A General Equilibrium Long-term path of the Word Economy*

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Abstract

Thinking of how the relative sizes of countries and how the geography of world production and trade will be affected in the long run must be based on sound economic reasoning about the determinants of long term growth. It must also be embedded in a general equilibrium framework that takes account of the interactions among markets and sectors, as well as between countries. This paper takes stock of a three phase research project. The first step consists of deriving and estimating a three-factor (labor, capital, energy) macroeconomic growth model for a large set of individual countries, which fits two forms of technological progress (standard TFP and energy efficiency). The second step consists of providing with the sectoral detail with a Computable General Equilibrium model of the world economy calibrated to fit these projections. In a third step we compare this baseline with two alternative scenarios on our main assumptions.

Keywords: Mirage CGE model, Dynamic Baseline, Growth model, Energy .

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1 Introduction

Global models, in particular Computable General Equilibrium (CGE) models, are based on macroeconomic variables, among which Gross Domestic Product (GDP), Total Factor productivity (TFP), the changing sectoral decomposition of GDP, population, labor force and its composition play a crucial role.[1] These models are aimed at simulating shocks on the world economy at medium or long-term. Therefore, reliable projected values for these variables are required. Some of these models are expected to be linked with other sectoral, technological and/or biophysical models. Lastly information is needed for world models as well as national/EU models covering a wide range of economic activities: demand for food, energy, transport, land use changes, etc.

Indeed, international research centers and organizations provide short term GDP forecasts (among others, the International Monetary Fund, IMF). These forecasts, generally based on macro-econometric models, fit well the short term changes in the world economy. However, concerning long-term scenarios for the world economy, we lack of a clearly documented, validated, and theoretically funded picture of the world economy in the long run. This is particularly the case when it comes to having a broad coverage in terms of countries, regions of the world economy and sectors. Against this background, we build on pioneering papers in the field (Burniaux & Chateau (2004), van der Mensbrugghe (2005), Walmsley (2006)) and tentatively combine two very different modeling frameworks, MaGE (Macroeconometrics of the Global Economy) and an updated version of MIRAGE.[2]

MaGE is a theoretical growth model in the long run embodying energy, energy efficiency, technical progress, demography and capital accumulation. MIRAGE is a CGE sectoral model of the world economy. MaGE is a country level model, to which constraints regarding the balance of world financial flows are imposed. It is estimated econometrically country by country or by country groups, while MIRAGE is calibrated. MaGE is based on a three-factor production function of labor, capital and energy, plus two forms of technological progress. It is estimated and then used in projection to recollect a long-run growth scenario for 147 countries imposed to MIRAGE. Based on these constraints, MIRAGE provides a fully consistent and theoretically funded projection of changes in consumption patterns, resource allocation and sectoral GDP composition, at the regional and country level, for all regions of the world economy. To our knowledge, the most advanced growth and CGE models implementation in this field are the exercises conducted for the ENV-Linkage model (Burniaux and Chateau, 2008) jointly with projections by Duval and De La Maisonneuve (2010) and Maliszewska and van der Mensbrugghe (2012) for China at the 2030 horizon (Envisage model).

The time horizon is 2100 though projections are done with a one year step. We account for the 2008-09 global crisis by initializing our projection model in 2013 while relying on IMF short-term forecasts between 2010 and 2012. Regarding labor force and its age structure, we firstly rely on United Nations and International Labor Organization labor projections. One important

[1]We acknowledge insightful comments by Jean Chateau and Dominique van der Mensbrugghe.

[2]The reference documents for MaGE and the original version of MIRAGE are respectively Fouré et al. (2012) and Decreux et al. (2007). This new version of MIRAGE is nicknamed as MIRAGE-e.

issue taken into account in MaGE is the female participation in the labor market: it is modeled consistently with an education catch-up, estimated and then projected. Similarly, accumulation of human capital is the main driver of TFP growth and therefore reshapes the world economy. We econometrically estimate and project the educational level of workers, conditional on their age. MIRAGE is fitted with the same projections in terms of population and labor force that are all exogenous. However, human capital accumulation is not modeled in MIRAGE: labor force grows with constant shares of skilled and unskilled. Accordingly, part of the TFP is capturing in MIRAGE the contribution of human capital accumulation.

Capital accumulation depends on the relationship between savings and investment rate, which is complex in open economies – a dimension often neglected in projection exercises. We estimate in MaGE a non-unitary relationship between savings and investment, departing from assumptions of either a closed economy or full capital mobility. The savings rate depends on life cycle, and hence on the structure of the population by age, as well as on income per capita. The projected savings rates are imposed to MIRAGE, while the allocation of investment across sectors remains endogenous.

Technological progress includes energy efficiency and total factor productivity in MaGE. It is derived theoretically and estimated econometrically at the macroeconomic level. However TFP will hardly follow the same path in agriculture, in industry and in services. To address this issue in MIRAGE, we model, estimate and project separately TFP in agriculture, by considering two categories of productions: animal and vegetal. Results of this exercise provide an exogenous variable to MIRAGE. TFP is then computed for manufacturing and services in MIRAGE, conditional on the TFP in agriculture and on GDP growth, *cum* a constraint on the productivity differential between these two sectors. Energy productivity in MIRAGE-e is also determined exogenously from MaGE.

Our paper contributes to the literature in two ways. Firstly, it provides a more detailed baseline of the world economy, though the country coverage is more limited due to data constraints. Walmsley (2006) developed a database covering 147 countries for the period 2001-2020 and fitting the dynamic GTAP model (Ianchovichina and McDougall, 2000). It was updated in Chappuis and Walmsley (2011) up to 2050.[3] The database is completed with various assumptions in order to end up with 226 regions. Population is split into 3 age categories only (below 15, 15-65 and older), while we use five years bins. This authorizes a more detailed modeling of savings and education. We model explicitly savings (life cycle) and the international mobility of capital (Feldstein-Horioka) to recover the investment rates instead of extrapolating the gross domestic investment over GDP ratio.[4] While we finally use only two categories of skills in MIRAGE, projection in MaGE are done at a more disaggregated level. MaGE projects skill composition on the basis of educational attainment for each five-year age group with a five-year step.

Secondly, we are providing projections up to 2100. Despite the intrinsic fragility of such results, it is a useful tool when it comes to evaluating policies related to environmental issues. The OECD is currently engaged in a similar exercise, but limited to the growth model (Chateau et al., 2012). The link with the CGE is not investigated **?**.

[3]Chappuis and Walmsely rely partly on Fouré et al. (2010) for certain variables.

[4]Incidentally, our depreciation rate is different from Walmsley who takes 4%.

Our paper departs from the literature in two ways. Firstly, we proceed in two steps. A macroeconomic growth model is providing a detailed projection of GDP and savings rate, while sectoral breakdown and results in terms of emissions are provided by a CGE model. This is different from Bagnoli et al. (2005) who develop a baseline for examining environmental impacts for a long-term horizon up to 2030. They rely on simulations of JOBS, a global recursive dynamic CGE model derived from the LINKAGE model (Van der Mensbrugghe, 2005) but focusing on environmental issues. They have three age-bins and pay attention to projecting participation rates. Productivity is derived from a catching up process. Sectoral productivity growth is imposed to the model and estimated form STAN (OECD) and Groningen data. Ultimately, the baseline is directly projected with the CGE model using these exogenous variables for 34 regions and 7 sectors.

Our paper also departs from the literature in terms of the dynamics considered. Our approach is putting the emphasis on a large coverage in terms of countries, combined with a versatile aggregation of sectors and regions, in recursive dynamic macroeconomic settings. It accordingly departs from the polar choice of having less countries and sectors, but in an inter-temporal macroeconomic framework, like in G-Cubed (McKibbin and Wilcoxen, 1999).[5] Neglecting the inter-temporal nature of agents decisions authorizes us to have a refined representation of population growth, TFP, energy efficiency ; in contrast G-Cubed is assuming a constant population growth by region up to 2050, a constant TFP growth and no energy efficiency gain.

2 Related literature

We now briefly survey the literature, mainly focusing on energy-oriented CGE baseline methods because these features are the core of our approach.

2.1 CGE Baselines

Country availability and time span of projections vary accross the existing approaches. Many models focus on the period up to year 2020 (like the GTAP model) but some exercises have been conducted up to 2050 (for instance the Linkage model).

The first step in developing a baseline is the building of a general trajectory of world growth. To do so, two different approaches compete among CGE models. The first option is to build a scenario for factor productivity growth in order to recover GDP from the CGE model. The second one is to build a GDP scenario such that the model recovers TFP gains accordingly.

On the one hand, recovering GDP from TFP growth assumptions has the advantage that data availability is not a limiting factor. Moreover, is allows to encompass easily different sector-specific trajectories without over-constraining the model. On the other hand, this kind of approach is very sensitive to assumptions on TFP growth or on its determinants. For instance, the EPPA model (Paltsev et al., 2005) assumes a logistic productivity growth which is identical for all countries and sectors, whereas no capital productivity is implemented.

[5] G-Cubed was developed with 8 regions and 12 sectors.

The symmetric approach of imposing GDP growth trajectories and to recover productivity gains is more data demanding but combines the pros of the two types of models. This approach also allows to rely more easily on macro projections by other institutions which are built upon the vast growth literature, though their documentation is not always available (see Fouré et al. (2012) for a short review). Main projections used in the GTAP model and former versions of MIRAGE were provided by the World Bank[6].

Regarding the sectoral decomposition of TFP, several approaches have already been developed. First of all, the LINKAGE model by Van der Mensbrugghe (2005) uses the GDP-driven framework described above and adds to the endogenous national TFP a sectoral component that is labour-only productivity and which results in (i) a constant exogenous agricultural TFP (ii) a constant 2-percentage-point-difference between industrial and services sectors' productivity (industry being more productive).

Independently, a literature has grown on agriculture-specific productivity, build after Nin et al. (2001). These papers (Coelli and Rao, 2005; Ludena et al., 2007, for instance) depart from the usual analysis of yields and start from non-parametric productivity indices based on the use of agricultural inputs. They show that productivity in agriculture is not constant, and that its growth rate is heterogeneous between countries.

As a consequence, our approach tends to take the best of these approaches regarding productivity. We try to have a comprehensive macroeconomic framework by imposing GDP from our growth model to the CGE, as well as we use sector-specific constraints and exogenous agricultural productivity to depict a coherent sector disaggregation.

2.2 Environmental baselines

Coming to the matters that are specific to energy-oriented CGE models, our paper builds on two thematic fields of the existing literature. First, the case of energy productivity and its impact on CO_2 emissions and second, the natural resources scarcity with its direct link to energy prices. In both cases, assumptions focus on one variable such that the other adjusts.

First, it is possible to rely on CO_2 emissions from other institutions (or, equivalently to energy demand), such as in the PACE model (Böhringer et al., 2009). In this case, improvement in carbon intensity of goods is deduced, although no comprehensive framework regarding energy consumption is developed. In addition, a particular attention has to be given to the coherence between the emissions projections' underlying growth assumptions and the growth model ones, because CO_2 emissions heavily depend on economic activity.

The opposite method consists in developing a precise scenario for autonomous energy efficiency improvements (AEEI) as in the EPPA model. These AEEI encompass non-price induced, technology-driven productivity changes. They impose an exogenous time trends in energy productivity in order to control for the evolution of demand reduction, which scales production sectors' use of energy per unit of output. These AEEI are specific to broad regions (namely 10 regions in EPPA) with two distinct profiles. On the one hand, China and Developed Countries

[6] The respective documentations are Ianchovichina and McDougall (2000) and Decreux et al. (2007).

face a regularly increasing AEEI. On the other hand, other countries' AEEI first decrease (up to around 2035) and then increase at different paces. This discrepancies are motivated by the empirical observation that energy productivity has regularly increased in countries that are already advanced in industry and services development, though stagnated or even decreased in countries where industrialization occurs.

The Linkage model implements a mixed framework, where energy demands are imposed to recover productivity changes, except for the crude oil consumption which is driven by an exogenous productivity scenario.

Another point about CO_2 emissions and energy consumption is about a limitation which is inherent to CGE modeling. These two types of variables are measured in physical quantities, though traditionally variables in CGE models are kept in dollars at constant prices. As pointed out by Laborde and Valin (2011), using CES functional forms on monetary values leads to incoherences in substitutions when commodities are relatively homogenous, like this is the case for energy goods. In order to deal with this issue, two approches can be developed. One can build up a world price matrix for physical quantities of agricultural goods, such that they can account for changes both in value and quantity. A more affordable approach is to impose to the model that production, consumption and trade being coherent both in monetary units and in physical quantities. We adopt this second approach.

Finally, the question of natural resource depletion can also be encompassed in two ways. As underlined by Paltsev et al. (2005), long run dynamics of energy prices are captured by natural resources depletion. Therefore one can have a model for such depletion and deduce the corresponding energy prices, as well as one can do the opposite. The former solution is chosen by the EPPA model, incorporating resource-specific natural resources use, as well as additional recoveries. The alternative assumption is to exogenously fix energy prices as in the ENV-Linkage model (and this option is also available in EPPA), such that natural resources adjust to match the targeted prices. ENV-Linkage's assumption is to rely on IEA's world price projections until 2030 and then assume a 1% growth of oil price.

3 The MIRAGE-e model

We use a new version of the multi-sectoral and multi-regional CGE model MIRAGE (Bchir et al., 2002; Decreux and Valin, 2007), which has been developed and used extensively to assess trade liberalization and agricultural policies scenarios (e.g., Bouët et al., 2005, 2007). MIRAGE has a sequential dynamic recursive set-up which is used to evaluate a long-term path for the world economy, and we focus on perfect competition. This version of the model relies on a different modeling of energy use, hence the extension of its nickname. The macroeconomic closure consists in fixing the share of each region in global current accounts imbalances, which varies yearly according to the projections from MaGE.

3.1 Representative firms

In the perfect competition version of MIRAGE, each sector is modeled as a representative firm, which combines value-added and intermediate consumption in fixed shares. Value-added is a bundle of imperfectly substitutable primary factors (capital, skilled and unskilled labor, land and natural resources) and energy. The nesting of the production function differs in MIRAGE and MIRAGE-e, in order to better represent energy use in the latter.

All primary factors endowments of countries are supposed to be fully employed and their growth rates are set exogenously from the MaGE projections. Installed capital stock is assumed to be immobile (sector-specific), while investment, which represents the long run adjusting possibilities of a capital market, is allocated across sectors (perfect mobility) according to their rate of return to capital. Skilled labor is perfectly mobile across sectors, while unskilled labor is imperfectly mobile between agricultural and other sectors. Land is assumed to be imperfectly mobile between agricultural sectors and natural resources are sector-specific.

Energy consumption of the five energy goods (Electricity, Coal, Oil, Gas and Refined petroleum) by firms are aggregated in a single bundle by firm which mainly substitutes with capital. The extent to which capital and energy are substitutable is not subject to consensus among CGE literature. It can vary according to the vintage of capital (for instance from 0.12 to 1 in the GREEN model), or be fixed between 0.5 (GTAP-E model) and 0.8 (PACE model).[7] We found out that energy consumption was very sensitive to the capital-energy elasticity of substitution. Calibrating this elasticity like GTAP-E provides an energy consumption in our reference scenario that is in line with International Energy Agency projections to 2025 (IEA, 2011). We therefore stick to the GTAP-e value, i.e. $\sigma_{KE} = 0.5$. The architecture of the energy bundle defines three levels of substitutions and is depicted in Figure 1 as well as its position in MIRAGE's production function. Oil, gas and refined oil are more inter-substitutable than with coal and finally with electricity. Values of the elasticities of substitutions are determined according to the literature. Whereas electricity-fossil fuels substitution comes from Paltsev et al. (2005), the two other elasticities come from Burniaux and Truong (2002).

However, in order to avoid unrealistic results, we made the assumption of "constant energy technology" in non-electricity energy production sectors (coal, oil, gas, petroleum and coal products) such that it is impossible to produce crude oil from coal or refined petroleum from gas and electricity. For these sectors, substitutions between energy sources are not allowed (Leontief formulation).

The value of energy aggregate $ETOT_{j,r,t}$ of sector j in country r is subject to productivity improvements $EE_{j,r,t}$ based on the growth model, as shown in Equation (1).[8] These productivity improvements are introduced at the capital - energy bundle $KE_{j,r,t}$ level.

$$ETOT_{j,r,t} = a_E EE_{j,r,t} KE_{j,r,t} \left(\frac{PKE_{j,r,t}}{PE_{j,r,t}} \right)^{\sigma_{KE}} \tag{1}$$

[7] The respective reference documents about the two models are Burniaux and Truong (2002) and Böhringer and Rutherford (2009).

[8] When dealing with bilateral variables, r will denote the origin of a good and s the destination country.

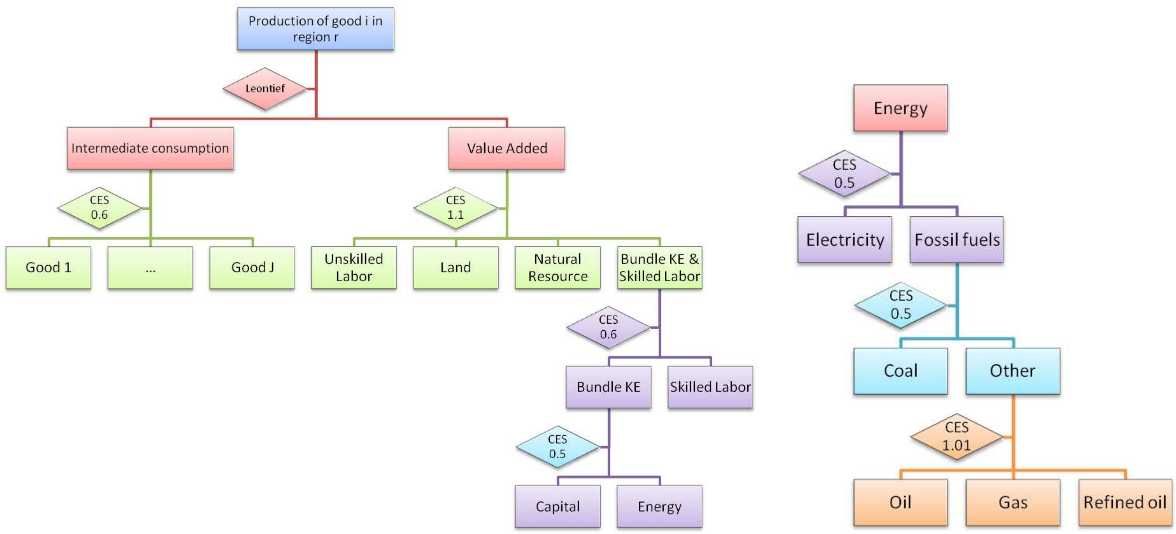

Figure 1: Production function of firms in MIRAGE-e

In Fouré et al. (2012), energy productivity has a different definition than its equivalent in MIRAGE. The former does not include TFP and the latter does not include the share coefficient. By trickling-down the effect of MIRAGE's sectoral TFP, $TFP_{r,t}TFPJ_{j,r,t}$, on to the capital-energy bundle CES function, we can make the analogy between the two expressions and deduce the value of energy productivity in MIRAGE $EE_{j,r,t}$, given the MaGE energy productivity $B_{r,t}$.

$$EE_{j,r,t} = \left(\frac{B_{r,t}}{TFP_{r,t}TFPJ_{j,r,t}}\right)^{\sigma_{KE}-1} = \frac{EProd_{r,t}}{(TFP_{r,t}TFPJ_{j,r,t})^{\sigma_{KE}-1}} \tag{2}$$

For non-electricity energy production sectors (coal, oil, gas and petroleum and coal products), we also set energy productivity constant in order to match our "constant energy technology" assumption, in line with the substitutions between energies in these sectors.

3.2 Representative consumer

The demand side is modeled through a representative consumer from each region that maximizes its intratemporal utility function under its budget constraint. This unique agent, which includes households and government, saves a part of his income and the rest is spent on commodities according to a LES-CES *(Linear Expenditure System - Constant Elasticity of Substitution)* function. Regional propensity to save yearly changes in the dynamic baseline according to MaGE's projections. Above a minimum consumption proportion at sectoral level, consumption choices between sectors are done according to a constant elasticity of substitution. Then, within each sector, a nesting CES allows for a particular status for domestic products, together with a product differentiation according to their geographical sources (Armington hypothesis, Armington, 1969), using the GTAP (Global Trade Analysis Projet) Armington elasticities estimated in Hertel et al. (2007). Even though the most complete version of Mirage allows for product differentiation across varieties, we decided to remain with simple demand trees in agriculture, raw energies and electronic devices to work with a tractable model.

Total demand is built from final consumption, intermediate consumption and investment in capital goods. The former and the latter follow the same as described above.

3.3 Energy and CO_2 emissions accounting

As pointed out by the literature, using CES functional forms with variables in monetary units leads to inconsistencies when trying to retrieve physical quantities. In our case, this matters for energy consumption, production and trade, as well as their consequences on CO_2 emissions.[9]

Therefore, in addition to the accounting relations in constant dollars, MIRAGE-e integrates a parallel accounting in energy physical quantities (in million tons of oil equivalent, $Mtoe$) such that the CO_2 emissions could be computed (in million tons of carbon dioxide, $MtCO_2$). Since the Constant Elasticity of Substitution architecture does not maintain the coherence in physical quantities, MIRAGE-e introduces two energy- and country-specific adjustment coefficients. These two aggregation coefficients allow us to maintain basic energy accounting relationship valid.

Namely, the produced quantity EY by one country must equal the demand addressed to this country both locally (ED) and from abroad ($EDEM$), as in Equation (3) ; and the consumption of energy (by households EC and firms $EEIC$) in one country must equal its local and foreign demand (Equation (4)). In these equations, as well as in the remainder of this paper, the subscript e will be an index for energetic goods (electricity, coal, oil, gas and petroleum and coal products). In addition, r denotes a country that is, when appropriate, the origin of a good and s its destination.

$$EY_{e,r,t} = ED_{e,r,t} + \sum_{s} EDEM_{e,r,s,t} \tag{3}$$

$$EC_{e,s,t} + \sum_{j} EEIC_{e,j,s,t} = ED_{e,s,t} + \sum_{r} EDEM_{e,r,s,t} \tag{4}$$

The corresponding adjustment coefficient $AgDem_{e,r,t}$ (resp. $AgCons_{e,r,t}$) rescales the demand addressed to (resp. the consumption of) the country such that it matches the produced (resp. demanded) physical quantities. In turn, only energy quantity production is proportional to the volume production Y. The epsilons in Equations (5) to (9) are constant conversion coefficients calibrated from the energy quantity data and allow to link energy quantities with corresponding volumes of demand for local good D, bilateral demand DEM, local final consumption C and

[9] Preliminary simulations of MIRAGE-e showed that there could be a gap of more than 20% between energy consumed and energy demanded by a country if proportionality is assumed between monetary and physical values.

local intermediate consumption EIC.

$$
\begin{aligned}
EY_{e,r,t} &= \epsilon^{Y}_{e,r} Y_{e,r,t} && (5)\\
ED_{e,r,t} &= \epsilon^{D}_{e,r} AgDem_{e,r,t} D_{e,r,t} && (6)\\
EDEM_{e,r,s,t} &= \epsilon^{DEM}_{e,r,s} AgDem_{e,r,t} DEM_{e,r,s,t} && (7)\\
EC_{e,s,t} &= \epsilon^{C}_{e,s} AgCons_{e,s,t} C_{e,s,t} && (8)\\
EEIC_{e,j,s,t} &= \epsilon^{EIC}_{e,j,s} AgCons_{e,s,t} EIC_{e,j,s,t} && (9)
\end{aligned}
$$

CO_2 emissions are finally recovered as being proportional to the energy quantities consumption, using energy-, sector- and country-specific factors determined by the data.

3.4 GDP projections

We use for our baseline exercise the long-run growth projections from the MaGE (Macroeconomics of the Global Economy) model, developed by the CEPII (Fouré et al., 2012). These projections are based on a three-factor (namely Capital, Labor and Energy) production function at the national level for 147 countries. We first briefly describe the methodology underlying such projections.

These three factors are gathered in a Constant Elasticity of Substitution (CES) function of Energy $E_{r,t}$ and a Cobb-Douglas aggregate of Capital $K_{r,t}$ and Labor $L_{r,t}$:

$$
Y_{r,t} = \left[\left(A_{r,t} K^{\alpha}_{r,t} L^{1-\alpha}_{r,t} \right)^{\frac{\sigma-1}{\sigma}} + \left(B_{r,t} E_{r,t} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \qquad (10)
$$

were $A_{r,t}$ and $B_{r,t}$ are respectively the usual Total Factor Productivity (TFP), which in this case is the efficiency of the combination of labor and capital, and an energy-specific productivity. In line with the literature (see e.g. Mankiw et al., 1992), α is set to 0.31. In turn, the $\sigma = 0.136$ parameter is calibrated based on the MIRAGE structure, using a pre-experiment simulation. In addition, Gross Domestic Product (GDP) $Y_{r,t}$ is considered net of oil rents, when appropriate, to avoid a biased measure of productivity. Oil rents are added separately and are assumed to be pure rents: the volume of production is constant, but its real value (in terms of the GDP deflator) increases with the relative price of oil.

This model is fitted with United Nations (UN) population projections as well as econometric estimations for capital accumulation, education and female participation to the labor force and the two technical progresses. The energy factor is not directly projected, though it is recovered from the firms' optimization program.

In particular, capital accumulation follows a permanent inventory process, where the stock of capital increases each year with investment but also depreciates. The depletion rate is set, in accordance with the MIRAGE model, to 6%, whereas investment to GDP ratios depend on the savings rates by an error-correction, Feldstein-Horioka-type relationship. Such relationship enables to depart from the common assumption of close economy. The savings rates are determined by both the demographic and economic situation, in coherence with the life-cycle theory.

The two productivity measures follow catch-up processes. Whereas TFP growth is fuelled by education level, Energy Productivity growth is tempered by the level of GDP per capita such that it mimics the impact of sectoral changes on the productivity of energy during a country's development process.

3.5 Closure and dynamic set-up

Thanks to MaGE's projections, this new dynamic baseline of MIRAGE has many original features regarding savings, GDPs, active population, energy efficieny changes and current account balances, all at the regional level. This set of projections has been also completed with oil, gas and coal world prices projections from the Annual Energy Outlook (EIA, 2010).[10]

Dynamics in this model are implemented as a sequentially recursive approach. That is, the equilibrium can be solved successively for each period by adjusting to the growth in the projected variables described above. For this long-run baseline, the time span is 96 years, the starting point being 2004. During this period of time, capital stocks change according to investment decisions based on rates of return to capital at the sectoral level and the depreciation rate, which is assumed constant and uniform across regions (i.e. $\delta = 6\%$).

$$K_{j,r,s,t} = K_{j,r,s,t-1}.(1-\delta) + INV_{j,r,s,t} \tag{11}$$

Skilled ($\bar{H}$) and unskilled ($\bar{L}$) labor supplies from each region are also yearly updated according to the the economically active population growth projected by MaGE $g^{Act}_{r,t}$.

$$\bar{L}_{r,t} = \left(1 + g^{Act}_{r,t}\right) \bar{L}_{r,t-1} \tag{12}$$

$$\bar{H}_{r,t} = \left(1 + g^{Act}_{r,t}\right) \bar{H}_{r,t-1} \tag{13}$$

Total population also increases exogenously under the dynamic baseline by inducing growth through the final demand.

Growth rates for regional GDP are also set exogenously according to MaGE projections and thus, the total factor productivity (TFP) is endogenously determined. Sectoral factor productivity, calculated by large sectors (i.e. Agriculture, Manufactures and Services) also intervenes in this dynamic baseline. Factor productivity in Agriculture is differentiated between Livestock and Crops sectors, and are calibrated according to our estimates from Section 4. Factor productivity in Manufactures and Services are endogenous variables, which are affected by regional GDP (through the TFP) and Agricultural factor productivities. Factor productivity in Manufactures is 2pp higher than in Services ($\Delta TFP_{j,r,t}$ is set 2pp higher for Manufactures), like in the LINKAGE model (Van der Mensbrugghe, 2005).

Energy productivity $EProd_{j,r,t}$ also increases exogenously during the baseline according to MaGE's projections on regional energy efficiency.It directly affects the energy demand per unit

[10] The latter and MaGE outputs have been converted into growth rates to be implemented in the dynamics from MIRAGE in order to keep our initial year fully coherent with GTAP database.

of output by sectors such as it was described above (Equation (2)).

$$EProd_{j,r,t} = EProd_{j,r,t-1}.\left(1+g^{B}_{r,t}\right)^{\sigma^{KE}-1} \quad \text{if} \quad j \notin Energy \tag{14}$$

World prices of fossil energies (i.e. oil, coal and gas) are also assumed to be exogenous during the new dynamic baseline. They yearly increase according to the World Energy Outlook projections (IEA, 2011) leading to adjustments of the corresponding stock of natural resources.

$$PWORLD_{e,t} = \left(1+g^{P}_{e,t}\right) PWORLD_{e,t-1} \quad \text{if} \quad e \in \{coal, oil, gas\} \tag{15}$$

where $g^{P}_{e,t}$ is the growth rate of energies' prices. Each fossil energy price has its own projections.

Such as in the original version of MIRAGE, regional investment is savings-driven and is allocated across sectors according to the capital rate of return. Even if it provides the possibility to work with foreign direct investment (Decreux and Valin, 2007), in this version we remain simple, allowing capital flows between regions only through the channel of current account imbalances.

The new dynamic set-up in MIRAGE particularly affect macroeconomic closures. The current account is driven by MaGE projections and updates yearly. By sake of consistency, the savings rate are also taken from MaGE, thus determined by demography, life cycle and purchasing power. Savings rates grow at the exogenous growth rate $g^{SAV}_{r,t}$ and current account are incremented by the sold deviation $\Delta SOLD_{r,t}$. Current account variations are not represented by a growth rate because of its capability of changing its sign across time.

$$SAV_{r,t} = \left(1+g^{SAV}_{r,t}\right) SAV_{r,t-1} \tag{16}$$

$$SOLD_{r,t} = SOLD_{r,2004} + \Delta SOLD_{r,t} \tag{17}$$

Equation 18 show the current account definition, as the difference between all sectoral investments $INV_{j,r,t}$ and national savings $SAV_{r,t}$, as well as its implementation $SOLD_{r,t}$ as a share of world GDP $WGDP_t$.

$$SAV_{r,t}.REV_{r,t} = WGDP_t.SOLD_{r,t} + \sum_j P^{INVTOT}_t.INV_{j,r,t} \tag{18}$$

4 TFP in Agriculture

Although we already have developed a methodology to compute and project TFP on the long run for national economies, two reasons lead us to consider agriculture apart. First, technical progress in agriculture seems to be lower than national TFP growth, and should therefore be studied further. Second, the definition of production factors in agricultural sectors is trickier than for a national economy.

Whereas data on labor-force in agriculture is available, no aggregated data on capital in agriculture seems to be available, on the contrary to disaggregated data (machinery, land, etc.). We therefore need to implement a multi-input, non-parametric methodology such as the Malmquist productivity index, based on productivity distance to a global frontier.

4.1 Data envelopment analysis (DEA)

Malmquist indices are designed to represent productivity growth rates both at a national or sectoral level. Computing such indices needs a two step approach. The ground concept from which Malmquist indexes are built are distance measures. These distances are a measure of the gap between the production of a country and the potential production it could have achieved if it had used its inputs at the best available technology. The first step is then to compute such distances measures. The logic behind the mathematical formulation, which is described precisely in Appendix A, is to build a peace-wise linear surface of the best performing countries to identify the technological frontier, starting from production and production factors data; and to measure the distance between each country's productivity and such a frontier.

Once these distances are known, the second step is to combine them in order to build a Malmquist index $M^{t,t+1}$ for each year and country, representing productivity growth rates. Instead of detailing the formulation in distances Färe et al. (1997) rely on the following decomposition(see Appendix A for details).

$$M^{t,t+1} = \Delta EFF^{t,t+1}.\Delta TECH^{t,t+1} \tag{19}$$

These two components have different meanings. The first one, $\Delta EFF^{t,t+1}$, is called efficiency change and represents the growth rate of the distance to the technological frontier. The second term, $\Delta TECH^{t,t+1}$, is a technical change term and represents the contribution of the country to the evolution of the technological frontier.

Such an index has some interesting properties. $M^{t,t+1} \geq 1$ if there have been progresses in TFP between year t and $t+1$ and $M^{t,t+1} \leq 1$ if technological regress has occurred. Furthermore, improvements (resp. deterioration) of $\Delta EFF^{t,t+1}$ or $\Delta TECH^{t,t+1}$ are equivalent to their value being greater (resp. lower) than 1.

4.1.1 Data

We use data from the Food and Agriculture Organization (FAO) on agricultural production and inputs. We choose to use two outputs for agriculture (crops and livestock) and five different inputs, due to their commonness across the world and their data-availability.[11] Inputs can be allocated to crops or livestock, or be shared between these two sectors.

- Output: We use gross production for Crops and Livestock, as given by the FAO for the 1961-2009 time period.
- Labor input (Non-allocatable): We use two data series to recover agricultural active population. We mainly use the economically active population in agriculture for 1980-2009 (maximum data availability) and we reconstruct the series for 1961-1979 using the growth rate of agricultural population.

[11] We are well aware of the roughness of some assumptions here that are due to the fact that our DEA method do not suffer gaps.

- Land input (Non-allocatable): Arable land and permanent crops (1961-2009)
- Machinery input (Allocated to Crops): Total agricultural tractors in use (1961-2009). We however also used the "Agricultural tractors" series to compensate the gaps in the first series.
- Fertilizers input (Allocated to Crops): Consumption in nutriments (2002-2009) and growth rate of Consumption in tons for 1961-2001.
- Livestock input (Allocated to Livestock): Livestock is computed based on Livestock Unit (LU) equivalent. We use data of FAO on Livestock (1961-2009) in number of heads (Buffaloes, Camels, Cattle, Pigs, Sheep and Goats) or thousand heads (Chickens, Ducks and Turkeys) and aggregate the data based on Ludena et al. (2007) factors (see Appendix A).

Several adjustments were needed to have a fully operational dataset. First, we had to deal with countries that changed their perimeter in the data over the period (Belgium-Luxemburg in 2000, Czechoslovakia in 1993, Ethiopia PDR in 1993, USSR in 1992, Yugoslavia in 1992 and Serbia-Montenegro in 2006). For these countries, we took the share of the different members the first disaggregated year that was available, and split the aggregated data before this date between the countries. Second, we aggregated the data for 9 broad regions (See Appendix A.3). These regions' productivity will be computed among all independent countries, and their values will be used for estimations.

4.1.2 Efficiency change

We depict in Figures 1 and 2 distances measures (whose growth rates are $\Delta EFF^{t,t+1} - 1$) for the different regions considered. Note that the distance used here equals 1 when a country is at the frontier and 0 when a country is not productive at all.

Figure 2 shows the distance to TFP frontier in Crops for the 9 selected regions of the world. The United-States remain at the frontier level over the whole period, whereas other countries do not seem to catch-up to the frontier. Some zones (namely China, Industrialized countries and Sub-Saharan Africa) even diverge from the frontier. The latter observation can in fact be linked to FAO data on yield observed over the past decades: no catching-up occurs in cereal yield between each continent or subcontinent and the United-States (excepted China before 1990).

Regarding Livestock, the catch-up occurs over the period and more significantly between 1985 and 2000, as show in Figure 3, though none of our broad regions is at the technological frontier.

4.1.3 Technical change and Malmquist index

On the other hand, technical change has been, on average, increasing for all country groups. It is interesting to note that, although efficiency increases were greater in the livestock sector, technical change growth is larger in the crops sector. Table 1 summarizes these growth rates.

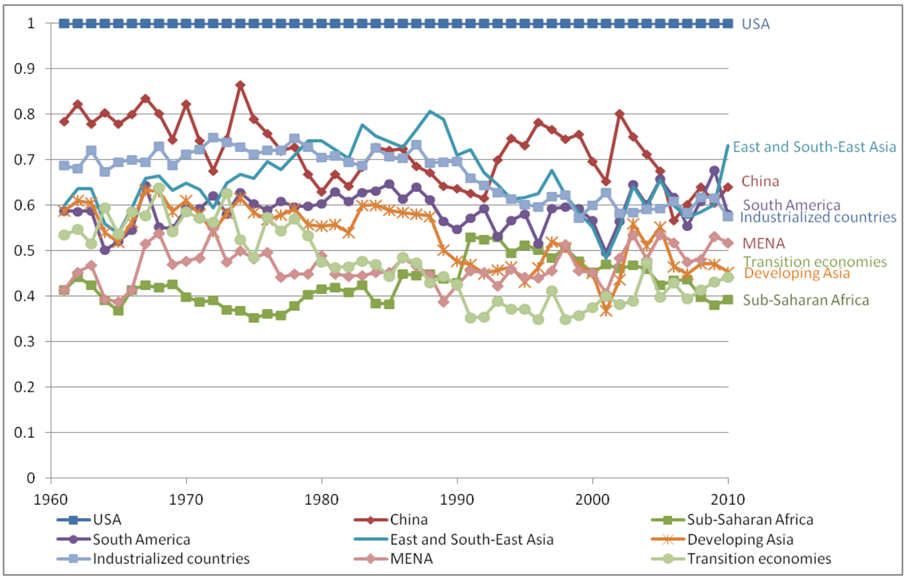

Figure 2: Distance to TFP frontier in Crops, 1960-2009

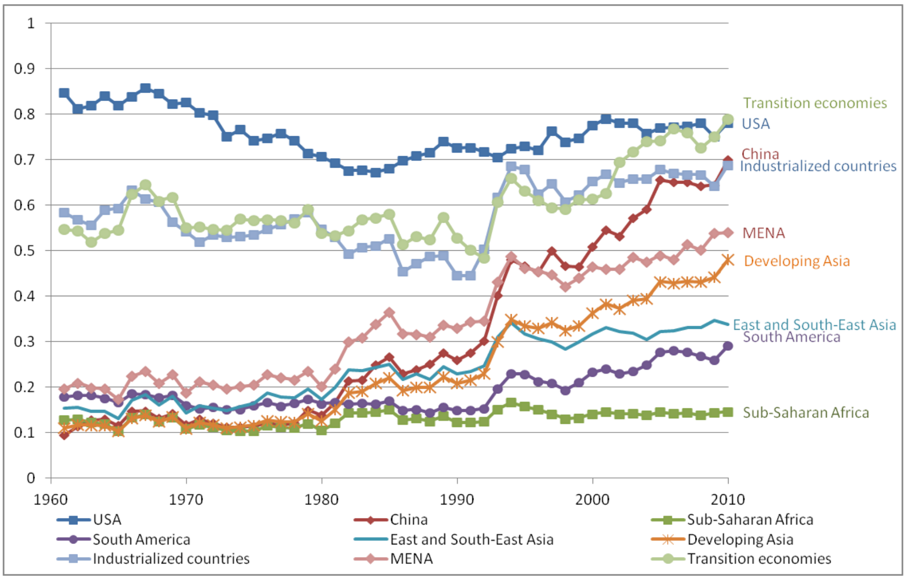

Figure 3: Distance to TFP frontier in Livestock, 1960-2009

Table 1: Average productivity growth (percentage points, geometrical means 1961-2009)

Region	Crops			Livestock		
	$\Delta EFF^{t,t+1}$	$\Delta TECH^{t,t+1}$	$M^{t,t+1}$	$\Delta EFF^{t,t+1}$	$\Delta TECH^{t,t+1}$	$M^{t,t+1}$
China	-0.5	0.7	0.1	4.1	0.2	4.3
Developing Asia	-0.5	0.6	0.2	2.9	0.2	3.2
East and south-east Asia	0.0	0.5	0.5	1.7	0.2	2.0
Industrial Countries	-0.2	1.9	1.6	0.2	1.1	1.3
MENA	0.5	0.1	0.7	2.1	0.3	2.4
Central and South America	0.3	0.4	0.7	0.8	0.9	1.7
SSA	-0.2	1.3	1.1	0.2	0.2	0.5
Transition economies	-0.4	0.9	0.4	0.7	0.9	1.6
USA	0.0	2.0	2.0	-0.3	1.8	1.6

Notes: USA stands for the United States of America, MENA for Middle-East and North Africa and SSA for Sub-Saharan Africa.
Source: Own computations.

4.2 Estimating efficiency catch-up

In order to project agricultural TFP at the regional level, we need to estimate a catching up function. We will then extrapolate the frontier and project the catching up of each region towards this frontier. We follow Ludena et al. (2007) in separating our projection in two parts: Efficiency change and Technical change, as well as in our methodology. After Nin et al. (2001), we assume that catching-up to the frontier occurs along a logistic function, as what suggests diffusion processes, which is a S-shaped curve, in terms of the distance to productivity frontier $D^{i,t}$:

$$D^{i,t} = \frac{1}{1 + e^{-\alpha_i - \beta_i t}} \tag{20}$$

Where α_i and β_i are two region-specific coefficient. That is, each country is, since 1961, assumed to be at a certain state of catching up, with its own speed. Reformulating this yields

$$Y_{i,t} = \log\left(\frac{D^{i,t}}{1 - D^{i,t}}\right) = \alpha_i + \beta_i t \tag{21}$$

We first perform Chow test in order to identify any structural break in time series that could have occurred between 1961 and 2004 (newer breaks would be difficult to identify because of the number of remaining observations). We perform the Chow tests only on the speed of convergence/divergence β_i, because the constant α_i only represents the starting point of the curve. Table 2 presents the last date for which we identified breaks in series, at a 1% confidence level.

The case of China is different from the others, because the Crops series only presents one break in 2001. We therefore chose to estimate over the period 1961-2001 instead of 2001-2009. Detailed information about the breaks is given in Appendix A.4. We finally estimate relation (21) on the corresponding periods and the results are presented in Table 3.

In the Crops sector, three types of country groups appear. First, only two regions seem to

Table 2: Structural breaks in distance function series

	Crops	Livestock
China	1961	1991
Developing Asia	1961	1990
East and Southeast Asia	1992	1992
Industrial countries	1989	1992
Middle East and North Africa	1992	1983
Central and South America	1961	1997
Sub-Saharan Africa	2000	1980
Transition Economies	1998	1999
USA	1961	1995

Source: Own calculations.

Table 3: Efficiency change estimation results

Region	Crops				Livestock			
	Time	Constant	N obs.	R-sq.	Time	Constant	N obs.	R-sq.
MENA	0.0184***	-0.848***	18	0.40	0.0353***	-1.601***	27	0.83
	(-0.005)	(-0.233)			(-0.003)	(-0.119)		
Transition Economies	0.0265**	-1.560***	12	0.45	0.0731***	-2.332***	11	0.75
	(-0.009)	(-0.403)			(-0.013)	(-0.615)		
East and south-east Asia	-0.014	0.998**	18	0.14	0.0119**	-1.263***	18	0.33
	(-0.008)	(-0.353)			(-0.004)	(-0.173)		
South America	0.00177	0.326***	49	0.02	0.0357***	-2.675***	13	0.79
	(-0.001)	(-0.048)			(-0.005)	(-0.238)		
Sub-saharan Africa	-0.0345***	1.290***	10	0.72	0.00444**	-1.983***	30	0.14
	(-0.007)	(-0.34)			(-0.002)	(-0.074)		
Developing Asia	-0.0132***	0.472***	49	0.53	0.0521***	-2.684***	20	0.85
	(-0.001)	(-0.052)			(-0.005)	(-0.205)		
Industrial countries	-0.0158***	1.098***	21	0.45	0.0159**	-0.0452	18	0.23
	(-0.004)	(-0.159)			(-0.007)	(-0.295)		
China	-0.0152***	1.339***	41	0.29	0.0784***	-3.072***	19	0.88
	(-0.003)	(-0.091)			(-0.007)	(-0.285)		
USA					0.0135**	0.601**	15	0.30
					(-0.005)	(-0.244)		

Notes: Standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01
Source: Own computations.

catch-up to the frontier (MENA and Transition economies). Two other zones seem to remain at the same distance to the frontier (East and south-east Asia as well as South America). The four remaining zone seem to face a negative catch-up (Sub-Saharan Africa, Developing Asia, Industrial countries and China). Finally, the USA is not in this table for it remained at the frontier all over the period. On the contrary, catch-up in Livestock sector is evidenced for all zones of the sample, though at different paces. The more fast-growing zone is China and the less fast-growing zone is Sub-Saharan Africa.

5 The three scenarios

We now illustrate our methodology: a decomposition of the world economy in regions and sectors is proposed, and we consider a central baseline plus two alternative scenarios.

5.1 Aggregation

The MIRAGE model is calibrated on the GTAP dataset version 7, with 2004 as base year. Our data aggregation isolates all energy sectors and combines other sectors into main representative sectors from agriculture, manufactures and services. For the regional aggregation, we retain main developed (e.g. the EU, Japan and the US) and emerging (e.g. Brazil, Russia, China) economies and the rest of the world is aggregated according to their relationship to the energetic market (i.e. oil rich countries, see Table 4).

Trade policy data is also taken from the GTAP database whose source is the Market Access Maps (MAcMap-HS6) dataset version 2 from CEPII. This dataset assume the reference group weighting scheme (Bouët et al., 2008) for the calculation of *ad-valorem* equivalent tariffs at the GTAP level of aggregation.

This version of Mirage also includes trade costs modelled as an iceberg trade cost. Data to calibrate trade costs associated to time have been calibrated using a database provided by (Minor and Tsigas, 2008) which follows the methodology from (Hummels and Schaur, 2012).

5.2 Assumptions

For the scenarios, we identified which of our assumptions could have influence on the results and we built three scenarios to encompass such influence.

- Reference: this encompasses all assumptions we chose to best represent the world economy dynamics, in a "Business as usual" perspective.
- High growth: In this scenario, energy efficiency improves as well as educational catch-up. Capital durability is increased and market access improves.
- Low growth: On the contrary, educational catch-up is slower, capital and goods market access are accordingly reduced, as well as female participation do not improve with education.

Table 4: Sector and country aggregation

Regions	**Sectors**
Developed	**Agriculture and Primary**
Oceania[a]	Vegetal Agriculture
Japan	Animal Agriculture
Korea and Taiwan	Other Agriculture
Canada	Primary (minerals)
United States	**Energy**
European Union (27 countries)	Coal
EFTA	Oil
Developing \ Emerging	Gas
China	Petroleum and Coal Products
ASEAN	Electricity
India	**Manufacturing Products**
Brazil	Food, Beverage and Tobacco
Rest of Latin America	Textile
Russia	Metals
Rest of Europe	Cars and Trucks
Oil rich Western and Central Asia[b]	Planes Ships Bikes Trains
Other Western and Central Asia[c]	Electronic Equipment
Turkey	Machinery Equipment
Northern African Countries	Other Manufactured products
Rest of World[d]	**Services**
	Transport
	Insurance, Finance and Business
	Public Administration, Education and Health
	Other Services

Notes:
[a] Australia, New Zealand and Rest of Oceania.
[b] Kazakhstan, Azerbaijan, Iran and Rest of Western Asia.
[c] Kyrgyzstan, Armenia, Georgia and Rest of ex-URSS.
[d] All remaining GTAP countries and regions.

Some assumptions for the dynamic baseline scenarios are implemented within the growth model, and will therefore impact MIRAGE-e through its exogenous parameters (GDP growth, savings, current account, energy productivity and female participation to the labor force). These assumptions are detailed in Table 5. This table also include CGE-specific assumptions on market access (trade costs and tariffs).

Table 5: Scenarios summary

Variable	Baseline	High growth	Low growth	Model[a]
Financial integration	Fouré et al. (2012)	Fouré et al. (2012)	Closed economy	G
Energy efficiency	Fouré et al. (2012)	+40% in 2100	+20% in 2100	G
Education	Fouré et al. (2012)	Double convergence	Half convergence	G
Obsolescence	6%	2 %	4%	G
Female participation	Fouré et al. (2012)	Fouré et al. (2012)	No improvements	G
Market access	As of 2004	-25% Trade costs -100% tariffs	+25% Trade costs +100% tariffs	M

Note: [a]G stands for "growth model" and M for "MIRAGE-e"

Financial integration In the reference case, investment rate (as a percentage of GDP) depends on savings through a dynamic error-correction relation. Where savings are determined by demographic variables, investment relies on a long-term relationship with savings to which it tends to converge. The savings rate and the resulting current account are imposed to MIRAGE-e with a yearly step. In MIRAGE, the capital flows are limited to the compensation of the current account imbalances. There is no modeling of Foreign Direct Investment for sake of simplicity.

In the Low Growth scenario, we make the assumption that financial openness halts such that investment and savings are equal. Such scenario would have a negative impact for countries which have a current account deficit, but will trigger investment for countries with a current account surplus.

Education Education relies on a catch-up process with geographical country group specific speed. In the Low Growth scenario, we assume that educational attainment diffuses less to developing countries, whereas the level in developed countries remains high. On the contrary, in the High Growth scenario, convergence is faster and discrepancies tend to collapse at the 2100 horizon. These convergence speeds are computed such that the half-life time[12] is twice (resp. half) the reference one.

Female participation Female participation in the growth model relies on a relation with education. On the one hand, for youngest age groups (15-19 and 20-24), participation of females tend to reduce over time due to longer study periods. On the other hand, for other age groups, the more educated the women, the more they participate to the labor force.

In the reference scenario, as well as in the High Growth one, we rely on this mecanism. However, transitions of female participation are fueled by higher education levels in the latter scenario. In

[12]Half-life time if given by $t^{1/2} = \frac{\ln X}{\ln(1-\lambda)}$ under the simplifying assumption that the frontier is constant. λ is the convergence coefficient and X depends on the frontier and initial position

the Low Growth scenario, we do not account for these dynamics and simply assume a business as usual change in the female participation (extrapolating the methodology of the International Labor Organization).

Market access In addition to these scenarios in the growth model, we compare our reference scenario (constant trade barriers and costs as of 2004) with an increased protection (+25% trade costs and +100% tariffs) in the Low Growth scenario, as well as a liberalization scenario (-25% trade costs and 0 tariffs).

Agricultural productivity We use the above estimated relations to project efficiency changes, whereas the technical progress growth is set constant, at its average value over the past (see Table 1). Table 6 shows the projection results for all the considered country groups for two time period (2010-2050 and 2050-2100), and with the Malmquist index decomposition.

Table 6: Average productivity growth (percentage points, geometrical means 2010-2100)

Region	Crops						Livestock					
	2010-2050			2050-2100			2010-2050			2050-2100		
	Eff	Tech	M	Eff	Tech	M	Eff	Tech	M	Eff	Tech	M
China	-0.66	0.66	0.00	-0.91	0.66	-0.25	0.83	0.22	1.06	0.03	0.22	0.26
Developing Asia	-0.80	0.63	-0.17	-0.97	0.63	-0.34	1.51	0.21	1.72	0.23	0.21	0.44
East and Southeast Asia	0.00	0.52	0.52	0.00	0.52	0.52	0.72	0.24	0.96	0.56	0.24	0.80
Industrial countries	-0.79	1.86	1.05	-1.06	1.86	0.78	0.39	1.06	1.46	0.22	1.06	1.28
Middle East and North Africa	0.72	0.15	0.87	0.41	0.15	0.55	1.06	0.27	1.33	0.30	0.27	0.57
Central and South America	0.00	0.42	0.42	0.00	0.42	0.42	1.94	0.86	2.82	0.72	0.86	1.59
Sub-Saharan Africa	-2.56	1.32	-1.28	-3.16	1.32	-1.89	0.37	0.22	0.59	0.36	0.22	0.58
Transition Economies	1.13	0.87	2.02	0.50	0.87	1.38	0.55	0.90	1.45	0.03	0.90	0.93
USA	0.00	2.02	2.02	0.00	2.02	2.02	0.24	1.83	2.07	0.14	1.83	1.97

Source: Own computations.

5.3 Reference Baseline

The "business as usual" baseline evolves according to the MaGE results used as inputs (regional GDP, energy efficiency, population growth, savings, etc.). The main changes in world consumption patterns, total factor productivy also decomposed by sectors, production and trade specialization patterns at regional level are given by MIRAGE.

GDP The results of Fouré et al. (2012) suggested that the Chinese and Indian economies could grow 8-fold between 2010 and 2050 at constant relative prices. Over the same period, the US and EU economies would inflate by 80-90%. We extend these projections up to 2100 and show in Figure 4 the average GDP growth (in volume) for several countries or country groups.

The Chinese growth rate is projected to reduce from 8.6% in 2010-2015 to 4% in 2045-2050 and finally to less than 3% in 2100. The drop occurring around 2095 in China and 2070 for Russia is due to their reaching the technological frontier and not benefiting any more from the catch-up effect. As a consequence, India begins to grow faster than China around year 2035 and face a

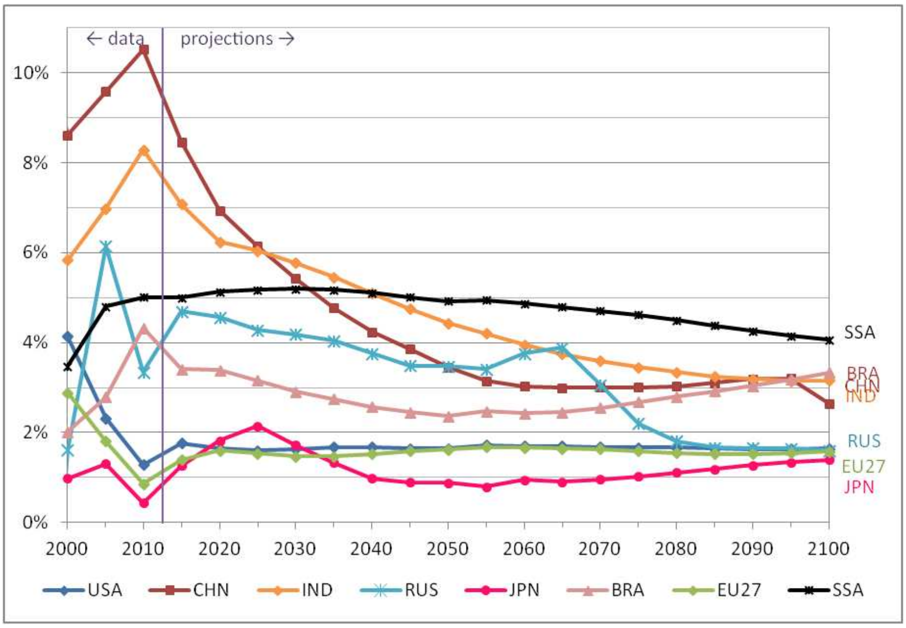

Figure 4: Five-year average growth rate, 1980-2100.[b]
Source: Fouré et al. (2012) up to 2050, author's calculations 2050-2100.

[a]Note: SSA stands for Sub-Saharan Africa, IND for India, RUS for Russia, CHN for China, BRA for Brazil, USA for the United States of America, EU27 for the European Union and JPN for Japan.

[b]Note: SSA stands for Sub-Saharan Africa, IND for India, RUS for Russia, CHN for China, BRA for Brazil, USA for the United States of America, EU27 for the European Union and JPN for Japan.

much slower decrease. At the end of the period, the most dynamic region is Sub-Saharan Africa, which achieve maintaining a growth rate over 4% between 2015 and 2100.

Factors and energy productivity Other output variables from the MaGE model are useful for the present study. Table 7 presents a summary of these variables. Labour force is projected to decrease between 2050 and 2100 in many countries and in particular in China and India. On the other hand, in the USA and EU27, a very slow growth is projected, in contrast with the very dynamic population of Sub-Saharan Africa. Countries present several profiles regarding savings rate. While a majority of countries keep their savings rate almost constant (the low value for Brazil and Latin America in 2010 being an exception), China and Russia faces structural changes. Whereas the U-shape for China can be explained by growth slowing for its decreasing part, and by population ageing slowdown for its re-increasing part, Russia face an increasing savings rate due to its fast-growing per-capita GDP (diminishing population and increasing oil rents and TFP). These structural changes pass through investment to form current account evolution. Investment is computed using an estimated error-correction model which states a long term relationship between investment and savings, while short run dynamics are driven by a spring force around long run tendency. In addition, savings and investment are constrained to be equal at the world level, while savings globally increase over the end of the period. This explains for instance the small decrease in the US current account.

Table 7: Labor force, savings rate, current account and energy productivity, 2010, 2050 and 2100

Country or zone	Labor force (million workers)			Savings rate (% of GDP)			Current account (% of GDP)			Energy productivity (2005 USD per barrel)		
	2010	2050	2100	2010	2050	2100	2010	2050	2100	2010	2050	2100
USA	161	198	241	11.3	13.2	11.8	-2.5	-0.5	-1.7	1193	1605	1805
Japan	65	52	46	23.6	21.5	22.9	2.3	1.7	1.4	2149	2341	2606
EU27	241	211	215	15.8	15.6	17.1	0.9	0.1	0.0	1889	2090	2261
Brazil	103	119	95	10.4	12.3	9.3	-4.8	-3.7	-6.9	753	1096	1346
Russia	77	58	54	14.2	25.8	34.2	-2.2	6.2	12.4	239	458	557
India	490	785	696	20.2	20.9	16.3	-3.3	1.9	-2.6	291	593	782
China	795	656	456	37.3	25.7	33.9	5.8	-3.1	2.5	245	635	841
Latin America	177	260	269	13.2	18.0	16.3	-0.9	0.9	-1.2	837	1180	1358
MENA	152	230	227	16.1	20.9	17.1	0.2	1.7	-3.0	472	930	989
SSA	310	854	1727	13.5	16.4	15.6	-1.4	1.0	-0.1	279	419	482
Rest of Asia	460	670	608	19.4	22.0	17.9	-0.1	0.9	-2.7	519	759	855
Rest of the World	71	74	82	20.3	22.0	26.0	2.3	1.6	3.9	859	900	855
Total World	3102	4167	4716	17.0	19.4	21.2	0.0	0.0	0.0	786	926	980

Notes: USA stands for the United States of America, MENA for Middle-East and North Africa and SSA for Sub-Saharan Africa. When appropriate, labor force is summed over the zone, savings rate and current account are averaged using GDP as weight and energy productivity is averaged using energy consumption as weight.
Source: Fouré et al. (2012) for 2050, authors' calculations for 2100.

Energy prices As noted before, world average prices are imposed to the model based on the projections by the International Energy Agency (IEA, 2011). Over the past few years, gas and oil price have faced large annual variations. This erratic behaviour cannot be handled properly in MIRAGE-e since it reflects short-term adjustments, not related to the optimal situation computed by the model. We therefore choose to smooth these two price trajectories between 2004 and 2013 such that the model can handle the general path.[13] These evolutions are presented in Figure 5. Moreover, IEA projections are only available until 2035. We extend their trajectory by applying a constant annual growth rate between 2035 and 2100, at the value of the last observed growth rate (2034-2035).

Consumption patterns, energy mix This long-run baseline shows changes in consumption patterns. Financial, Insurance, Business and Transport services increase their participation at the world level, while Food consumption falls. Consumption in technological products slightly increases (e.g. Machinery and Electronic devises) but most traditional manufactured sectors (e.g. Textile, Cars & Trucks) remain quite stable in terms of consumption shares (Figure 6).

Regarding energy consumption, changes in the world energy mix respond to price changes, as shown in Figure 7. We can see that the share of gas in final energy mix (net of energy used to generate electricity and refined petroleum) increases during the period when its price decreases (until 2015). The share of coal, oil, gas and refined petroleum decrease over time such that electricity reaches 40% of world demand in 2100. This may be due to the fact that electricity

[13] We use a linear extrapolation for years with erratic evolution of price for oil (2008-2009) and gas (2005-2013).

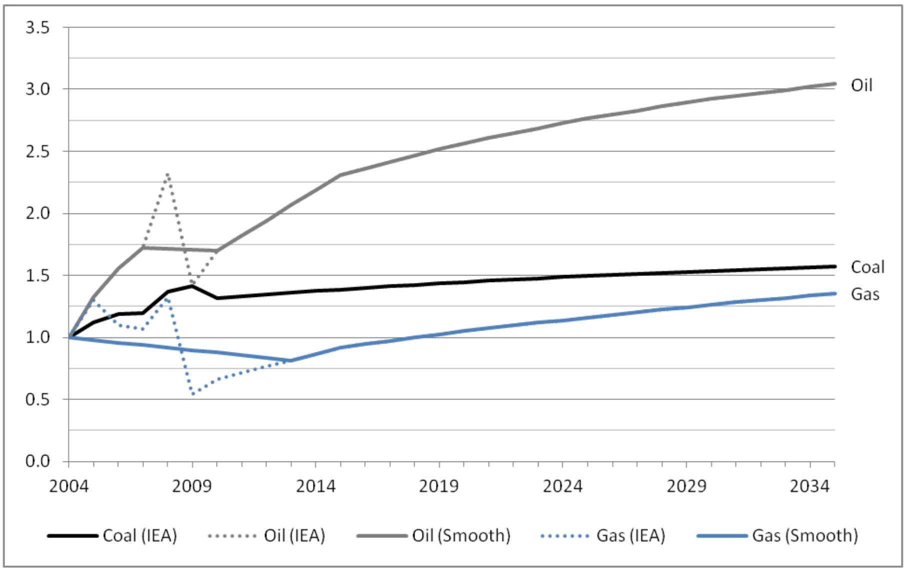

Figure 5: World average price of primary energy (2004 = 1)

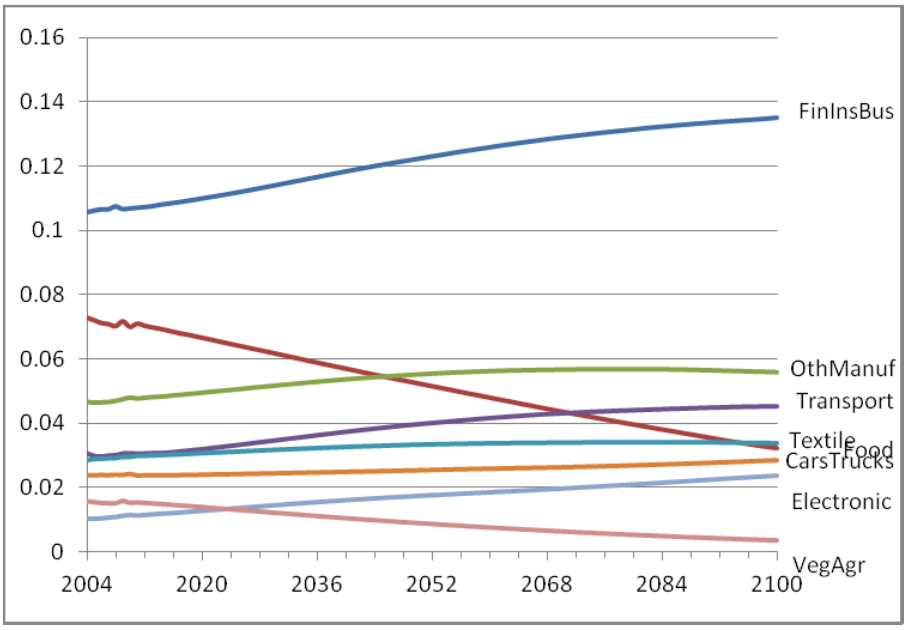

Figure 6: World Consumption shares by sector (2004=1)

price rise less than other energy prices. For instance, it is less dependant on oil price than petroleum and coal products (which mainly includes refined petroleum). However, electricity generation may hide a large part of energy consumption. The share of coal in the demand for electricity generation increases over the period, due to its relative price growing slower than the oil and gas one, at least after 2015. This will have consequences on CO_2 emissions, since coal is far more CO_2 intensive than the two other primary energies.

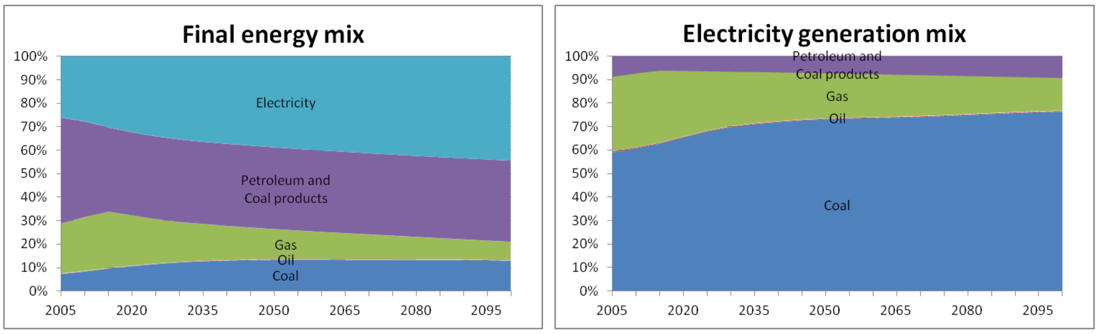

Figure 7: Final energy mix and electricity generation mix of the world (Percentage of total energy consumption)

Sector-specific TFP Region TFP are differently affected by sectoral factor productivity. In our long-run baseline we consider that agricultural TFP is exogenously introduced according to our estimations. Agricultural TFP is differentiated between livestock and crops because of their different factor content. In contrast, manufactures and services' TFP are endogenously determined in MIRAGE, around the national trend depicted in Figure 8.

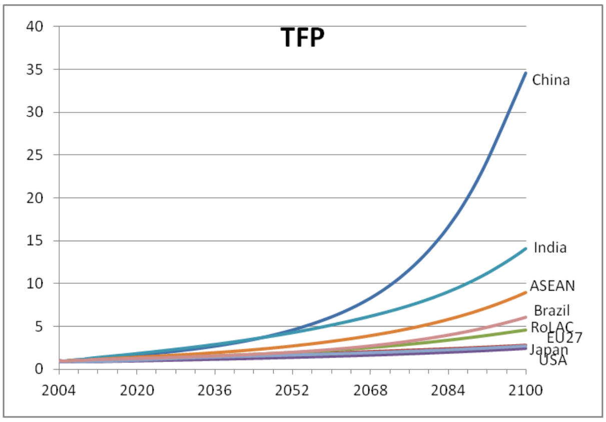

Figure 8: Total factor productivities by region (2004=1)

While Russia quickly increases its factor productivity for crops, Latin American countries (including Brazil) shows a similar trend in their livestock TFP. Asian countries (China, India and ASEAN) lead on the development of manufactures and services TFP (Figure 8). These TFP growth echo quite well what happens in MaGE. For these Asian countries, as well as for North Africa, TFP rise steadily in the growth model due to massive accumulation of human capital (though to a lesser extend in India), in conjunction with a low productivity starting point (especially for India). This effect is communicated to MIRAGE-e though GDP improvements which are not explained by factor accumulation.

Sectoral Outputs Output evolve differently across sectors and regions. Large countries, such as China and India, increase their participation in food production at the world level. Latin American countries including Brazil also become main food providers. Livestock (i.e. AnimAgr) illustrate this trend of regional production shares. However, for vegetal agriculture, developed countries (e.g. USA, EU27) recover their position as main world providers by the end of the period. In manufacturing, China becomes the most important producer of electronic devices with other Asian countries (e.g. ASEAN). Even for cars and trucks China will become a major actor in global production, while the USA, the EU27 and Japan lose their traditional leadership as illustrated in Figure 9.

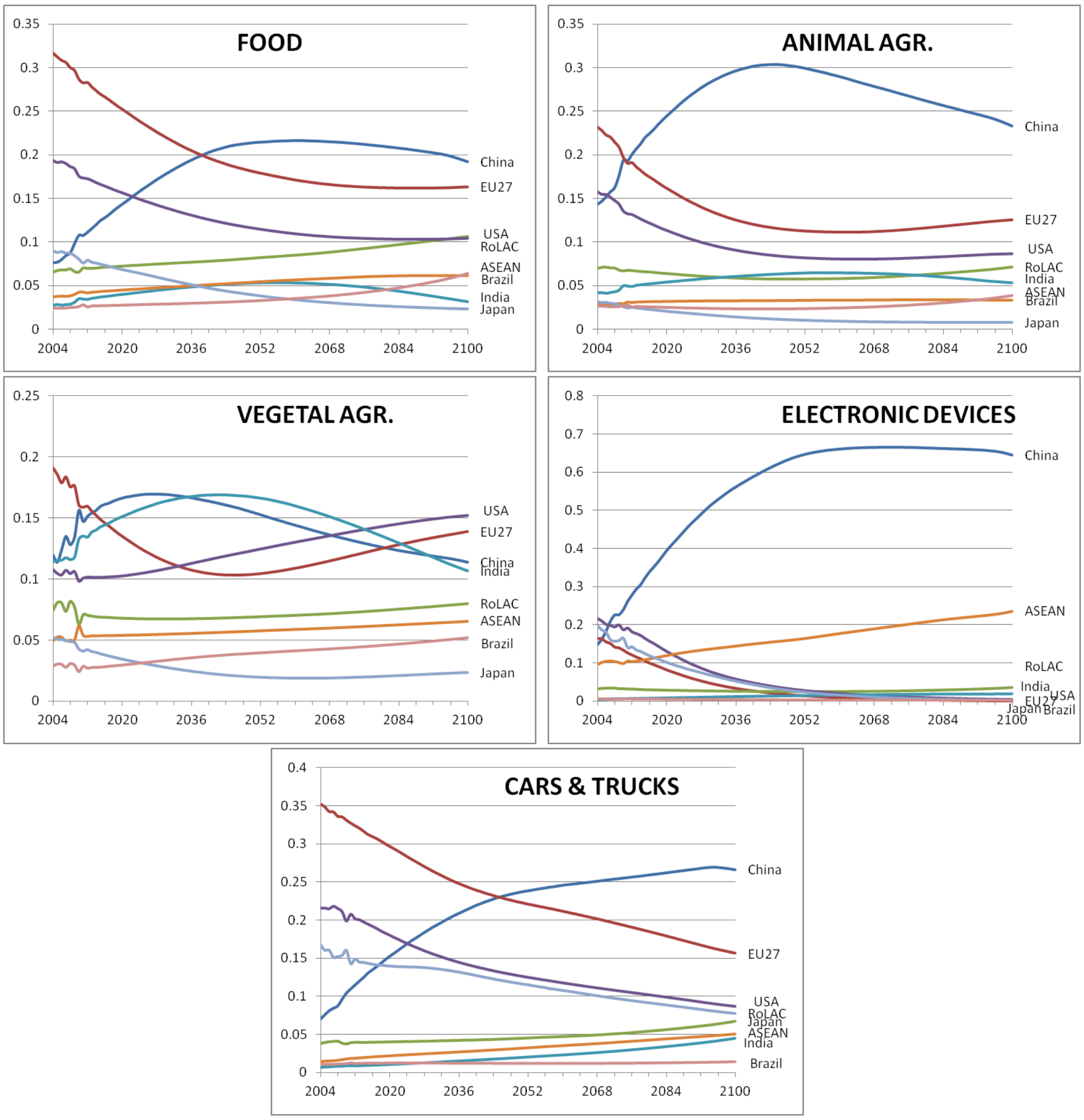

Figure 9: Regional Production (vol) shares for main products

In the raw energy sectors, the US is and will stay the main world producer of gas (even doubling its share) while the Middle East countries lose their leading position on the market. Nevertheless, this region will remain the main provider of oil. Moreover, no radical changes in production shares are observed in this sector, excepted the rise of Rest of Africa. Coal production becomes mainly concentrated in China while the USA and the EU27 highly reduce their presence as suppliers; as well as Rest of Africa increase its share (Figure 10).

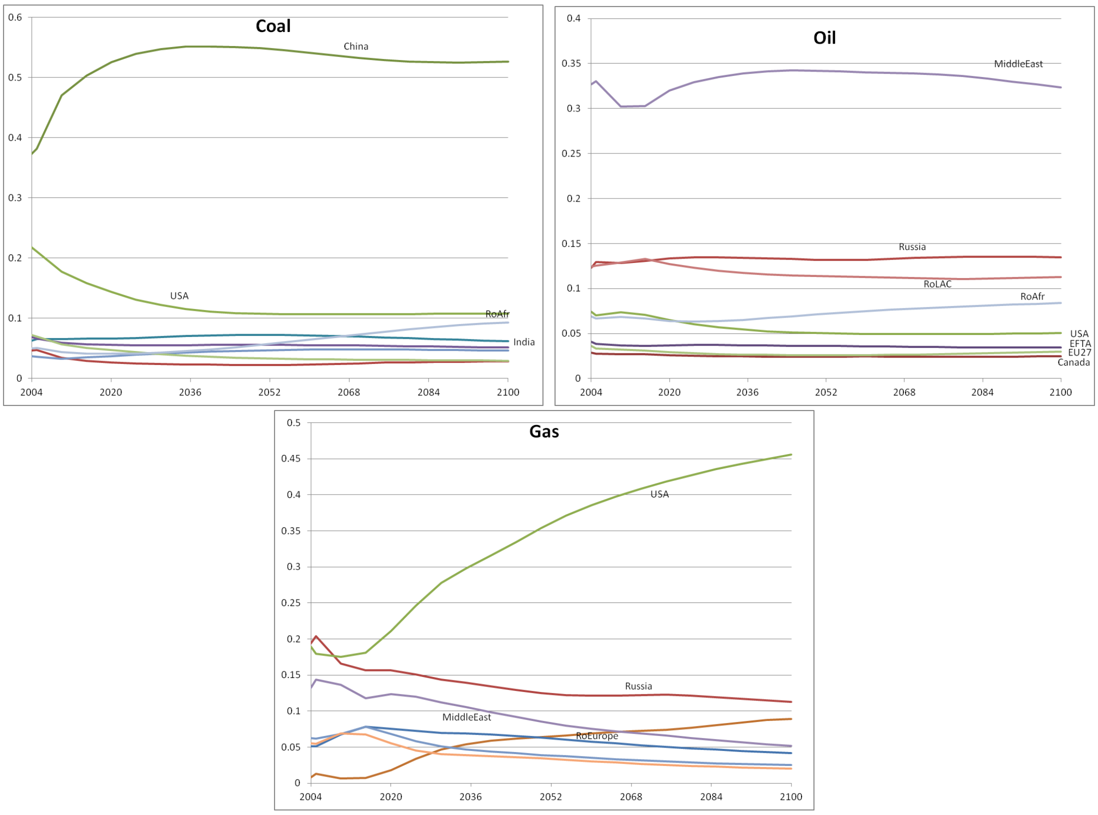

Figure 10: Regional Production (Mtoe) shares for main energy products

CO_2 Emissions Regional growth, changes in consumption and production patterns and the improvement in the use of energy also affect CO2 emissions. Such as it is shown in Figure 11 China will be highly committed in terms of CO_2 emissions' control, such as other developing countries with great growth rates (e.g. India). In contrast, developed countries (e.g. USA, EU27 and Japan) will reduce their participation in the global CO_2 emissions. These results make us think about the present responsibility of developing countries on future emissions and climate change impact, and the necessity of their commitments on environmental control and CO2 mitigation policies.

Our CO_2 projections are high compared to existing literature, such that world emissions are multiplied by 10 between 2004 and 2100. Two main reasons are behind this fact. First, our model does not take into account eventual backstop technologies or renewable energies that could help reduce emissions, as well as no environmental policy is implemented. In such terms, we present a true "Business as Usual" scenario. Second, we would need a complete natural resource depletion model to precisely describe long-run issue for coal, oil and gas consumption. Up to 40% of CO_2 is emitted by China in 2100, and its main energy source is the most carbon-intensive one: Coal. This situation would have been different if coal prices were not that low compared to other energy sources.

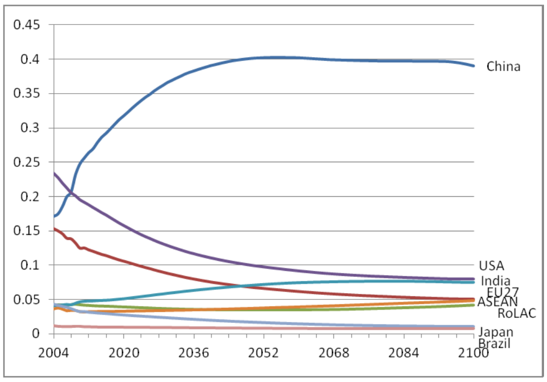

Figure 11: CO2 emissions by regions (shares)

Trade Since production and consumption patterns change during this long-run baseline, trade specialization is also redefined (Figure 12 and Figure 13). Here we analyze trade patterns for the main developed countries and China, however, this analysis could be also extended to other regions of the world. China becomes a net exporter of machinery and electronic devises, while it imports mainly energy inputs (Oil) and food (Food, all type of agricultural products). The USA will increase its export shares in vegetal agriculture and gas, while they also increase import shares in machinery products and financial, insurance and business services. Japanese exports will turn to Other manufactured products replacing traditional exports from the Machinery and Car & Trucks sectors. Japan will need and thus import more business services, machinery and metals products. Finally, the EU27 will specialize in business services and for trade in goods it will mainly exports primary, agricultural and food products. Import shares in the EU27 will increase for machinery, metals, cars & trucks and other services than finance and business.

5.4 High and Low Growth Alternatives for the Long-run: a baselines' comparison

5.4.1 Growth model results

We briefly present the results of the two scenarios modeled with MaGE. We focus on four variables which are GDP growth, savings rate, current account and labor force. These variations are presented in Table 8 in terms of percentage points (p.p.) deviation or percentage deviation (%). For instance, the first column, third row, should be read as "European Union gains 0.04 percentage points of growth in the High Growth scenario". The seventh column, third row, should be read as "the High Growth scenario adds 1.44% of the reference labor force to European Union".

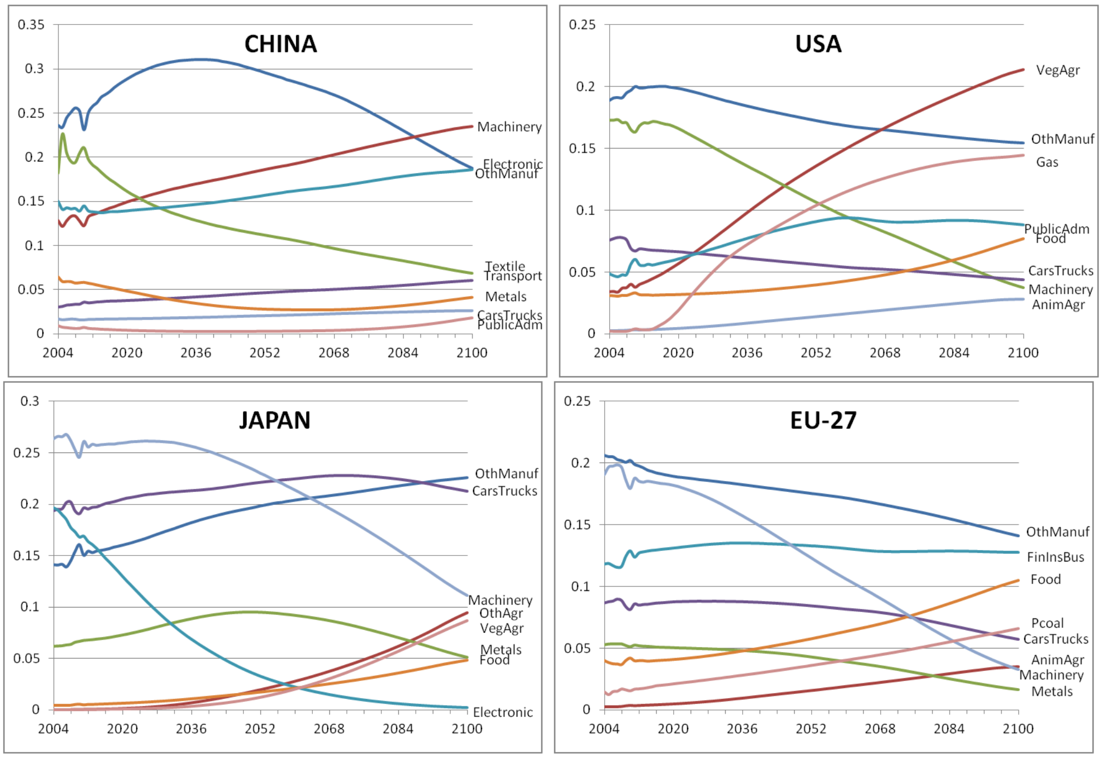

Figure 12: Sectoral Exports (vol) shares for main countries

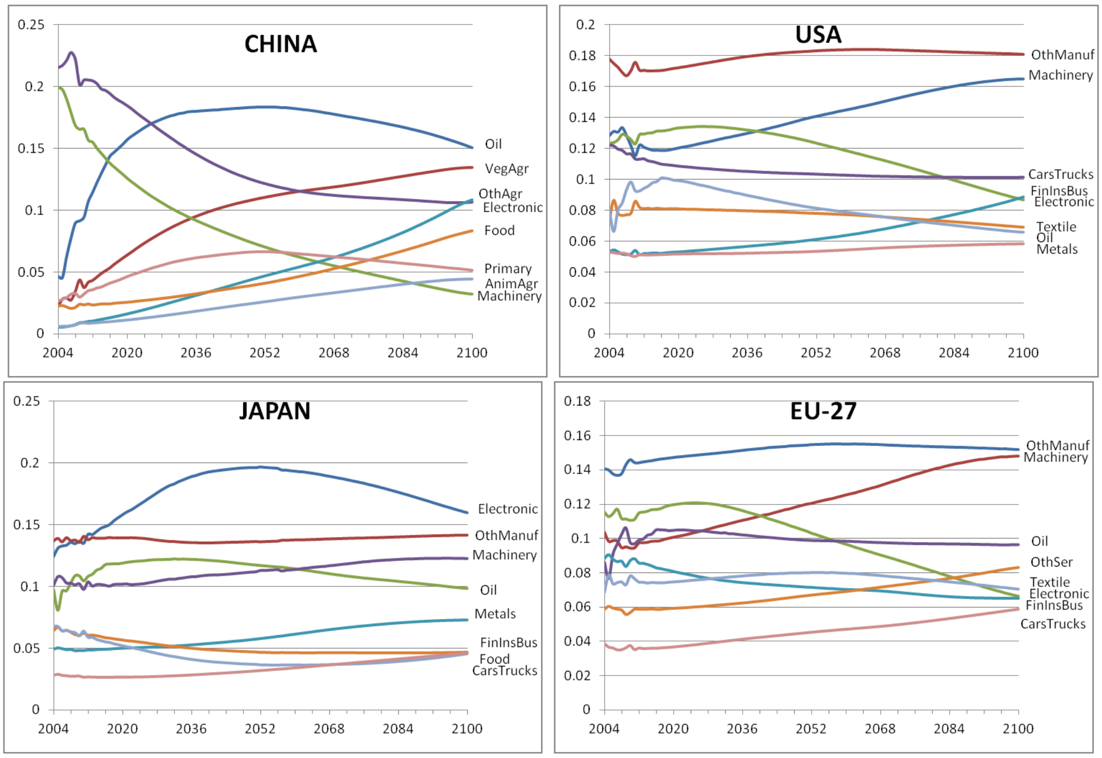

Figure 13: Sectoral Imports (vol) shares for main countries

Table 8: GDP growth, savings rate, Current account and Labor force variations (deviation from baseline)

Country or zone	GDP growth 2010-2100 (p.p. deviation)		Savings rate 2100 (p.p. deviation)		Current Account 2100 (p.p. deviation)		Labor force 2100 (% deviation)	
	High	Low	High	Low	High	Low	High	Low
USA	0.02	-0.05	0.13	0.14	-1.05	1.67	0.61	-6.62
Japan	0.03	-0.06	0.40	-0.35	-1.59	-1.40	0.71	-11.77
EU27	0.04	0.01	0.46	1.15	-1.18	-0.03	1.44	-3.72
Brazil	0.65	-0.83	8.48	-0.90	5.78	6.87	5.60	0.02
Russian Federation	0.04	0.29	0.27	4.57	-1.32	-12.36	0.94	-2.29
India	0.78	-0.63	2.54	-0.48	0.73	2.64	5.25	-12.67
China	0.16	-0.41	3.81	-4.63	0.88	-2.52	4.09	-3.63
MENA	0.41	-0.61	3.55	0.78	1.20	3.00	6.07	-15.56
SSA	0.71	-0.35	2.32	0.65	0.85	0.13	2.83	-1.15
R.o. Asia	0.52	-0.45	0.15	1.77	-0.97	2.73	5.67	-5.72
R.o. World	0.09	0.00	0.94	1.50	-0.94	-3.91	1.53	-5.98
Total world	0.35	-0.30	1.58	-0.32	0.00	0.02	3.76	-5.13

Notes: USA stands for the United States of America, MENA for Middle-East and North Africa and SSA for Sub-Saharan Africa. When appropriate, labor force is summed over the zone, savings rate and current account are averaged using GDP as weight and energy productivity is averaged using energy consumption as weight.
Source: Author's calculations.

The first observation is that, regarding GDP growth, the names of the two alternative scenarios are appropriate. The aggregation of all assumptions lead to greater GDP in all zones, with a average 0.1 additional world average annual growth. The greatest winners of this scenario are India and Brazil. In the Low Growth case, losses are less concentrated, with Brazil loosing more than 1 point of annual growth over the whole period.

Regarding labor force, changes in the High Growth scenario only reflect the impact of higher education on female participation. This impact is of course greater in countries which educational level is the lowest in the reference scenario (Sub-Saharan Africa, Brazil and India) and lowest in countries with an already well-educated population (USA and Russia). On the contrary, deviation in the Low Growth scenario reflects the overall effect of education on female participation, thus the more impacted countries are those with the lowest female participation rates over the past, like Middle-East and North Africa as well as Sub-Saharan Africa.

Since there are no changes in demographics between the scenarios, changes in savings rate only come from the dynamics of GDP growth. Except for Brazil, these changes are not very large in terms of % of GDP.

Current accounts respond to different logics in the two scenarios. First, in the High Growth one, they are a consequence of the savings rates variation. The percentage change is not however exactly the same due to the error-correction relationship with investment. Secondly, in the pessmistic scenario, the changes almost only come from the changes of Investment rates due to their equalization to savings rate. Since all current accounts are at equilibrium in this scenario, countries with large deficits see their current account increase, like the USA, and vice-versa.

5.4.2 MIRAGE-e results

Let's compare the 'business as usual' baseline to the alternative High and Low Growth scenarios for the long-run. In the High Growth one, the energetic factor represents a lower constraint and induces an easier factor accumulation. Other factors and goods markets are more flexible and open with the assumption of greater mobility and market access improvement for goods, while in the Low Growth scenario shows enclosed economies with a restrictive factor accumulation and limited market access. We do not present all results once again but only those where differences with the reference baseline are remarkable.

Consumption, GDP and TFP Consumption pattern at the world level remains the same under all baseline scenarios (Figure 14). Nevertheless, under the High Growth baseline, regional consumption shares in the world GDP quickly increase in developed regions (e.g. the EU27 and the US) by enlarging the gap between them and with the BRICs, particularly with China and India. In contrast, the gap in consumption share between the EU27 and the US disappears at the end of the Low Growth baseline, while it only reduces with China, whose consumption share in the global GDP is the greatest compared with the others baselines.

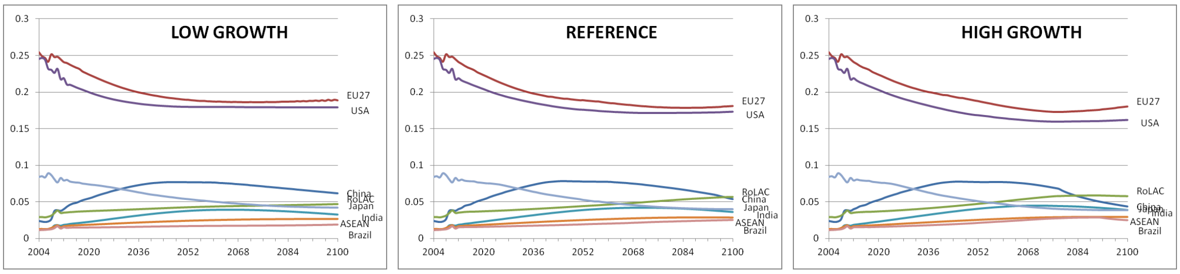

Figure 14: Consumption shares in Global GDP

In conclusion, even if global GDP reaches a greater (lower) level in the High Growth (Low Growth) baseline compared to the reference, regional shares do not display significant changes. In 2100, global GDP would reach 356,871 billion US$ under the Low Growth scenario while the High Growth one almost double it (i.e. 710,793 billion US$).

Our TFPs show different trends among regions and scenarios (Figure 15). For developed regions (e.g. EU27, US and Japan) the dispersion between the reference and the alternative scenarios is lower than for BRICs (e.g. Brazil, China and India). Thus, productivity in developing economies appears as more sensitive to changes in the future context.

Sectoral production and Trade Alternative scenarios also affect sectoral production pattern across regions (Figure 16) and thus determine changes in trade patterns (Figure 21 and Figure 22 in Appendix B). The sectoral composition of trade is also affected by the different baseline scenarios. While an High Growth scenario is boosting trade in (industrial and agricultural) goods, it discourages trade in services and energy.

Regional production shares is quite changing in agricultural sectors. An High Growth baseline improves the US participation in vegetal agriculture production and thus on its exports. For

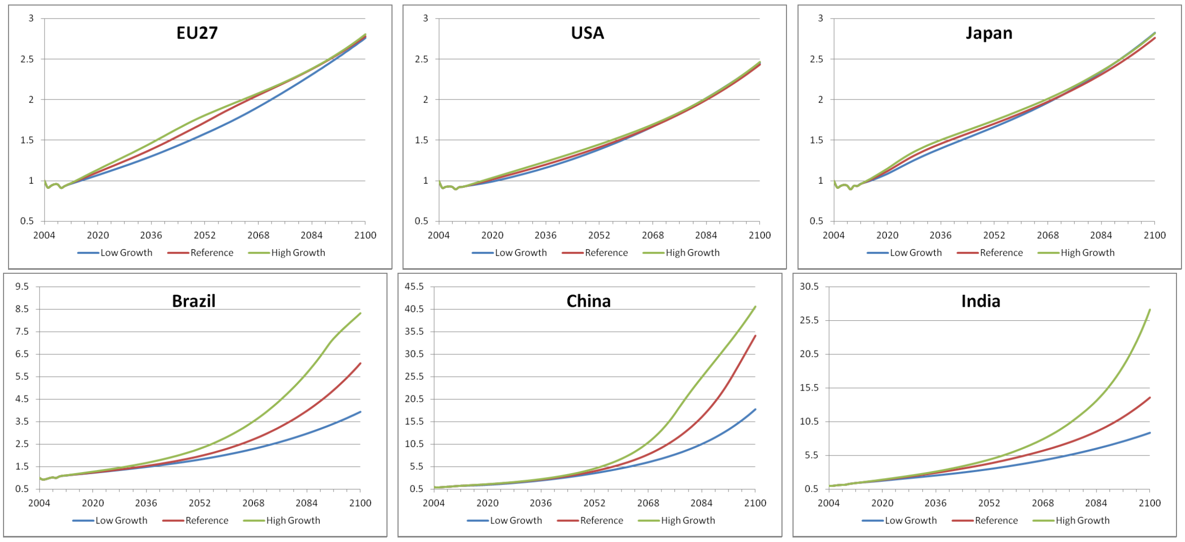

Figure 15: TFP comparison for selected regions (2004=1)

the EU27 under the same scenario, its negative trend reverses by the end of the period, and its vegetal agricultural exports increase. This scenario does not seem very optimistic for Asian countries, such as China and India, which drastically lose their position in agricultural world production. However, the Low Growth baseline shows the opposite trend for these countries, which appear as the greatest suppliers of vegetal agriculture. Concerning animal agricultural output, the regional pattern is quite similar. Under the High Growth scenario, developed regions slightly reverse their negative trends in production shares, while Chinese share strongly falls from the middle of the period onwards. Latin American countries also benefit from this scenario, increasing their participation as animal-based products suppliers. Opposite results are thus shown under the Low Growth baseline.

Food production in the reference was lead by China, while the EU27 and the US were quickly loosing their position in the market. Nevertheless, the High Growth baseline reverses this situation by allowing developed countries to regain their places by the end of the period and boost their food exports. Under this situation, China is the only country that is strongly affected by the decline in its food production and becomes one of the greatest food importers. The Low Growth scenario displays the opposite pattern: greater participation for China in food production and lower output shares for developed countries in this sector.

In manufactures China dominates world production. However, under the High Growth baseline this country loses its position to give the chance to other developing countries (e.g. ASEAN in electronics devises, Latin American countries in cars and trucks). These production shares are paired with trade shares in China: while exports in electronic devises and textiles fall, they increase in machinery products and other manufactures. In contrast, for developed regions this scenario is in fact optimistic compared to others because the fall in manufactures production shares is retained thanks to the flexibility and openness imposed by that stage. However, manufactured exports from these countries decrease while they increase in raw energies, food and crops.

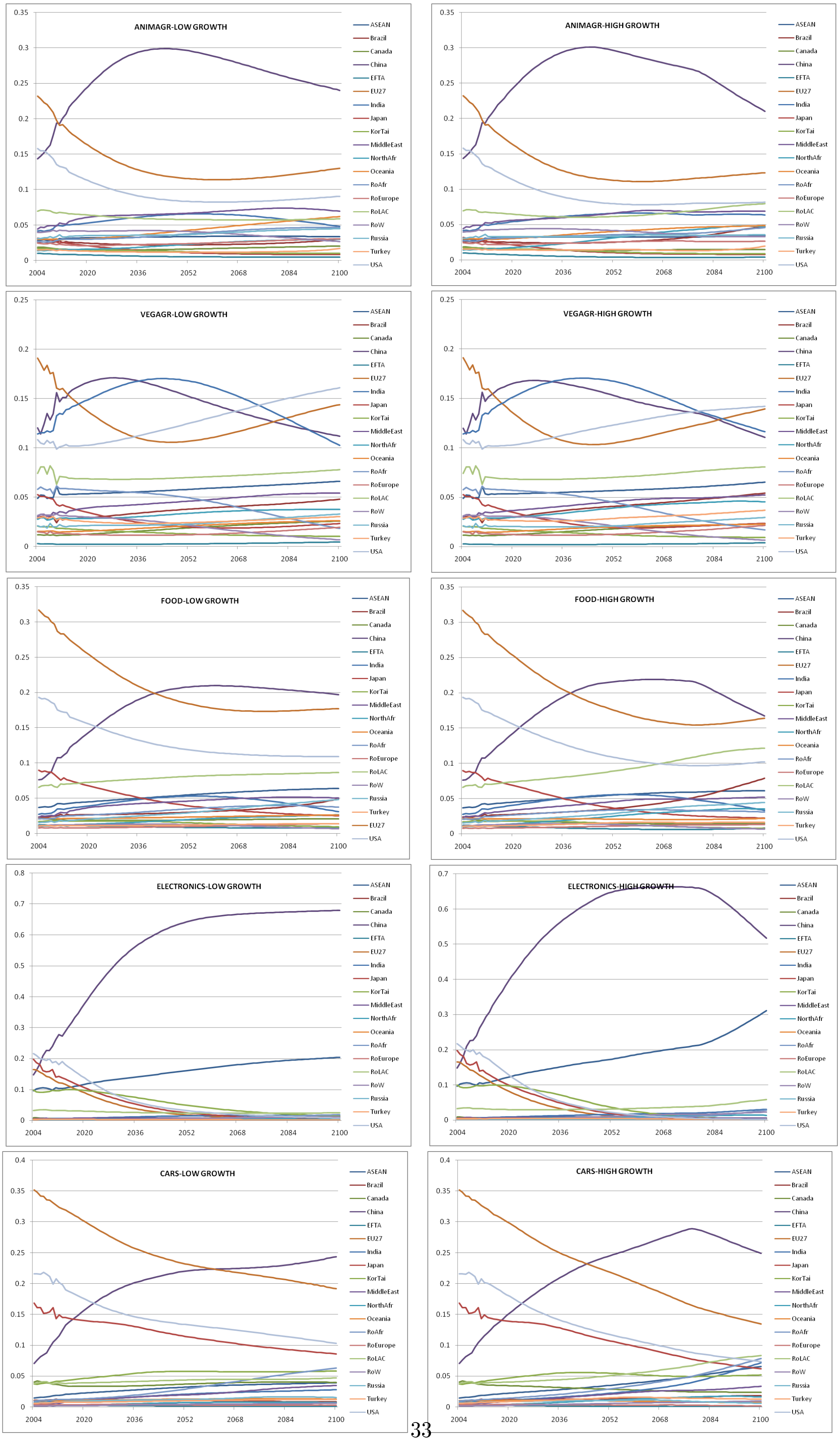

Figure 16: Sectoral outputs (regional shares)

Energy and CO2 Emissions In the alternative scenarios, the shares of the different countries in energy production do not vary much. However, the amounts produced differ a lot. Figure 17 presents world production for the three primary energy sources in 2100. Differences from the baseline mainly come from the demand side. In the High Growth scenario, demand should increase a lot, but improvements in energy productivity tend to compensate the increasing demand. Therefore, only oil production is significantly higher. In the Low Growth scenario, energy productivity is slightly higher too, but it fails to compensate the decreasing demand due to the drop in all productions.

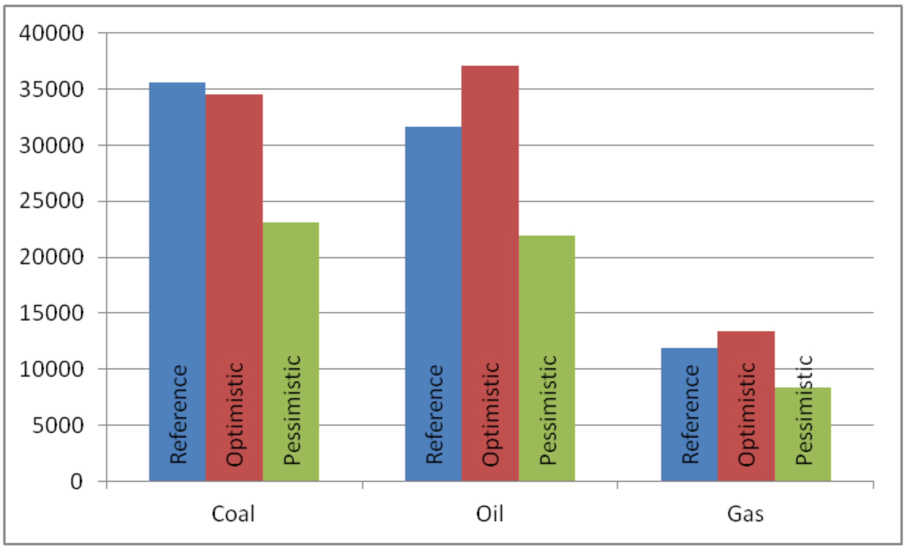

Figure 17: World production of primary energies in 2100 (Mtoe)

Although, CO2 emissions shares at regional level are quite stable across baseline scenarios, an high growth is also paired to a greater level of emissions (Figure 18). Fortunately, a greater energy consumption is partially counterbalanced by a quickly increase in a more efficient use of this resource.

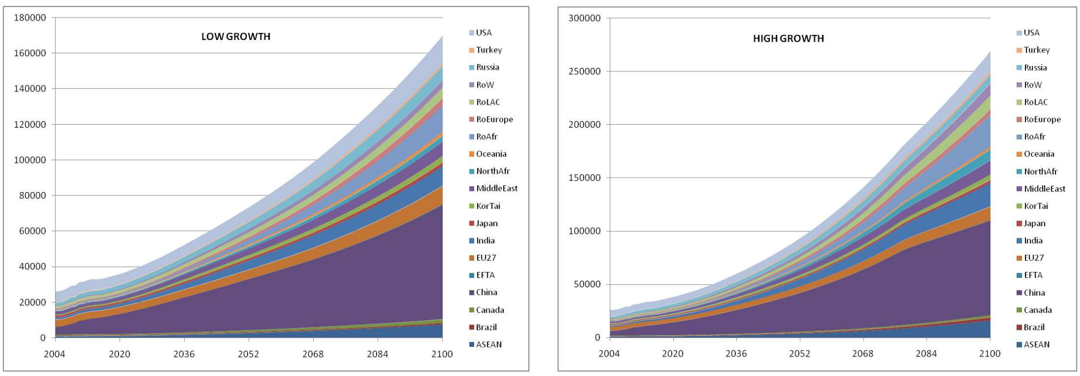

Figure 18: CO2 emissions by region in MtCO2eq

Appendix

A Malmquist index additional information

A.1 Distance functions and Malmquist Index

The goal of DEA is to build a piece-wise linear surface, for each year t and country i, corresponding to the maximum production that country i could have obtained with its inputs (output-oriented DEA). That is, finding which countries use the more efficiently their inputs in order to derive a productivity frontier. Such DEA methods have already been used to compute Malmquist TFP indices at a national level (see Färe et al., 1997) or for agriculture-specific TFP (see Coelli and Rao, 2005; Ludena et al., 2007).

DEA uses distance function to compute improvements in TFP. Suppose that we have a set of all feasible inputs/outputs vectors S^t. For a country which produces a vector of outputs y^t with its inputs x^t, output-oriented distance function to the frontier at date s can be defined following Färe (1988):

$$\begin{aligned} D^s\left(x^y, y^t\right) &= \inf\left\{\theta \ s.t.\ \left(x^t; y^t/\theta\right) \in S^s\right\} \\ &= \sup\left\{\theta \ s.t.\ \left(x^t; \theta y^t\right) \in S^s\right\} \end{aligned} \tag{22}$$

This implies that $D^s\left(x^t, y^t\right) \leq 1$ if and only if $\left(x^t, y^t\right)$ is a feasible input/output combination at date s ; and $D^s\left(x^t, y^t\right) = 1$ if and only if $\left(x^t, y^t\right)$ is on the boundary or frontier of technology.

Most of the times, numerical estimations are required to compute the frontier and distances. The frontier is approximated by a piece-wise linear surface delimited by the countries which are the more efficient at date s and distance of the other countries are computed by a maximization program (for sector m^* in country k^* at date t, relative to period s technology):

$$D^s\left(x^t, y^t\right)^{-1} = \max_{\theta, z^k}(\theta) \tag{23}$$
$$\text{s.t.} \begin{cases} y_m^{k^*,t} \leq \sum_k z^k y_m^{k,s} & \text{for} \quad m \neq m^* \\ \theta y_{m^*}^{k^*,t} \leq \sum_k z^k y_{m^*}^{k,s} & \\ \sum_k z^k x_{n_{m^*}}^{k,s} \leq x_{n_{m^*}}^{k^*,t} & \text{for} \quad n \in A \\ \sum_k z^k x_n^{k,s} \leq x_n^{k^*,t} & \text{for} \quad n \notin A \\ z^k \geq 0 & \text{for} \quad k = 1, ..., K \end{cases}$$

In order to simplify notations, we write θ instead of $\theta_{m^*}^{k^*,t,s}$ which is the inverse of the distance we want to compute; and z^k instead of $z_{m^*}^{k,k^*,t,s}$ which determines to which point countries k^* is projected to on the frontier. In addition, we used a refinement introduced by Nin et al. (2004) which takes profit of the information about which inputs are allocatable to a specific sector ($\in A$) and which are not ($\notin A$).

We solve numerically these programs using GAMS. The program solves, for each year t and each $s \in \{t-1; t; t+1\}$, the maximization programs of all countries and sectors at the same time using a linear objective function and the additional constraint that all $\theta_{m^*}^{k^*,t,s}$ be positive: [14]

$$\beta = \sum_{m^*,k^*} \theta_{m^*}^{k^*,t,s} \tag{24}$$

Färe et al. (1997) define the Malmquist index of productivity growth as the geometrical mean of two indexes, respectively based on technological frontier at date t and $t+1$, for constant returns to scale:

$$M^{t,t+1} = \sqrt{\left(\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right)\left(\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}\right)} \tag{25}$$

This formula can be rewritten in a more convenient way:

$$M^{t,t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\sqrt{\left(\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right)} \tag{26}$$

which separates the Malmquist index in an efficiency (distance to the frontier) term $\Delta EFF^{t,t+1}$ and a technical change term $\Delta TECH^{t,t+1}$. Such an index has some interesting properties. $M^{t,t+1} \geq 1$ if there have been progresses in TFP between year t and $t+1$ and $M^{t,t+1} \leq 1$ if technological regress has occurred. Furthermore, improvements (resp. deterioration) of the two components $\Delta EFF^{t,t+1}$ and $\Delta TECH^{t,t+1}$ are associated with values greater (resp. lower) than 1.

A.2 Computing livestock

Table 9: Aggregation coefficient for animal stock by region

Region	Buffaloes	Camels	Cattle	Chickens	Ducks	Goats	Pigs	Sheep	Turkeys
Asia	0.50	0.50	0.50	4.4	4.72	0.05	0.26	0.05	23.38
SSA	0.46	0.46	0.46	3.3	6.22	0.04	0.17	0.04	10.64
Eastern Europe	0.63	0.63	0.63	4.8	7.75	0.04	0.30	0.04	18.78
Rest of America	0.74	0.74	0.74	5.3	7.18	0.05	0.26	0.05	19.15
MENA	0.51	0.51	0.51	4.2	8.50	0.06	0.27	0.06	11.12
OECD	1.00	1.00	1.00	5.5	8.44	0.06	0.30	0.06	27.91
Former USSR	0.54	0.54	0.54	4.5	7.75	0.06	0.27	0.06	21.60

Notes: SSA stands for Sub-Saharan Africa and MENA for Middle east and North Africa.
Source: Ludena et al. (2007).

[14] We are then left with 139 programs. We also tried, as a comparison, solving a program for each sector and country (for a total of 38086 programs), to find no differences in the results.

A.3 Region Aggregation

Table 10: Malmquist indices regional aggregation

Industrial countries	**China**	**Central and South America**
Australia	China	Argentina
Austria	**Developing Asia**	Bolivia
Belgium	Bangladesh	Brazil
Canada	China	Chile
Switzerland	Indonesia	Colombia
Germany	India	Costa Rica
Denmark	Iran, Islamic Republic of	Ecuador
Spain	Cambodia	Guatemala
Finland	Korea	Mexico
France	Lao People's Democratic Republic	Nicaragua
United Kingdom	Sri Lanka	Panama
Greece	Malaysia	Peru
Ireland	Pakistan	Paraguay
Italy	Singapore	Uruguay
Japan	Thailand	Venezuela
Luxembourg	Turkey	Rest of Central America
Netherlands	Vietnam	Caribbean
Norway	Rest of East Asia	Rest of South America
New Zealand	Rest of South Asia	**Sub-Saharan Africa**
Portugal	Rest of Southeast Asia	Botswana
Sweden	Rest of Western Asia	Ethiopia
United States of America	**East and south-east Asia**	Madagascar
Rest of EFTA	Indonesia	Mozambique
South Africa	Cambodia	Malawi
United States of America	Korea	Nigeria
United States of America	Lao People's Democratic Republic	Senegal
Transition economies	Malaysia	Tanzania
Albania	Philippines	Uganda
Bulgaria	Singapore	South-Central Africa
Belarus	Thailand	Central Africa
Czech Republic	Vietnam	Rest of Eastern Africa
Croatia	Rest of East Asia	Rest of South Africa Customs Union
Hungary	Rest of South Asia	Rest of Western Africa
Kazakhstan	Rest of Southeast Asia	Zambia
Kyrgyzstan	**Middle-east and North Africa**	Zimbabwe
Poland	Egypt	
Romania	Iran, Islamic Republic of	
Russian Federation	Morocco	
Slovakia	Tunisia	
Slovenia	Turkey	
Ukraine	Rest of North Africa	
Rest of Europe	Rest of Western Asia	
Rest of Former Soviet Union		

A.4 Breaks in distances series

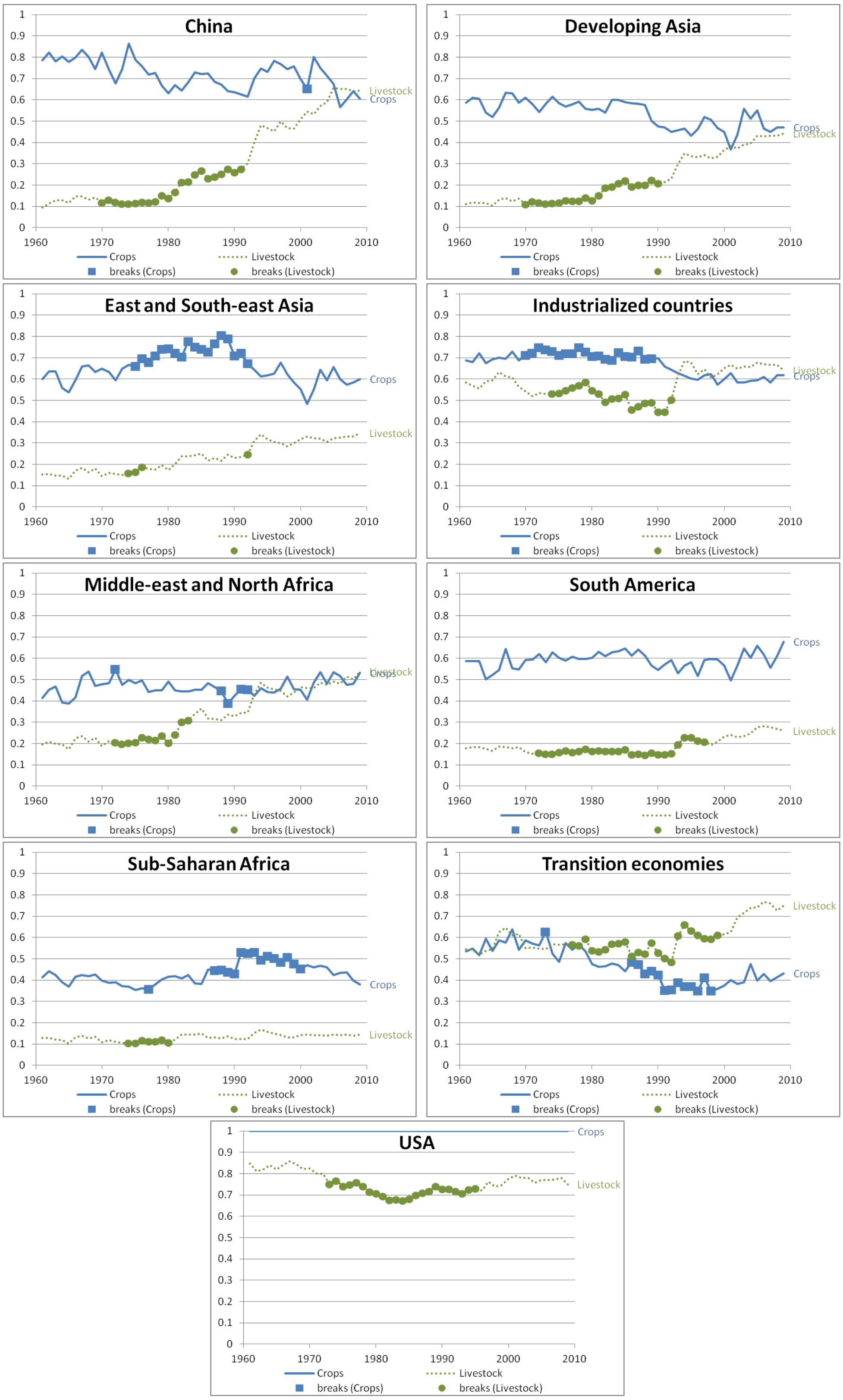

Figure 19: Breaks in distance function series by region

A.5 Projection by region

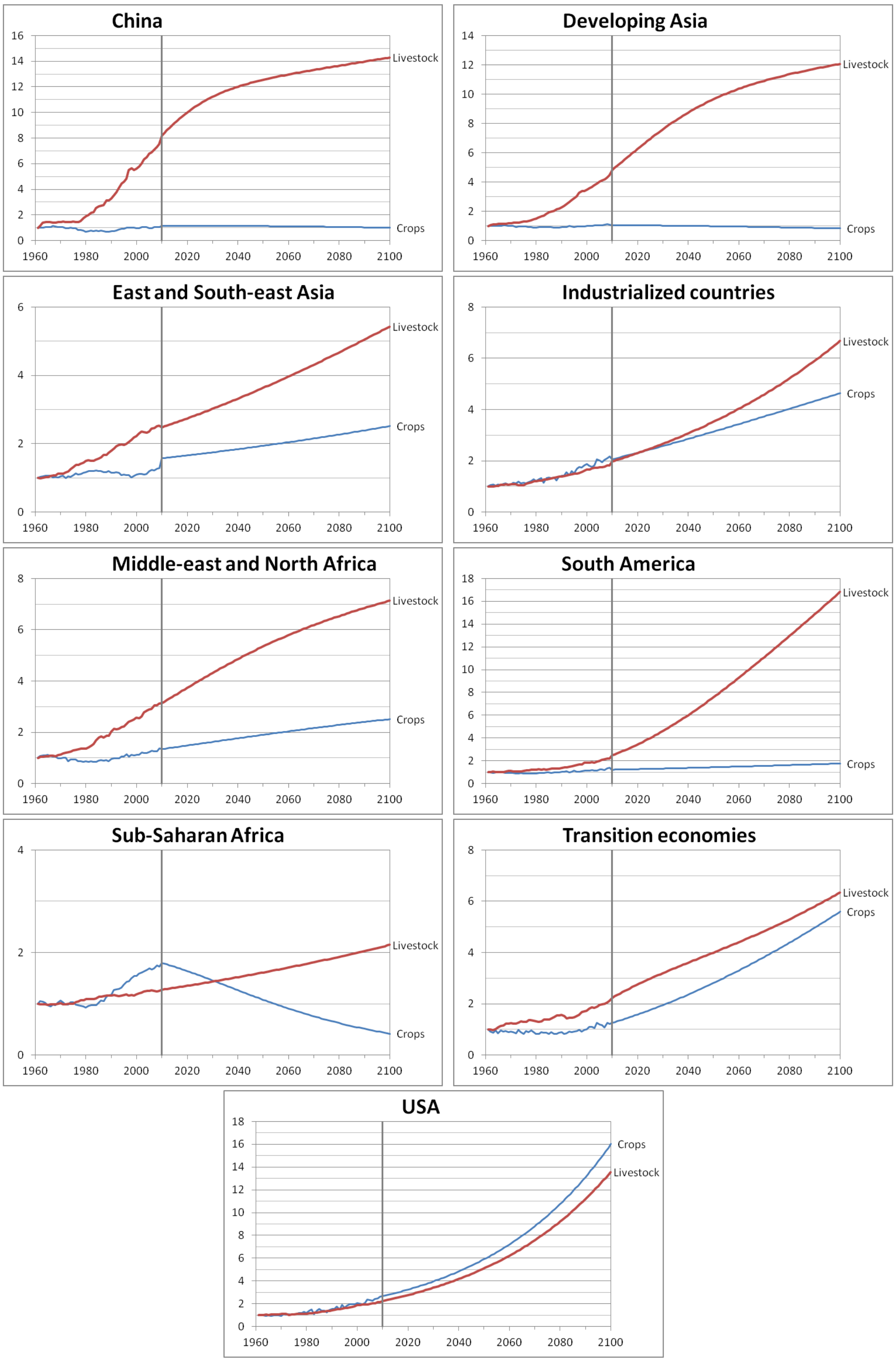

Figure 20: Projected malmquist indexes by region (2004=1)

B Additional results

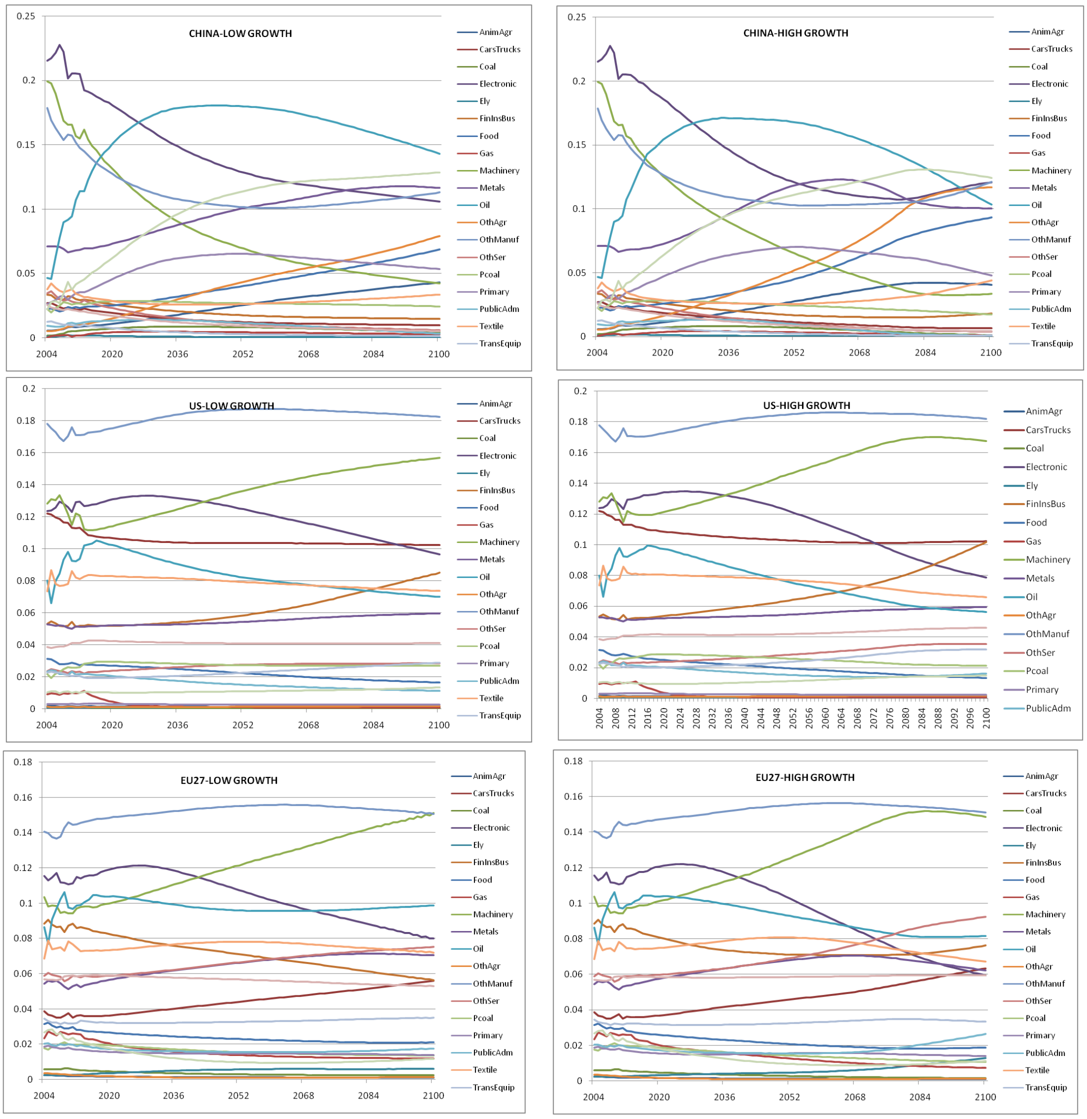

Figure 21: Selected countries Import shares:Low Growth v. High Growth

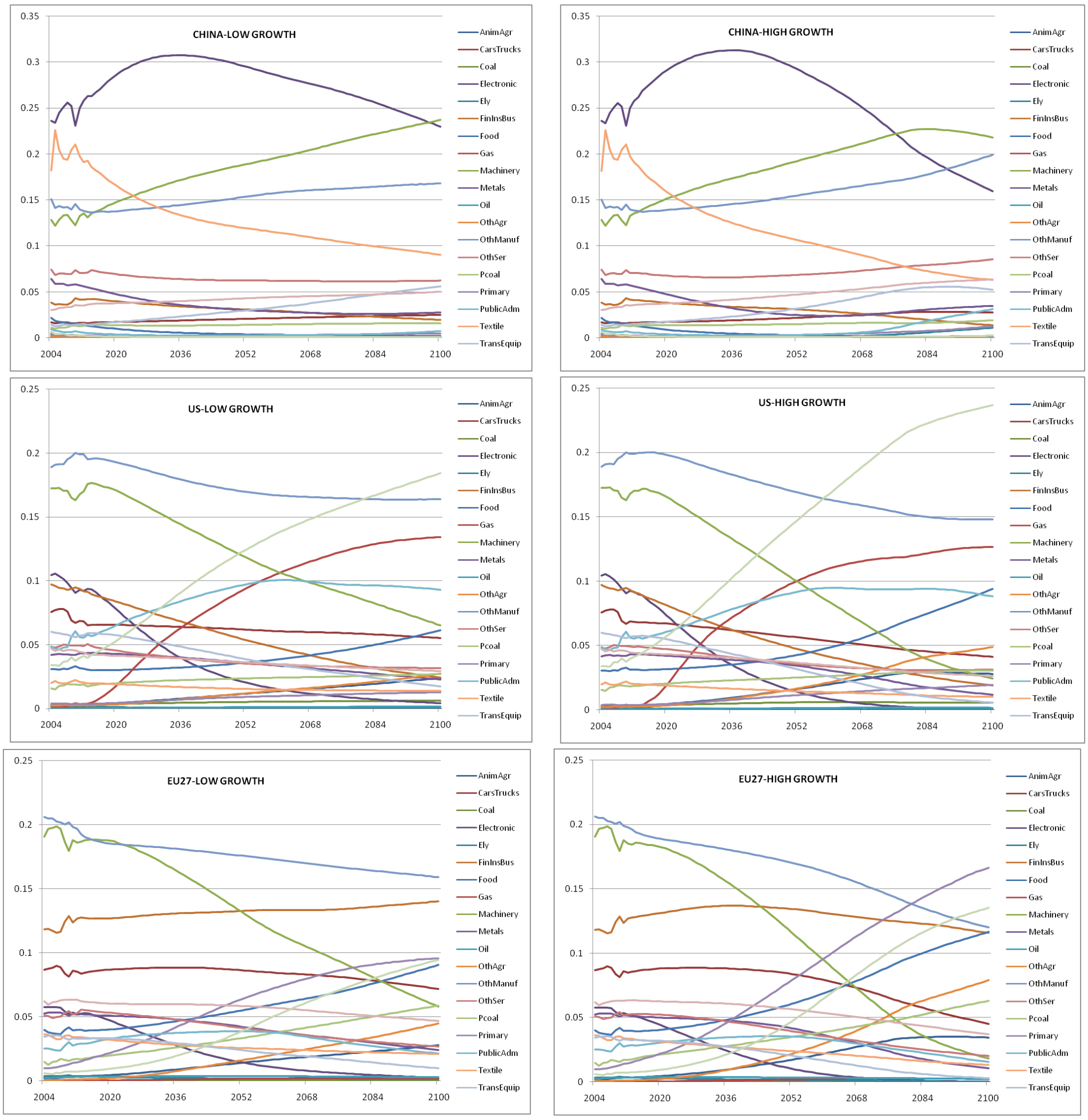

Figure 22: Selected countries Export shares: Low Growth v. High Growth

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