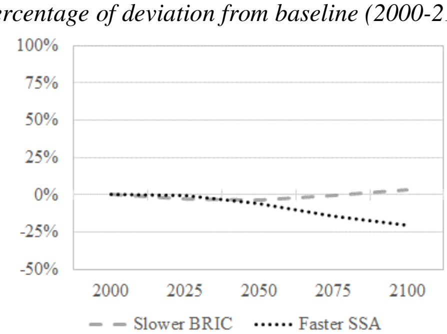
4.d. World GDP per worker
Percentage of deviation from baseline (2000-2100)



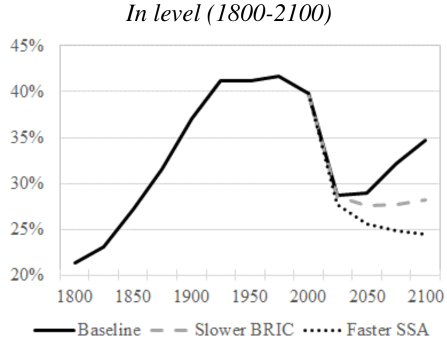
4.e. World migration rate
As percent of the world population +25 (1900-2100)



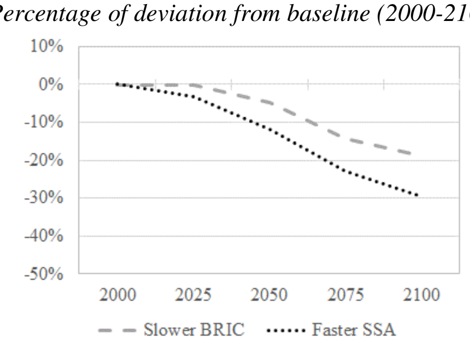
4.f. World stock of migrants aged 25 and over
Percentage of deviation from baseline (2000-2100)



4.g. World Theil index of wage inequality
In level (1800-2100)

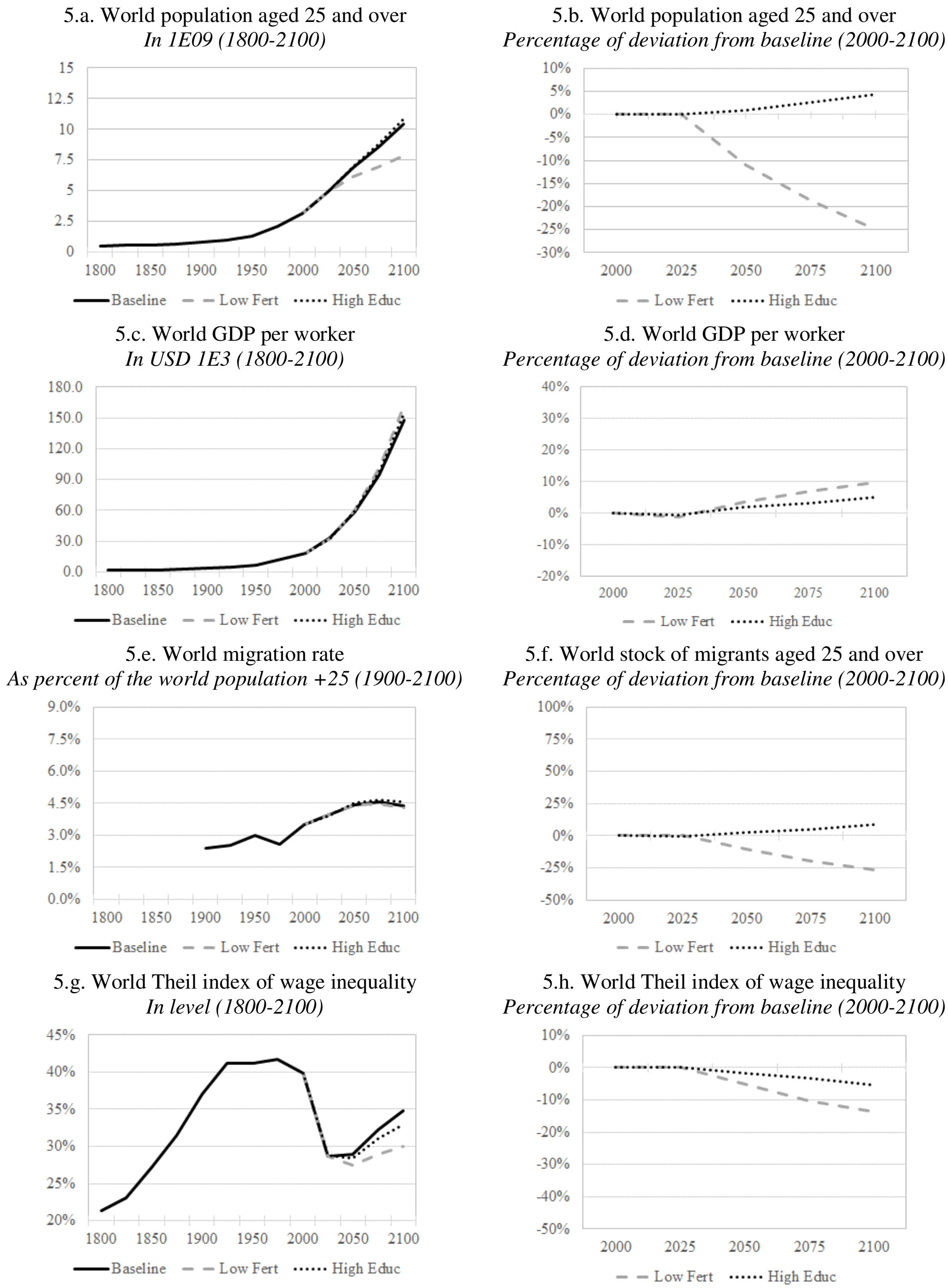


4.h. World Theil index of wage inequality
Percentage of deviation from baseline (2000-2100)



Source: Own calculations for the years 2000 to 2100. Prior to 2000: Population data from the United Nations database; GDP data from Maddison (2007); Migration data from McKeown (2004); Rescaled inequality data from Bourguignon and Morrisson (2002) and Sala-I-Martin (2006).

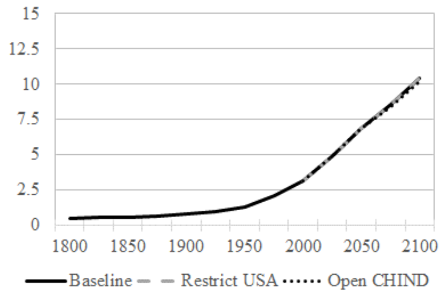
Figure 5. Projections under socio-demographic variants



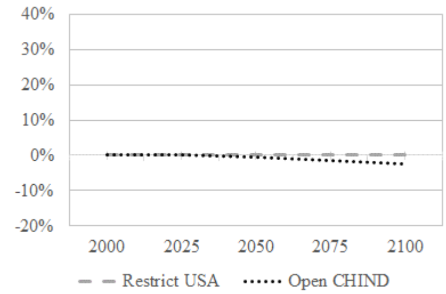
Source: Own calculations for the years 2000 to 2100. Prior to 2000: Population data from the United Nations database; GDP data from Maddison (2007); Migration data from McKeown (2004); Rescaled inequality data from Bourguignon and Morrisson (2002) and Sala-I-Martin (2006).

Figure 6. Projections under migratory variants

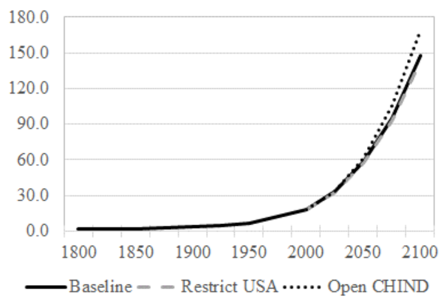
6.a. World population aged 25 and over
In 1E09 (1800-2100)



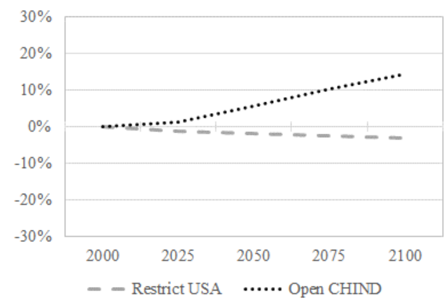
6.b. World population aged 25 and over
Percentage of deviation from baseline (2000-2100)



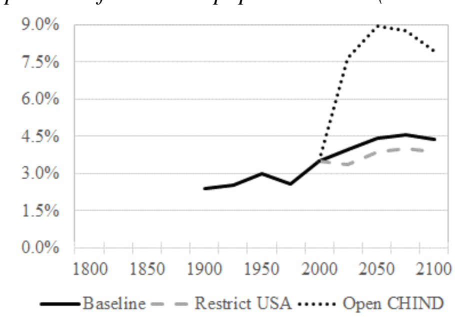
6.c. World GDP per worker
In USD 1E3 (1800-2100)



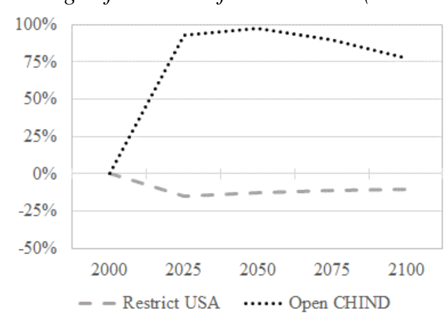
6.d. World GDP per worker
Percentage of deviation from baseline (2000-2100)



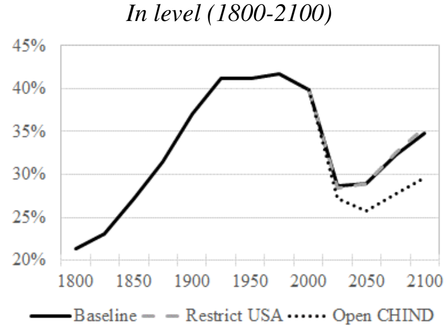
6.e. World migration rate
As percent of the world population +25 (1900-2100)



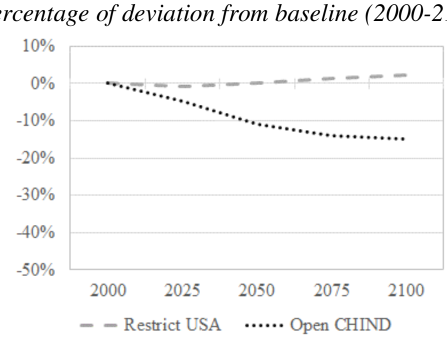
6.f. World stock of migrants aged 25 and over
Percentage of deviation from baseline (2000-2100)



6.g. World Theil index of wage inequality
In level (1800-2100)



6.h. World Theil index of wage inequality
Percentage of deviation from baseline (2000-2100)



Source: Own calculations for the years 2000 to 2100. Prior to 2000: Population data from the United Nations database; GDP data from Maddison (2007); Migration data from McKeown (2004); Rescaled inequality data from Bourguignon and Morrisson (2002) and Sala-I-Martin (2006).