Opening a Pandora's Box: Modelling World Trade Patterns at the 2035 Horizon

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Abstract

Economic projections for the world economy, in particular when building Computable General Equilibrium (CGE) baselines, are generally very conservative and hardly take into account the wide range of possible evolutions authorized by the underlying economic mechanisms considered. Against this background, we aim at projecting "open-minded" world trade trajectories. Considering the 2035 horizon, we examine how world trade patterns will be shaped by changing comparative advantages, demand and capabilities of the different regions. We combine a convergence model fitting three production factors (capital, labor and energy) and two factor-specific productivities with a dynamic CGE model of the world economy calibrated to reproduce observed elasticity of trade to income. We proceed for each scenario in three steps. We firstly project growth at country level based on factor accumulation, educational attainment and efficiency gains. This framework (demographics, Gross Domestic product, savings rates, factors and current account trajectories) is then imposed to the CGE as a baseline. We finally implement trade policy scenarios (tariffs as well as non-tariff measures in goods and services), such that the model provides factor allocation across sectors as well as demand and trade patterns. We end up with extremely differentiated trajectories for the world economy within only two decades. In turn, we obtain a wide range of foreseeable world trade patterns.

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Content

Introduction

What will the main patterns of world trade in two decades be? This question is of utmost importance as it is telling us whether the institutional environment of international trade is well shaped to secure a level playing-field. Indeed there is much uncertainty in such reasoning. Two sources of errors of judgement are possibly present: about the projection of the drivers of international trade, and an irreducible source of error related to the basic unpredictability of some key variables.

The first prerequisite is accordingly to properly project the drivers of international trade: conditional on trade frictions and prices, the volume of trade is basically a function of countries' Gross Domestic Product (GDP), according to the extensively documented principle of gravity. The problem here is to rely on a sound representation of economic growth, providing GDP projections forthe largest number of countries in the world. Should one use a very detailed modelling of growth, including e.g. regulations or a detailed representation of the public sector, or focus on the main mechanisms and treat national idiosyncrasies as unobservable? There is a trade-off here: restricting the projections to the set of OECD countries (plus a handful of emerging economies), or embracing a much larger set of countries with a more stylised modelling of growth.

The second prerequisite is to acknowledge the unpredictability of certain key variables. Energy prices may strongly vary over the next two decades, not primarily as the result of uncertainties surrounding economic growth, but because of geopolitical tensions (e.g. Middle-East) or conversely technological breakthroughs (e.g. shale gas or jump in energy efficiency). Female participation to the labour forceis expected to increase as countries develop, but this driver of growth is also subject to uncertainties. Educational convergence may speed up or be hampered with sizeable impacts on productivity. The future of international capital mobility is highly uncertain. Productivity convergence may accelerate or decelerate as a result of approaches to technology transfer and firm mobility. Lastly, large migrations flows may be observed as a result of unexpected push factors, while fertility rates are highly uncertain.

Against this background, this paper aims at a methodological purpose. We firstly show how to feed a dynamic sectoral model of the world economy with projected economic growth for the larger set of countries, based on stylised conditional convergence model of economic growth fitting three factors (capital, labour and energy), two types of technological progress (total factor productivity of the capital-labour combination, and energy efficiency) and international capital mobility. These projections provide also savings rates (based on a life cycle hypothesis) and current accounts. GDPs and savings are projected at the country level, while constraints are imposed in terms of global balance between savings and investment. Our second value added is to show how the induced GDP, savings, energy efficiency and current account trajectories up to 2035 can be imposed to a Computable General Equilibrium (CGE) model of the world economy, relying on identical assumptions in terms of population, labour force, education, current accounts. The CGE, in turn, will provide factor allocation (across sectors), demand patterns (preferences and budget shares) and thus trade patterns, conditional on trade costs.

Beyond illustrating step by step how to best combining the modelling tools, our exercise is conducted with open-minded assumptions on the evolution of key drivers of growth in order to let economic mechanisms fully play, hence *opening the Pandora's Box* of growth projection. We examine the impact on economic growth of large and combined shocks on its key drivers. Not all shocks are supposed to affect developing and developed economies in the same way. We also show how to combine these shocks with scenarios on the evolution of trade costs. On the top of energy prices, a tariff war, driving countries outside of the legal framework of the World Trade Organization (WTO), back to the post-Tokyo Round tariff levels, is considered. Similarly, we examine the impact of generalised inspection of shipments, as a response to pandemic or terrorism. Finally we address changes in barriers to services trade. Our aim is not to pretend that any of these scenarios is plausible, given the current information on the world economy. What we do is instead to show how usual modelling tools can be combined to characterise the broad range of possible world trade patterns associated in presence of high uncertainty.

This methodological paper thus adds to a growing body of recent literature on long term prospects for the world economy. Qualitative scenarios combining the two modelling frameworks as a background for a more multidisciplinary approach centred on Europe were developed at the 2050 horizon on behalf of the European Commission (EU, 2011). The International Monetary Fund (IMF, 2011) uses a partial equilibrium approach in order to address the consequences of the reduction in exchange rates misalignment on trade patterns, in presence of global value chains and possibly imperfect pass through. Fontagné et al. (2012) aim at designing scenarios possibly used as background for environmental studies, and consider the 2100 horizon in order to explore methodological issues associated with the use of long term dynamic baselines in CGE models. Closer to our approach, World Bank (2007) relied on a multisectoral model of the world economy comparable to MIRAGE, to draw scenarios for the world economy at the 2030 horizon. No growth model was explicitly used, since scenarios were driven by assumptions on total factor productivity imposed to the CGE. In contrast, Petri and Zhai (2012) rely on growth projections from the Asian Development Bank using a growth model in the same spirit as ours (ADB, 2011). They use this series of GDPs to derive scenarios at the 2050 horizon with a CGE model to which assumptions on Total Factor Productivity (TFP), higher food prices, higher energy prices or protectionism were imposed. Finally, Anderson and Srutt (2012) consider the 2030 horizon and build a baseline for the GTAP CGE model by combining ADB (2011)and Fouré et al. (2010).

The value added of this paper is to highlight the technical issues and the wide range of uncertainty raised by the combination of macroeconomic and multisectoral models, hence opening the Pandora's box of long term projections. (i) It builds scenarios designed for some 150 countries in the world, taking into account their interaction via capital mobility and trade in goods and services. (ii) Scenarios are implemented in a consistent way both in the growth model (Macroeconometrics of The Global Economy – MaGE) and in a multisectoral dynamic CGE model of the world economy (MIRAGE). (iii) Scenarios tackle a wide range of potentialities with a careful attention paid to the decomposition of effects. This is accordingly, to the best of our knowledge, the only exercise conducted so far on such a scale at the 2035 horizon with a methodology designing scenarios in a consistent manner for the growth model and the CGE.

The rest of the paper is organised as follows. Assumptions for the growth projections and of our scenarios are presented in Section 1. Our methodology is detailed in Section 2. We implement scenarios in the growth model in Section 3. Results from the global and sectoral model of the world economy are summarized in Section 4. Section 5 concludes.[1]

[1]A companion paper discusses in depth our main findings.Fontagné L., Fouré J. and A. Keck (2013), Simulating world trade in the decades ahead: Driving forces and policy implications. WTO working paper, Geneva.

1- Modelling growth projections and designing scenarios for the world economy

This paper is at the junction of three strands of the applied economic literature: (i) economic growth projections; (ii) design of dynamic baselines in applied general equilibrium modelling, with a focus on environment; and(iii) design of medium or long term scenarios for the world economy. The first two are indeed not independent, as the second can either rely on the former (GDP driven baselines), or directly provide GDP projections based on assumptions on changes in the sector-specific TFP (TFP driven baselines). The third strand of literature combines quantitative elements (potentially provided by projections and baselines) with qualitative and sometimes multidisciplinary expertise on the main drivers of economic, social and environmental change. We now briefly survey where the literature stands in terms of growth projections, dynamic baselines and finally scenario building.

1.1 Growth projections

The increasing interest for long-term economic related issues, like environment depletion and energy scarcity, has motivated several growth projection exercises. The business community initiated the documentation of the great shift towards the emerging economies (Wilson and Purushothaman, 2003; Ward, 2011), followed by international institutions. With some exceptions (Duval and de la Maisonneuve, 2010, and Johansson et al., 2012), scholars did not involve this field, leading to a lack of well-documented and economically-grounded projection models. Such reluctance can easily be explained by the large uncertainties surrounding projections that proved rarely accurate and are conditional to changes in the geopolitical context. Nevertheless, such long-term investigations are a prerequisite for many downstream analyses, like the one conducted in this paper addressing future patterns of world trade.

This contrasts with the importance of economic growth factors in the economic literature. Starting from the standard neo-classical Solow model, mechanisms for production factors accumulation have been identified, for instance from the demographic determinants of savings (see for instance Masson et al., 1998) to capital formation (Feldstein and Horioka, 1980) or from human capital catch-up to productivity improvements (Aghion and Howitt, 1992). Long-term growth projection models build on this vast literature, combining existing analysis.

At least three drivers are common to all empirical studies: capital stocks, labor force and total factor productivity. These were taken into account by Wilson and Purushothaman, combining existing labor force projections, constant investment rates and a convergence scenario for TFP. Duval and de la Maisonneuve (2010) also identify human capital per worker as a driver, and calibrate conditional convergence scenarios between countries for each of the four determinants. With the same kind of framework, Johansson et al. (2012) restrict their analysis to fewer countries, but with an emphasis on structural and fiscal policies' impact (retirement age, trade regulation, public debt and credit availability). Finally, Fouré et al. (2013) introduce energy as a production factor, along with energy-specific productivity, and base their projection framework on an econometric analysis of both convergence mechanisms and structural relations. Comparing projections performed in these papers points to sizeable differences in the results. The share of China in 2050 world GDP in Fouré et al. is for instance almost twice the share projected by Duval and de la Maisonneuve. Such outcome calls for transparency in assumptions, modeling frameworks and open-minded scenarios when it comes to introducing such projections into dynamic CGEs.

1.2 Dynamic baselines

Large scale policy simulations generally rely on multisectoral dynamic models of the word economy. CGE is the most commonly used modelling framework. Policies are simulated as shocks to the model. The deviation of variables of interest from their reference trajectory is then computed. One may argue that the modeller's interest is in the deviation, not in the initial equilibrium. Such reasoning is however flawed when medium or long run policies are concerned: an economic policy affecting China will have a dramatically different impact on the world economy if China is twice as large, which should be the case in less than years only at current growth tendencies.

As capital accumulation, energy and primary resources prices will be determined by the model, a first prerequisite is thus to supplement the model with a world database including demographics. However, as CGE models hardly describe the intrinsic mechanisms of growth (conditional convergence) they will neither provide a satisfactory representation of efficiency gains in combining production factors, nor a plausible trajectory of countries at different levels of development. Accordingly, there is a need for constraining the CGE to reproduce a pre-defined path of GDP growth, or a pre-defined path of TFP, for each country (or region) in the world. This is what dynamic baselines aim at doing.

Many baselines focus on the period up to 2020 (like the GTAP model) but some exercises have been conducted up to 2050 (for instance with the Linkage model). Relying on a more ambitious approach, Fontagné et al. (2012) tentatively consider the 2100 horizon in order to provide environmental studies with a theoretically consistent baseline of the world economy. Whatever is the horizon, the building blocks of a baseline are the same.

The first step is the projection of a general trajectory of world growth, based on simple and robust economic mechanisms. 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 availability of detailed data on demographics or education 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.

The symmetric approach of imposing GDP growth trajectories to a CGE and recovering productivity gains is more data demanding as we need to project growth for every country as a first step. The big advantage is to model growth properly, by taking into account conditional convergence and possibly different kind of technical progress, based on the vast literature of macroeconomic growth. Such advantage is of utmost importance when one is interested in modelling economies of different kind (mature, emerging, and developing) in the long run. Incidentally, this approach also allows to relying more easily on macro projections made available by a vast literature (see Fouré et al. (2013) for a short review). For instance, main projections used in the GTAP model and in former versions of MIRAGE (Decreux et al., 2007) were provided by the World Bank (Ianchovichina and McDougall, 2000).

The only crucial assumption of GDP-driven CGEs is the relative dynamism of productivity in broad sectors. Several approaches have been proposed to address this difficult issue. The LINKAGE model

(Van der Mensbrugghe, 2005) adds to the endogenous national TFP a sector-specific component that is labour-only productivity. This approach 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 emerged on agriculture-specific productivity, built after Nin et al. (2001). Coelli and Rao (2005) and Ludena et al. (2007) 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.

Besides these efforts to provide the community of modellers with dynamic baselines for their policy simulations relying on CGEs, a related strand of literature aimed at specifically tackling environmental issues. Two key issues were raised: first the productivity of energy 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.

As for environmental baselines, the first approach is 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, improvements in carbon intensity of goods are 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 scenario for Autonomous Energy Efficiency Improvements (AEEI) as in the EPPA model. These AEEI encompass non-price induced, technology-driven productivity changes. An exogenous time trend in energy productivity is imposed 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 face a regularly increasing AEEI. On the other hand, other countries' AEEI first decrease (up to around 2035) and then increase at different paces. These 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 modelling. 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 Constant Elasticity of Substitution (CES) functional forms on monetary values leads to incoherence in substitutions when commodities are relatively homogenous, like this is the case for energy goods. In order to deal with this issue, two approaches can be developed. One can build up a world price matrix for physical quantities of energetic goods, such that they can account for changes both in value and quantity. A more parsimonious approach is to impose to the model that production, consumption and trade are coherent both in monetary units and in physical quantities.

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.

1.3 Scenario design

We briefly survey in the following medium term scenarios of the world economy relying on a combination of growth projection and CGE modelling. These exercises have been developed mainly by the World Bank, by the OECD, as well as Petri and Zhai (based on Asian Development Bank projections) and finally Anderson and Strutt (based on Asian development Bank and our own projections).

World Bank (2007) relied on LINKAGE (a multisectoral model of the world economy comparable to MIRAGE, described in van der Mensbrugghe, 2006-a) to draw scenarios for the world economy at the 2030 horizon. Instead of recovering TFP from the CGE to which GDPs and factor accumulation would be imposed, assumptions on the TFP are imposed to the CGE to recover GDPs as documented in van der Mensbrugghe (2006-b). In addition, energy efficiency was assumed to improve exogenously by 1 % per year worldwide. In contrast, energy efficiency is theoretically derived and then projected at a country basis in MaGE, before being introduced in the CGE in our exercise. Finally, international trade costs were assumed to decline by 1 % per year, in line with our own pre-experiment aiming at mimicking the historical income elasticity of international trade. This exercise was calibrated on the GTAP-2001 database (we used GTAP-2004 for MIRAGE).

Petri and Zhai (2012) combined growth projections from the Asian Development Bank at the 2050 horizon (ADB, 2011) with a CGE model in order to develop scenarios. Besides their focus on Asia, contrasting with our world-wide perspective, the big difference with our study is not in the horizon considered. It is in the methodology used to design the scenarios. Our approach is threefold. We first design a business as usual scenario of world growth, and run a pre-experiment in order have our CGE reproducing the income trade elasticity observed in the past. Second we construct two scenarios for the growth model, which are then imposed to the CGE in a consistent way. Third, we shock the CGE, completing our two scenarios with evolutions that can be only tackled by the CGE, like possible changes in transaction costs. Petri and Zhai, in contrast, use a business as usual macroeconomic baseline and only proceed with what is our third step.[2] This makes an important difference as many assumptions of our scenarios (e.g. fertility, female participation to the labour market, educational catching up) will have cascading effects for growth and trade channelling through the different mechanisms of the two models.

Anderson and Srutt (2012), consider the 2030 horizon and build a baseline for the GTAP CGE model. They combine growth rates for GDP, investment and population from ADB (2011) with our own (previous set of) projections for the world economy (Fouré et al., 2010) for countries not present in the ADB projections. Finally, projections of skilled and unskilled labour growth rates were taken from Chappuis and Walmsley (2011). Historical trends in agricultural land from FAO and in mineral and energy raw material reserves from BP (2010) were prolonged over the next two decades. TFP growth rates were recovered from the CGE model. Scenarios were implemented (as in Petri and Zhai)

[2] Their simpler approach authorises deeper developments in terms of income distribution. While we rely on a representative household and two labour categories (skilled, unskilled), Petri and Zhai supplement their CGE with an income distribution module to allocate total consumption to four income bins.

directly in the CGE: they concern a drop in the TFP and further trade liberalisation. Implications for world trade were derived. Two drawbacks of such approach were the combination of different growth models in the first place (ADB and MaGE-V1.2) and the implementation of the scenarios directly in the CGE instead of taking benefit of the two modelling frameworks. The scenarios themselves can also been questioned, as a further trade liberalisation is no necessary outcome for the future economy. Anderson and Strutt acknowledge the absence of scenario on trade costs, transport costs, current account imbalances, which are dimensions present in our analysis.

Finally, Chateau et al. (2011) at the OECD used the ENV-Growth model in order to design climate change scenarios, in line with the five Shared Socioeconomic Pathways (SSP) developed by the Integrated Assessment Modeling Consortium. These scenarios are organized around the trade-off between climate change mitigation and adaptation, both translated into demographic (population and education), technological (catch-up speed and frontier growth) and natural resources (prices and available resources) related scenarios, both implemented in the growth model. They clearly identify the drivers of growth as being capital accumulation, TFP and labor force (and to a lesser extent human capital and energy), but cannot directly investigate the savings-investment relationship due to the original specifications of SSPs and do not explicitly deal with uncertainty in labor force participation neither with trade integration (excepted though positive externality in TFP). These scenarios are also being integrated with OECD's ENV-Linkages CGE model, in a way similar to ours, but to our knowledge results are not yet available.

2- What we do

This paper adopts the GDP-driven CGE approach, as described above. To proceed, we combine a growth model derived theoretically, estimated and used in projection for more than 140 countries. The building blocks of this model are conditional convergence (based *inter alia* on human capital accumulation), energy use and efficiency, demographic transition and savings behaviour. This first step is performed with the MaGE model (Fouré et al., 2013). Using this framework, we implement scenarios for the world economy. The second step consists in imposing GDP trajectories (depicted in the various scenarios) 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. To proceed we use a new version of MIRAGE, nicknamed MIRAGE-e, where the last letter stands for environment (Fontagné et al., 2012). The CGE finally provides with a sector decomposition of growth, factor allocation, country specialization and world trade patterns, the latter being our ultimate objective. In the second stage, additional shocks can be imposed to the CGE. This two-step approach is ultimately mobilised to build alternative scenarios of the world economy.

We now describe successively the growth model (MaGE), the CGE model (MIRAGE-e) and the design of the scenarios.

2.1 The growth model

Projections of world macroeconomic trends are elaborated with the MaGE model, documented in Fouré et al. (2013). Based on a three-factor (capital, labor and energy) and two-productivity (capital-labor- and energy-specific) production function, MaGE is a supply-side oriented macroeconomic growth model, defined at the country level (147 countries). It proceeds in three steps. First, a production factors and productivity database is gathered from 1980 to 2009. Second, behavioral relations are econometrically estimated for factors accumulation and productivity growth based on this dataset. Finally, these relations are used to project the world economy up to the 2100 horizon.

Starting from World Bank, United Nations and International Labor Organization data, we built a dataset of production factors and economic growth over the period 1980-2009. Our theoretical framework consists in a CES production function of energy and a Cobb-Douglas bundle of Capital and Labor. This theoretical framework allows recovering energy-specific productivity from the profit-maximization program of the representative firm, whereas capital and labor productivity is recovered as the Solow residual.

Behavioral relations are econometrically estimated from this dataset on three topics: population, capital accumulation and productivity. Population projections are given by United Nations population projections, split in 5-year age bins. For each of these age groups we first estimate education, then deduce labor force participation. Educational attainment follows a catch-up process to educational leaders in secondary and tertiary education, with region-specific convergence speeds. While male labor force participation follows the logistic relation determined by the International Labor Organization, female participation changes with educational level.

Capital accumulates according to a permanent-inventory process with a constant deprecation rate. On the one hand, investment depends on savings with a non-unitary error-correction relationship, which differentiates long-term correlation between savings and investment and annual adjustments around this trend. Both two levels of estimations are conducted separately for OECD and non-OECD members, due to the significant differences we found between the two country groups. On the other hand, savings depend on the age structure of the population consistently with the life-cycle hypothesis, as well as on economic growth.

Capital-labor and Energy productivity follow two catch-up relationships to the best-performing countries. The former is conditional to, and fueled by educational level (tertiary education for innovation and secondary education for imitation), whereas the latter is modified by development level to reflect the sectoral organization of countries.

We are finally able to recover GDP and factors projections from these relations and thanks to the theoretical link between energy productivity, energy price (exogenously imposed) and energy consumption.

2.2 The CGE 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 liberalisation and agricultural policies scenarios (e.g., Bouët et al., 2005, 2007). We use the version of the model fitting perfect competition for sake of simplicity. MIRAGE-e version of the model proposes a different modelling of energy use, and introduces the modelling of CO2 emissions.

MIRAGE-e was adapted to the exercise conducted here. MIRAGE has a sequential dynamic recursive set-up which will be used consistently with the output of MaGE: capital accumulation and current account will be driven by the results of the first step of our exercise. The macroeconomic closure consists in having the share of each region in global current accounts imbalances varying yearly according to the projections from MaGE.

On the supply side, in this perfect competition version of MIRAGE, each sector is modelled 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 labour, land and natural resources) and energy.

We assume full employment of primary factors,whose growth rates are set exogenously from MaGE projections. Installed capital is assumed to be immobile (sector-specific), while investment is allocated across sectors according to their rate of return. The overall stock of capital evolves by combining investment and a constant depreciation rate of capital. Skilled and unskilled labour is perfectly mobile across sectors, while land is assumed to be imperfectly mobile between agricultural sectors and natural resources are sector-specific.

Firms' energy consumption comprises five energy goods (Electricity, Coal, Oil, Gas and Refined petroleum) that are aggregated in a single bundle which mainly substitutes with capital. The extent to which capital and energy are substitutable is not subject to consensus in the 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). Since energy consumption is very sensitive to this elasticity of substitution, its calibration is of utmost importance. We choose to reproduce stylized energy consumption trends as in International Energy Agency projections to 2025 (IEA, 2011), which led us to calibrate this elasticity like in GTAP-E. The architecture of the energy bundle defines three levels of substitution. Energy used can be delivered by electricity or fossil fuels. Fossil fuels can be coal and otherwise either oil, gas or refined oil. As a consequence, oil, gas and refined oil are more inter-substitutable than with coal and finally with electricity. Values of the elasticities of substitutions were chosen in line with the literature: electricity-fossil fuels substitution is based on Paltsev et al. (2005), the two other elasticities come from Burniaux and Truong (2002).[3] Finally, the value of the energy aggregate is subject to the efficiency improvements projected by the growth model. As stressed above, a challenging issue for CGE models is about CO_2 emissions and energy consumption in physical quantities, as opposed to other variables measured in dollars at constant prices. In practice, using CES functional forms with variables in monetary units leads to inconsistencies when trying to retrieve physical quantities. 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) thanks to the use of two country- and energy-specific endogenous adjustment coefficients such that the CO_2 emissions could be computed in million tons of carbon dioxide. CO_2 emissions are recovered as being proportional to the energy consumption in quantity, using energy-, sector- and country-specific parameters calibrated on the data.

Production factors in MIRAGE-e are evolving, on a yearly step, as follows. Population and participation to the labour market evolve in each country (or region of the world economy) according to the demography used in MaGE. This determines the labour force, as well as the skill composition (skilled, unskilled). Primary resources and land are considered at their 2004 level: prices adjust demand to this supply. Instead of modelling the fossil energy sectors, we rely on more specialised modelling of the International Energy Agency (IEA, 2011), which provides us with projections of coal, oil and gas prices up to 2035. Given demand, resources adjust accordingly in MIRAGE. Capital is accumulated according to the usual permanent inventory assumption. Capital usage is fixed (we use a 6% depletion rate), while gross investment is determined by the combination of savings (the savings rate from MaGE applied to the national income) and the comparison of the current account and domestic absorption. Finally, while total investment is savings-driven, its allocation is determined by the rate of return of investments in the various activities. By sake of simplicity, and as we lack reliable data on foreign direct investment at the country of origin, host and sectoral level, we allow

[3] 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): it is impossible to produce crude oil from coal or refined petroleum from gas and electricity. In these sectors, substitutions between energy sources are not allowed (Leontief formulation).

capital flows between regions only through the channel of current account imbalances. We are aware that Foreign Direct Investment is channelling technology transfer and productivity catching-up; this mechanism will be integrated separately when building the scenarios.

Firms' demand for production factors is organized as a CES aggregation of land, natural resources, unskilled labour and a bundle of the remaining factors. The latter is a CES aggregate of skilled labour, and another bundle of capital and energy. Lastly, energy itself is an aggregation of energy sources as defined above.

On the demand side, a representative consumer from each region maximizes its intra-temporal utility function under its budget constraint. This agent, which includes households and government, saves a part of his income. This behaviour is determined by the savings rate projected by the growth model on the basis of the combination of individual countries demographic profiles with a life-cycle hypothesis. Expenditure is allocated to commodities and services according to a LES-CES (Linear Expenditure System - Constant Elasticity of Substitution) function. According to the latter assumption, above a minimum consumption at sectoral level, consumption choices between sectors are done according to a constant elasticity of substitution. This assumption is a tractable representation of preferences in countries at different level of development. It is accordingly well designed for our purpose.

Then, within each sector, goods are differentiated according to their origin. A nested CES function allows for a particular status for domestic products, according to the usual Armington hypothesis (Armington, 1969). We use elasticities provided by the GTAP database (Global Trade Analysis Project) and estimated by Hertel et al. (2007).Total demand is built from final consumption, intermediate consumption and investment in capital goods.

Efficiency in the use of primary factors and intermediate inputs is based on the combination of four mechanisms. First, agricultural productivity is projected separately, as detailed in Fontagné et al. (2013). Second, energy efficiency computed by MaGE is imposed to MIRAGE (it enters into the capital-energy bundle). Third, a 2 p.p. growth difference between Total Factor Productivity (TFP) in manufactures and services is assumed (as in van den Mensbrugghe, 2005). Finally, given the agricultural productivity and the relation between productivity in goods and services, MIRAGE-e is able to recover endogenously the country specific TFP from exogenous GDP (from MaGE) and production factors. While this TFP is recovered from the pre-experiment, it is set as exogenous in the simulation of the scenarios, as explained later. Dynamics in MIRAGE-e is implemented in 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 31 years, the starting point being 2004.

Feeding the world population and providing the industry with all agro-related primary resources it needs will be a challenge for the next decades. Accordingly, it is of utmost importance to properly assess to what extent technical progress in the agricultural sector will help relaxing this constraint. Whereas data on labour-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 (moving) frontier (for details, see Fontagné et al, 2012). 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 inputs (Labour, Land, Machinery, Fertilizers, and Livestock), due to their commonness across the world and their data-availability. Inputs can whether be allocated to crops or livestock, or be shared between these two sectors.

MIRAGE-e 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 and on a geographical basis (see Table 1). We also include international transaction costs and non tariff measures (NTM) in services, 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), whereas NTM in Services are *ad-valorem* equivalents taken from Fontagné et al. (2011).

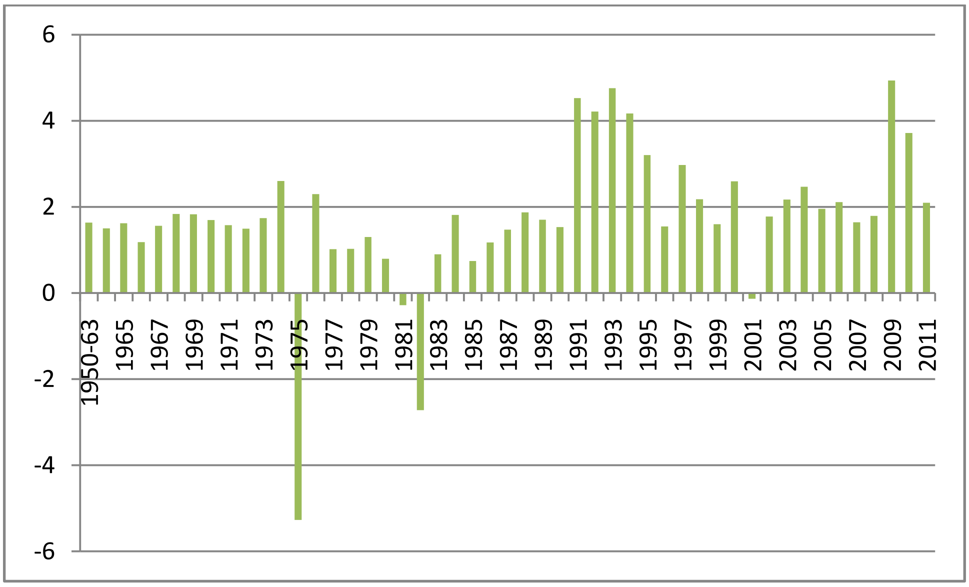
Table 1 – Sector and country aggregation in MIRAGE

Regions	Sectors
Developed countries	***Agriculture***
EU27	Crops
European Free Trade Association	Livestock
USA	Other Agriculture
Canada	***Energy***
Japan	Coal
Australian and New Zealand	Oil
Korea	Gas
Developing/Emerging countries	Petroleum and coal products
Brazil	Electricity
Russia	***Industry***
India	Food
China	Textile
Association of Southeast Asian Nations	Metals
Middle-East	Cars and Trucks
Turkey	Transport equipment
North Africa	Electronic devices
South Africa	Machinery
Mexico	Other Manufacturing
Rest of Africa	***Services***
Rest of Europe	Transport
Rest of Latin America	Finance, Insurance and Business services
Rest of the world	Public administration
	Other services

2.3 The dynamic baseline calibration

A challenging issue with large scale CGE models is whether the main stylised facts of world trade can be easily reproduced with such framework. As for the well-documented magnified reaction of world trade to booms and busts of the world economy, as shown in Figure 1, the exercise is hopeless. CGE represent long term equilibrium, and will hardly reproduce short term adjustments.

Figure 1 – World trade to income elasticity of trade (goods)



Source: Authors' calculation. WTO data 1950-2011

More importantly, we would like our CGE to reproduce the medium term income elasticity of trade present in the historical data. We show in Table 2 what the trade income elasticity is, for different sub-periods.

Table 2 – World trade to income elasticity (goods), for different sub-periods

1950-59	1960-69	1970-79	1980-89	1990-99	2000-09	1950-2009
1.62	1.54	1.31	1.19	2.82	1.42	1.64

Source: Authors calculation. WTO data 1050-2011

The 1990s have been documented as conveying an increase in this elasticity (Freund, 2010), partly because value chains were fragmented globally, and partly because contributors to world economic growth made the choice of an export-oriented growth (like China). We can hardly consider that the phenomenon will have the same intensity in the next two decades, just because there is a physical limit to product fragmentation and because complexity costs are increasing while opportunities of exploiting new comparative advantages are largely already exploited.

In a much longer perspective, trade in goods has indeed increased faster than industrial or agricultural production since 1950, and even more than GDP. The long-term elasticity obtained with respect to GDP was 1.46 over the period 1950-1989, hence before the rapid growth of world trade in the 1990s. This half-century experience is the kind of order of magnitude that a model like MIRAGE should aim at reproducing. Such elasticity is mirroring increases in world trade that have had several determinants:

- Energy price (and above all oil price) has been decreasing since the 70's;
- Technological progress has occurred in the transport sector;
- Tariffs have decreased over time
- Some non-tariff measures have been phased out
- Global value chains have been fragmented, leading to a growing discrepancy between trade, measured in gross terms and GDP, measured in value added terms

We therefore developed two baselines in order to encompass the elasticity of world trade of goods (and manufacturing goods in particular) in MIRAGE-e. The first one, "Past Trade" tried to reproduce historical evidence, whereas “Pre-experiment” adjusted the model in order to start with a plausible elasticity for the upcoming decades.

In order to test whether MIRAGe-e could be able to reproduce historical evidence, we firstly implemented a sensitivity reference case (“Past Trade”) using different sets of assumptions. The basic case is the standard version of the model, with no change in transaction costs. Tariffs are kept constant. There is no TFP growth in the transport sector beyond what is endogenously determined by the model to match growth projections from MaGE, as referred to above. There is no change in the trade costs which are kept at their initial (2004) level. Energy prices are taken from the central scenario already discussed. We run the model over 30 years and compute the trade to income elasticity.

Results reported in Table 3 show that the trade-to-income elasticity embodied in MIRAGE-e is low, as for any model of this type: 1.22 (first row in Table 3). This elasticity actually matches what was observed over the 1980s.

In order to reproduce the higher elasticity observed in the 1950s and 1960s, as shown in the middle of panel of Table 3, we must integrate a combination of decreasing trade costs, progress in transport technologies, low energy price and trade liberalisation, based on the following assumptions reproducing the above mentioned determinants of the long term income trade elasticity:

- Very low energy prices (a decrease by 3% yearly for oil, and no growth for coal and gas, as of the 1980-2004 average from BP historical data);
- 2% additional TFP growth in the transport sector compared to other services (containerization, standards, etc.), own guesstimate;
- 50% cut in trade costsin a broad sense (time, red tape formalities, quality of the communications, etc.), own guesstimate;
- 4% annual decrease of tariff rates (corresponding to the evolution of simple average tariffs between 1973 and 2004 in Deardorffand Stern (1983) for available countries).

The elasticity observed in the 1970s can be reproduced only by introducing in the model the observed tariff cuts. No additional assumption has to be made on transport technologies or even trade cost. Indeed, the assumption on low energy price would be irrelevant for that period.

The elasticity observed in the 2000s can be nearly matched with a (large) drop in trade costs.[4]We alternatively introduce large TFP gains in the transportation sector or even a decreasing price for energy.

Finally, what cannot be reproduced with this kind of model, with plausible assumptions, in the trade to income elasticity observed in the 1990s; as already stressed, this period might be unique and one should not aim at reproducing it in the baseline used for projections covering the next decades.

[4]Indeed, using the same time span but ending in 2011 would give a higher elasticity.

Table 3 – Long-term trade to income elasticity in MIRAGE-e under alternative assumptions

Baseline	Assumptions on				Elasticity
	Energy prices	TFP boost in transport	Trade cost cut	Tariffs cuts	
Standard	**Ref**	**0%**	**0%**	**0%**	**1.22**
Price	Decreasing	-	-	-	1.33
TFP transport	-	4%	-	-	1.28
Trade cost	-	-	50%	-	1.37
Tariffs	-	-	-	4% annual	1.32
Past trade	**Decreasing**	**4%**	**50%**	**4% annual**	**1.65**
TFP transport	-	2%	-	-	1.27
Trade cost	-	-	25%	-	1.29
Pre-experiment	**Ref**	**2%**	**25%**	**0%**	**1.34**

Note: All the scenarios are implemented between 2004 and 2035, linearly (trade costs) or at constant growth rate (TFP and decreasing energy price).
Source: Author's calculations

Regarding our reference scenario, we believe that many of the conditions of the XXth century that lead to such high elasticity of trade to GDP will not be verified in the upcoming decades, in particular regarding energy price. That is why we implemented a **pre-experiment** with the following assumptions:

- 2% additional TFP growth in transport sector
- 25% trade cost cuts
- Reference energy prices
- No tariff cut.

As the decomposition shows, the boost in the TFP of the transport sector and the drop in trade costs have effects of similar magnitude. When combining these assumptions, MIRAGE-e reproduces a long term elasticity of trade equal to 1.34, in line with what was observed in the 1970s or in the 2000s. This pattern of MIRAGE-e, shown in the last row of Table 3, is the new reference to which we will apply the scenarios described below.

2.4 Two scenarios for the world economy

We now illustrate the construction of two contrasted scenarios that can be applied in the consistent way to the growth model – MaGE – and to the CGE of the world economy – MIRAGE-e. We firstly present the design of the scenarios in MaGE, before turning to the implementation inMIRAGE-e.

In order to design contrasted scenarios of the world economy, we combine various shocks, aiming to open widely the cone of possible trajectories, as follows. For convenience, we named the resulting scenarios, combining these differentiated shocks, as "low" and "high", such that they describe expected changes in world GDP.

For the low and high scenario, we assume changes in education attainment, female participation in the labour market, energy price that applyhomogenously across countries. In contrast high income-countries, versus low- and middle-income-, are affected differently by changes in fertility, migrations,energy efficiency, TFP and capital mobility.[5]

We proceed in two steps for expositional purposes. First, we shock variables one at a time and examine the impact of the shock on the variable of interest, as well as on growth. The shocks imposed to MaGE in a first step are reported in Table 4.

Table 4 – Shocks to MaGE

Variable \ Scenario	Low	High
Differentiated demography	Reference fertility in high income countries, low fertility in other	Reference fertility in high-income countries, high fertility in other countries
Migrations	Reference case	Additional migrations from SSA and MENA to EU and from SAM to USA/CAN.
Education convergence	1.5 half-life time	0.5 half-life time
Female participation	No improvements	Reference case
Differentiated TFP	-50% TFP growth rate for low and mid income countries, -25% for high-income.	+50% TFP growth rate for low and mid income countries, +25% for high-income.
Energy price	High price scenario (EIA)	Low price scenario (EIA)
Differentiated Energy productivity	+50 % high income in 2050, reference for other	+50% for low and mid income in 2050, reference for other
Capital mobility	Convergence to I=S in 2050	Low correlation coefficient (non-OECD) for everyone

The first variable to be shocked is demography. We start from the low and high fertility scenarios of the UN. The "low" case is defined as less fertility in the middle- and low- income countries. This will have a negative impact on growth, if not necessarily on income per capita. We do not assume any further reduction in fertility in high-income countries. Symmetrically, the "high" case corresponds to high fertility in the middle- and low- income economies only. We may well observe in certain developed countries an unexpected rebound of fertility, but such outcome will hardly be a general pattern.

[5] In MaGE, countries are classified by income level, as the latter is a driver of conditional convergence. Accordingly our shocks are defined using the income classification of the World Bank. For the presentation of the results, as well as for the simulations with MIRAGE, we use the WTO classification of countries in two groups: developed and developing. The correspondence between the two classifications is detailed in Appendix B.

The second variable of interest is migrations. We already have some migration flows embedded in the UN demographic projections. These correspond to the “normal migration assumption” in which net migrations are generally kept constant, at least at our time horizon. United Nations already introduced changes on a country by country basis corresponding to anticipations of immigration policy changes and our shock adds to these flows. We consider migrations from Sub-Saharan Africa, Middle-East and North Africa to Europe and from Latin America to the United States. First, annual additional outflow from SSA to Europe amount to 1.2 million people and 800 thousands from MENA. This corresponds roughly to a doubling of net migration in Europe, compared to UN data for the period 2000-2010. Second, migrations from Latin America to the United States represent 1.2 million persons per year, also doubling North America’s net inflows. We were not able to trace precisely UN projection migrations (by sex, age group or education level). Therefore, these initial migrants, present in UN projections, who are present in all scenarios, are assumed not to differ from local inhabitants. Additional migrants in the “high” case are taken from working-age population (from 15 to 64), are divided between age groups and gender proportionally to the share of these categories in the population of the country of origin, and are assumed to keep their initial level of education. This is only in terms of life expectancy that the additional migrants mimic the host country natives.

We then address the impact of accelerated, or decelerated, convergence in education. In MaGE, educational catch up towards the frontier has an important role, as it drives the convergence in TFP. The productivity frontier itself is not constant, as the leading country (that might change over time) is continuously improving its educational level. We estimated in MaGE, for each region of the world, what is the structural speed of convergence to the educational frontier. Here, we consider the half-life time[6] of this process, and we increase it by 50% in the low case. We expect this to reduce their technological catch-up and finally to hamper their growth. Alternatively, we divide by two the estimated half-time, in order to take into account an acceleration of the accumulation of capital in middle- and low- income countries, in line with what was observed in certain emerging economies recently.

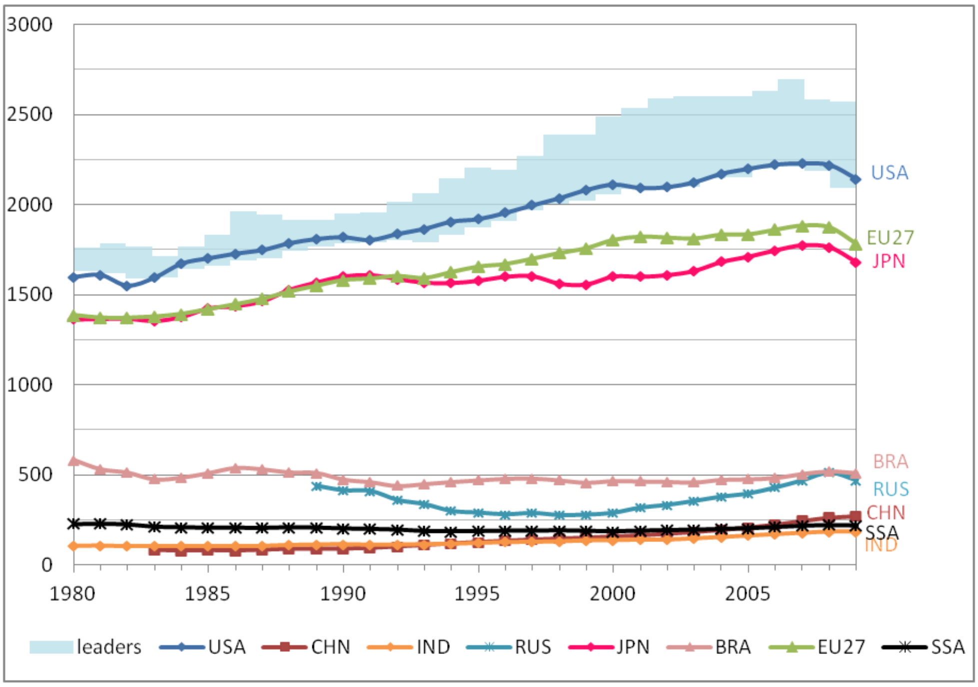
The fourth variable that will be shocked in MaGE is female participation to the labour market. In the “low” case we consider that the expected improvement in middle- and low- income economies, an additional engine of growth, will not happen for societal reasons. In the “high” case we keep this improvement as in the reference.

The fifth variable of interest is TFP. As already explained, TFP is endogenous in MaGE. It is determined by a catching up process in which distance to the technological frontier and education drive the convergence. This process is kept unchanged, including the impact of changes in education, except that we add an exogenous gain or loss of TFP, in respectively the “high” and “low” cases. A gain in TFP will result from additional technology transfer, through Foreign Direct Investment, exports (e.g. via contracts related to utilities, armament, power generation) or even collaborative research. The TFP growth rate would be increased, with indeed larger benefits for catching up countries having higher TFP growth rates initially. In the “low” case, in contrast, a deteriorated economic environment will lead to opposite evolutions, which will be topped by capital destruction, long term unemployment. We have had periods of sharp decline of the growth rate of TFP, or even drops in the level of TFP for certain countries. Here again the catching up countries will be more impacted, with a detrimental effect on their growth rate. Such shocks correspond to episodes that have historically been observed. As shown in Figure 5, there have been many periods and countries

[6] Half-life time is defined as the time necessary to reduce by half the distance to the educational frontier, assuming a constant frontier.

for which TFP growth slowed down and even become negative during the past 30 years, or at the opposite periods of buoyant TFP growth. The most notable circumstances are the transition of Russia after the fall of USSR and the 90's for Japan. Our scenarios try to consider the impact of long phases like these, which cannot be captured by an econometric estimation. The mechanisms described above (FDI, technology transfers, collaborative research) are topped by an overall technological boost in the "high" case, leading to a 50% increase in TFP for middle- and low-income countries, and a 25% increase only for high income economies. Everyone will be better off, but the technological leadership of high-income countries will be eroded. The "low" case is mirroring "hard times" whereby limited TFP gains in the North (only three-quarter of the gains projected in the reference scenario) lead this group of countries to greater reluctance to technology transfer and crispation on intellectual property rights. As a result, TFP gains are even more reduced (-50%) in the group of catching-up countries. This is a less cooperative world in which everyone is worse off, but where the richest countries preserve part of their initial advantage.

Figure 2 – Level of TFP and TFP leaders, 1980-2009



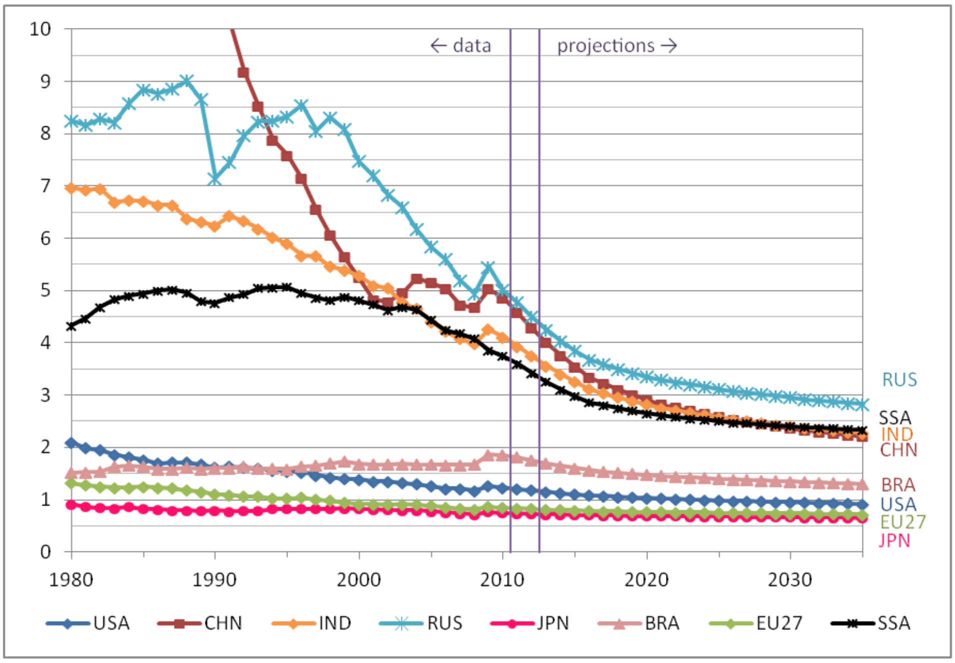
Notes: TFP level is corrected for oil rents bias. Leader countries each year are the 5 countries with highest TFP, excluding Luxemburg. These countries are among the USA, Denmark, Sweden, Ireland, Belgium, France, the Netherlands and Germany), depending on the year considered.

The sixth shock in MaGE is on the energy price. Uncertainty in energy prices may reside in a misevaluation of fossil reserves, or unhandled breakthrough such as the introduction of shale oil or a faster transition to renewable energies. We use the two scenarios of the EIA: high price scenario for the "low" case and reciprocally, encompassing a wide range of oil price, ranging from 50 to 190 US dollars per barrel.

Another variable of interest is the energy efficiency of countries. What could impact significantly energy efficiency are technological breakthrough, as discussed about TFP scenarios, since the sectoral transition to less energy-intensive activities is endogenous, monitored by the conditionality of catching-up energy productivity to GDP per capita, as depicted for MaGE's reference case in Figure

3.[7] Here, we assume that countries at different levels of development will benefit from such progress unevenly. In the "low" case, technical progress occurs in the high income countries, but is not passed onto middle- and low- income ones. The efficiency gains in terms of energy are accordingly concentrated in the already most efficient countries (we assume a 50% increase, with respect to the reference scenario), with less impact on the overall energy efficiency of the world economy. In the "high" case efficiency gains are concentrated in middle- and low- income countries, based on the assumption of increased transfers of the existing technology.

Figure 3 – Energy intensity of the GDP in the reference scenario of MaGE (1980-2035), barrel of oil per 1,000 2005 USD of GDP

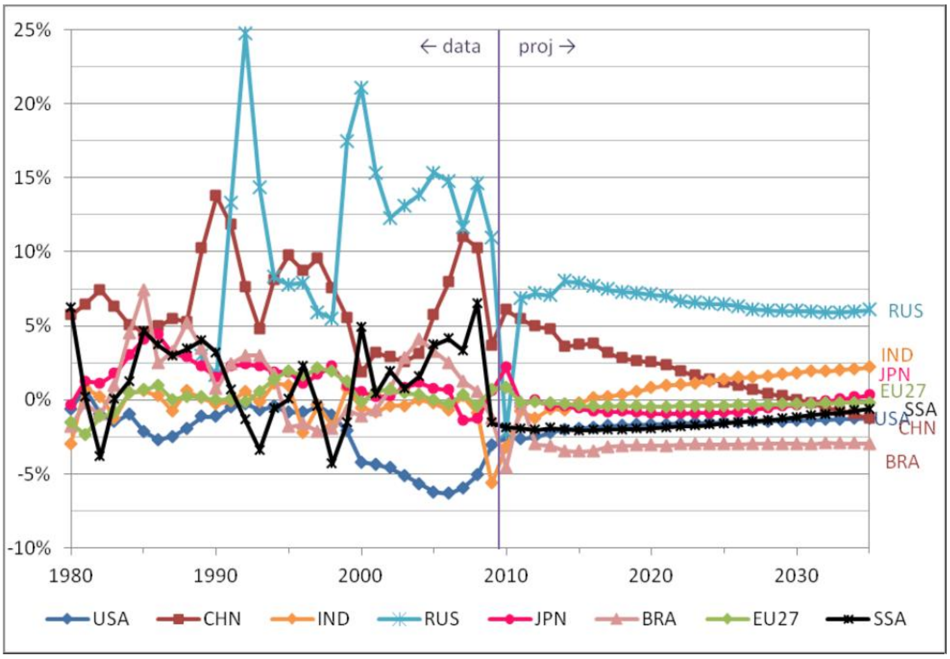


Finally, capital mobility is an important determinant of growth as it is shaping the difference between national savings and investment. Increased capital mobility should authorise a better allocation of capital worldwide and thus enhance growth overall. In our "high" case, we align the correlation between domestic savings and investment at the world level to its lowest regional level, which is the one of non-OECD countries. Incidentally, this choice leads to no gain in capital mobility for the latter group of countries. In the "low" case, there is on the contrary a "financial de-globalisation", according to which countries return progressively to financial autarky by 2050 (hence beyond the horizon of this exercise: the process remains unachieved at the 2035 horizon).

Notice that assumptions on demographic profiles, and capital mobility will modify the dynamics of the saving-investment balance depicted in Figure 4, characterised by a natural rebalancing of the Chinese economy.

[7] At the beginning of projections, almost every country has already passed the turning point between efficiency decrease and improvement.

Figure 4 – Saving-Investment balance in the reference scenario, 1980-2035, percentage of GDP



The next step is to use the results of these two scenarios imposed to MaGE as an input for MIRAGE. This is giving us two baselines that will be shocked afterwards with consistent additional shocks affecting variables absent from MaGE (e.g. sectoral value added). For each scenario "high" and "low", we firstly compute the baseline scenario in MIRAGE to which we impose GDP, population, total labour force, skill level, savings, energy productivity, agricultural productivity, current account and energy price. We also reproduce global trends in transaction costs consistent with the observed income elasticity of international trade (as already discussed) and recover TFP. As energy price is exogenous, natural resources adjust endogenously in the baseline. Our two baselines assume a *status quo* on the front of the tariffs as well as the non-tariff barriers. We finally get to baselines, "high" and "low" for MIRAGE, referred to as "High Ref" and "Low Ref" respectively (Table 5).

Table 5 – The two baselines of MIRAGE-e (2035 horizon)

	Low Ref	**High Ref**
MaGE scenario	Low	High
Energy prices	High price	Low price scenario
Transaction costs for goods*	25% cut	25% cut
Transports TFP*	2% annual growth	2% annual growth
Tariffs	No change wrt 2007	No change wrt 2007

* As discussed in the text, these two trends are introduced in a pre-experiment in order to reproduce the long-term income elasticity of world trade

The last step consists in implementing trade scenarios upon each of the two baselines (tariffs, transaction costs and NTM in services) while GDP and energy price are set endogenous (TFP and natural resources being fixed to their baseline level). In the "Low sim" scenario an increase in transaction costs and tariff is applied to the low baseline. The "Highsim" scenario starts from the high baseline and describes a more cooperative world where obstacles to trade in goods and services are reduced compared to their 2007 level.

Table 8 – The two scenarios implemented in MIRAGE-e (2035 horizon)

	Low Sim	High Sim
Applied to baseline	Low Ref	High Ref
Transaction costs for goods	+50% from developing countries +20% from developed countries	-50% from developing countries -20% from developed
Tariffs on goods	Trade war scenario (Tokyo round tariffs)	-50% compared to 2004
NTM in services	No change	Liberalisation in services (-50%)

In the "Low sim" scenario, we apply to the "Low Ref" baseline a series of shocks reproducing an increase in transaction costs, as well as a tariff war. Facing a low growth profile, and possibly geopolitical tensions, countries increase red tape controls and formalities and systematise the controls of shipments. Developing countries are more affected by this evolution as their exports are perceived as "unsafe" by advanced economies. This degradation of the world trading environment is progressive: we add a 20% increase in transaction costs of developed countries' exports linearly over the considered period (2014-2035). The increase culminates at 50% for developing countries' exports. The second dimension of this degradation of the trading environment is about protectionism. Either countries respect de jure commitments at the WTO and rely massively on anti-dumping duties and safeguards, or they go back to their bound tariffs, or they just enter into a non-cooperative scenario whereby previous commitments are no longer respected. To reproduce such outcome, we make the assumption that the world economy goes back to the post-Tokyo round levels of protection progressively over the two decades considered. This is implemented in the following way.

For manufacturing, we try to reproduce post-Tokyo Round tariffs. When available, we use data from Deardorff and Stern (1983) by sector. For aggregated regions, we take the simple average. Otherwise we take the oldest data from WDI to which we add a 25% increase. For the Agro-food sector, we simply reverse the Uruguay round (Agreement on Agriculture) and add 36% to tariffs for developed countries and 24% for developing countries, whereas for Energy goods, we keep tariffs constant. Tariffs within FTAs are supposed not to be subject to tariff war and were not increased in our scenario. This concernsEU27, EFTA, NAFTA, AU-NZ and USA-AUNZ.These tariff increases provide a target for 2030, which we implement linearly between 2013 and 2030. Tariffs are constant after 2030. We exemplify this procedure in Table 6 for selected sectors.[8]

[8]This methodology implies that targeted tariffs may be lower than or equal to the 2004 tariff in GTAP. For primary products we do not have primary products tariffs in Deardorff and Stern and keep 2004 levels. For 252 triplet out of 9261 this situation is either due to an averaging bias (a sector for which the tariff decreased less than what our average value) or to an aggregation bias (our simple average does not match GTAP weighted average).

Table 6 – Tariff scenario by importer for selected sectors, simple average, "LowSim" versus "Ref"

Sector	Cars and Trucks (Manuf.)		Primary(Manuf.)		Coal (Energy)		Crops (Agro-Food)		Food (Agro-Food)	
Scenario										
Importer	Ref	LowSim	Ref	LowSim	Ref	LowSim	Ref	LowSim	Ref	LowSim
ASEAN	19.2	21.5	2.1	16.2	1.3	1.3	10.0	12.3	20.3	24.0
AUNZ	6.4	24.0	0.3	0.3			0.5	0.6	3.0	3.0
Brazil	14.0	45.2	3.1	45.2			7.0	8.7	10.8	45.2
Canada	3.0	3.4	0.1	0.1			0.7	0.9	10.3	10.3
China	17.2	43.3	1.2	43.3	3.5	3.5	6.4	8.0	10.5	43.3
EFTA	0.5	5.1	4.7	4.7	0.2	0.2	26.0	35.1	40.2	40.2
EU27	3.2	10.5	0.1	0.1	0.0	0.0	8.8	11.9	15.8	15.8
India	19.3	90.8	9.0	90.8	23.8	23.8	29.0	35.9	49.6	91.6
Japan	0.0	5.7	0.3	0.3	0.0	0.0	9.5	12.9	20.3	20.3
Korea	7.3	20.1	1.6	20.1	0.9	0.9	43.1	53.5	25.2	27.8
Mexico	14.6	17.6	8.6	15.4	5.1	5.1	8.1	10.0	16.4	18.1
MiddleEast	10.5	31.6	2.7	30.7	2.6	2.6	11.2	13.8	15.5	32.4
NorthAfr	19.5	32.2	6.7	31.0	7.5	7.5	19.1	23.4	18.7	31.5
RoAfr	13.1	16.3	5.7	16.1	3.3	3.3	11.1	13.7	16.9	18.5
RoEurope	5.0	10.9	1.6	10.7	0.4	0.4	9.4	11.6	21.8	21.9
RoLAC	14.2	18.8	3.8	17.4	1.9	1.9	7.9	9.8	16.3	18.6
RoW	16.3	19.4	2.4	16.2	1.8	1.8	9.7	12.0	18.7	22.6
Russia	9.9	11.7	4.3	9.0	3.8	3.8	5.9	7.3	14.3	15.2
SouthAfr	15.3	17.4	0.3	16.0			6.1	7.5	14.0	19.6
Turkey	5.7	7.3	0.4	6.4			20.1	24.9	25.6	25.6
USA	1.8	3.5	0.1	0.1			6.1	8.3	5.4	5.4
Total	10.4	22.0	3.0	20.5	4.9	4.9	12.2	15.4	18.6	26.3

Note: "Ref" is the baseline tariff used for "Low Ref" and "High Ref". "LowSim" is the scenario value.

Source: Authors' calculations based on GTAP, Deardorff and Stern (1983) and World Development Indicators.

The "high" scenario ("high sim" thereafter) describes a more cooperative world. Firstly, tariffs on goods are reduced (-50%) compared to their 2007 level. Secondly, taking benefit of sustained growth and rapid convergence of emerging countries (increasing their income level and reducing the cost competitive pressures), countries address seriously the issue of trade in services. There is a large decrease in the obstacles to trade in services, while transaction costs on goods continue to decrease. They do so faster for developing countries where the margins of progress are bigger. We assume a 50% decrease in transaction costs for developing countries and 20% for developed countries.[9] Regarding the decrease in the obstacles to trade in services, we start with the Ad Valorem Equivalents computed by Fontagné et al. (2011), here modelled as a trade cost. We then set the target to -50% in 2030, and this phasing out is implemented linearly between 2013 and 2030. The outcome of this exercise is shown in Table 7.

[9] Remind that the impact of energy prices on the demand for transport is endogenously taken into account in MIRAGE-e

Table 7 – NTM tariff equivalent in services by importer, simple average

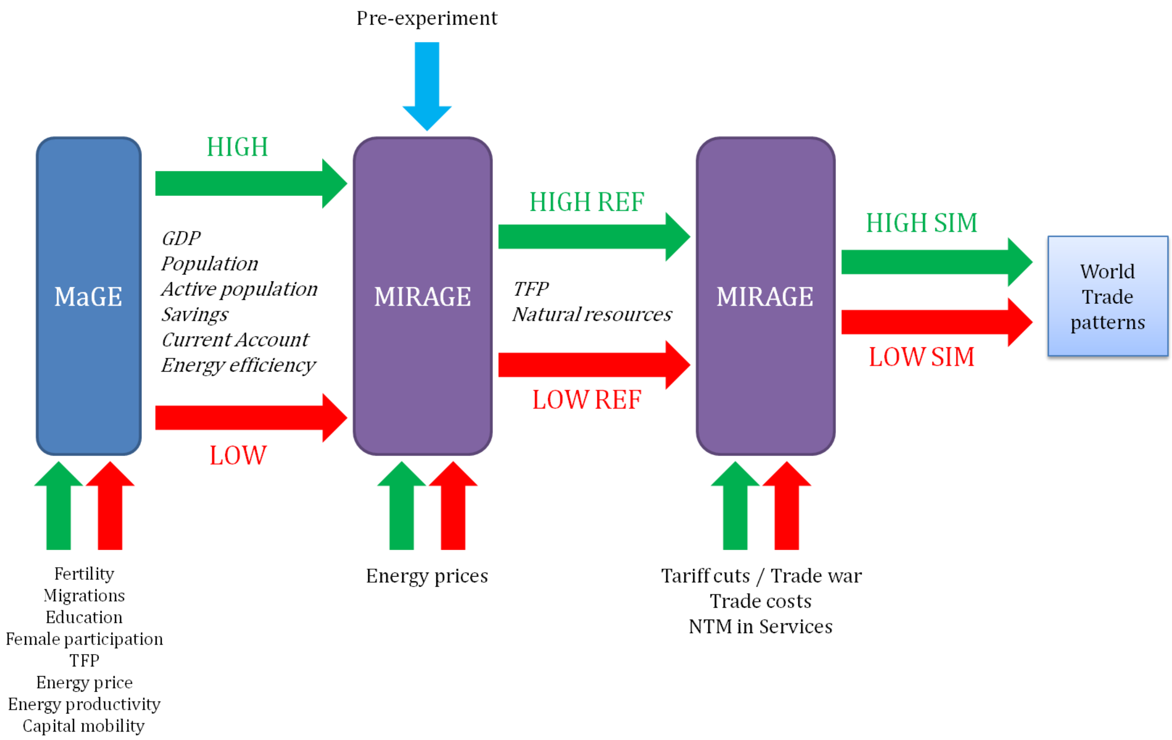
Sector	Finance, Insurance, Business serv.		Other Services		PublicAdministration		Transport	
Scenario / Importer	Ref	HighSim	Ref	HighSim	Ref	HighSim	Ref	HighSim
ASEAN	44.2	22.1	48.0	24.0	34.4	17.2	26.6	13.3
AUNZ	62.4	31.2	78.0	39.0	44.5	22.3	29.4	14.7
Brazil	49.8	24.9	108.4	54.2	36.8	18.4	37.7	18.8
Canada	31.0	15.5	56.5	28.2	35.9	18.0	27.1	13.5
China	91.8	45.9	43.9	22.0	59.6	29.8	71.9	35.9
EFTA	47.4	23.7	65.2	32.6	28.9	14.4	31.8	15.9
EU27	30.0	15.0	39.0	19.5	29.9	15.0	19.4	9.7
India	105.5	52.7	103.6	51.8	68.4	34.2	51.3	25.6
Japan	47.2	23.6	38.8	19.4	48.4	24.2	27.7	13.8
Korea	40.8	20.4	71.7	35.9	36.2	18.1	13.4	6.7
Mexico	56.5	28.2	65.1	32.5	38.9	19.5	36.0	18.0
MiddleEast	68.0	34.0	72.2	36.1	46.8	23.4	48.0	24.0
NorthAfr	55.4	27.7	70.9	35.4	38.0	19.0	43.5	21.8
RoAfr	68.6	34.3	62.9	31.4	46.6	23.3	43.9	21.9
RoEurope	63.7	31.8	76.2	38.1	48.7	24.3	42.8	21.4
RoLAC	65.5	32.8	77.2	38.6	39.3	19.7	32.6	16.3
RoW	44.7	22.4	53.6	26.8	27.6	13.8	22.2	11.1
Russia	41.1	20.5	44.3	22.1	42.1	21.1	22.8	11.4
SouthAfr	65.0	32.5	88.5	44.3	51.3	25.7	41.4	20.7
Turkey	70.4	35.2	81.6	40.8	50.0	25.0	54.1	27.1
USA	45.8	22.9	70.1	35.0	8.8	4.4	22.6	11.3
Total	44.2	22.1	48.0	24.0	34.4	17.2	26.6	13.3

Note: "Ref" is the baseline level and "HighSim" is the scenario values.

Source: Authors' calculations based on Fontagné et al. (2011).

Finally, the overall three-step method is summarized in Figure 6.

Figure 5 – Design of scenarios in MaGE and MIRAGE



3- Implementing the scenarios in MaGE

We start by considering the impact of alternative assumptions regarding the variables of interest, shocked one at a time. We then turn to the combination of differentiated shocks in two scenarios.

3.1 Demographyand migrations

The demographic scenarios were defined as reference fertility in high income countries and low fertility in other countries in the Low scenario, versus reference fertility in high-income countries and high fertility in other countries in the High scenario.

Table 8 – Differentiated population scenarios, 2035, million people

	Ref	low	high
United States of America	373	+0.0%	+0.0%
Japan	117	+0.0%	+0.0%
European Union	513	-0.9%	+0.9%
Brazil	223	-7.8%	+8.1%
Russian Federation	134	-6.9%	+7.0%
India	1580	-7.5%	+7.7%
China	1382	-6.8%	+6.9%
Latin America	452	-7.6%	+7.8%
Middle east and North Africa	544	-6.6%	+6.6%
Sub-Saharan Africa	1320	-6.4%	+6.4%
Rest of Asia	1238	-7.2%	+7.3%
Rest of the World	193	-3.8%	+3.9%
Total world	8068	-6.1%	+6.2%

The shock is quite symetrical between the high and low scenario. Note that there are 5 countries in EU that are not “High income” economies in the sense of the World Bank (Bulgaria, Lithuania, Latvia, Poland, Romania).

The next step in terms of demography is to introduce migrations (beyond conservative migration flows already present in UN demographic projections). In the Low scenario, there is no change in migrations compared to our baseline projection. Accordingly, we present only the High scenario. Our assumptions are a yearly migration outflow of 1,200,000 people from SSA to the EU, yearly. Another 800,000 migrate from MENA countries to the EU. Finally, 1,200,000 people migrate to the US from Latin America every year. Age, sex and education levels are kept in destination as in origin country. In contrast, mortality and activity rate become as in destination country (although female participation to the labor force would be impacted by the integration of migrants in the average education level computation). Results in terms of population are shown in Table 9. Notice that world total population is affected because mortality is lower in the destination country of migrants than in their origin country.

Table 9 – Total population in presence of additional migrations, million people, 2035

	Ref	high
United States of America	373	+6.6%
European Union	513	+8.3%
Latin America	452	-5.0%
Middle east and North Africa	544	-2.4%
Sub-Saharan Africa	1320	-1.8%
Total world	8068	+0.1%

Note: Other regions are not impacted by the migration scenario.

As noted before, when migrants leave their origin country, they keep their initial level of education. Given the amounts considered, migrants would have a significant impact on the share of population in each level of education. We show in Table 10 the outcome of our assumptions in terms of education attainment in the secondary and tertiary levels. Education increases in MENA and Latin America because of the age group aggregation. Due to heterogeneous mortality rates between age groups and between countries inside the country group, the drop in population distorts age structure across time (even if migrants at time t are equally distributed across age groups). Not surprisingly, origin countries have (on average) less human capital than destination country and therefore immigrants lower a bit education level, which explains results for the EU and the US.

Table 10 – Secondary and tertiary education, 2035, percentage of working-age population

	Secondary		Tertiary	
	Reference	high	Reference	high
United States of America	99	-0.5	64	-1.0
European Union	93	-1.5	38	-1.4
Latin America	74	+0.2	25	+0.1
Middle east and North Africa	72	+0.1	25	+0.1
Total world	71	+0.3	20	+0.3

Note: Other regions are not impacted by the migration scenario.

The last direct consequence of the migration considered is on savings rates due to the distortion of age structure (both in the origin and destination country), which is the main determinant of savings in our life-cycle framework. Savings also determine investment capacities for a given level of international financial flows.We show in Table 11 how migrations scenarios impact investment and savings.

Table 11 – Investment and savings rate, 2035, % of GDP

	Investment		Savings	
	Reference	High	Ref	High
United States of America	14	+0.21	13	+0.34
Japan	21	-0.11	21	-0.18
European Union	17	+0.33	16	+0.56
Brazil	17	-0.00	14	-0.03
Russian Federation	21	-0.01	27	-0.06
India	20	+0.00	22	-0.01
China	31	-0.00	30	-0.04
Latin America	18	-0.24	18	-0.65
Middle east and North Africa	20	-0.11	23	-0.28
Sub-Saharan Africa	16	-0.06	16	-0.30
Rest of Asia	22	-0.04	23	-0.08
Rest of the World	19	-0.10	21	-0.16
Total world	20	-0.08	20	-0.08

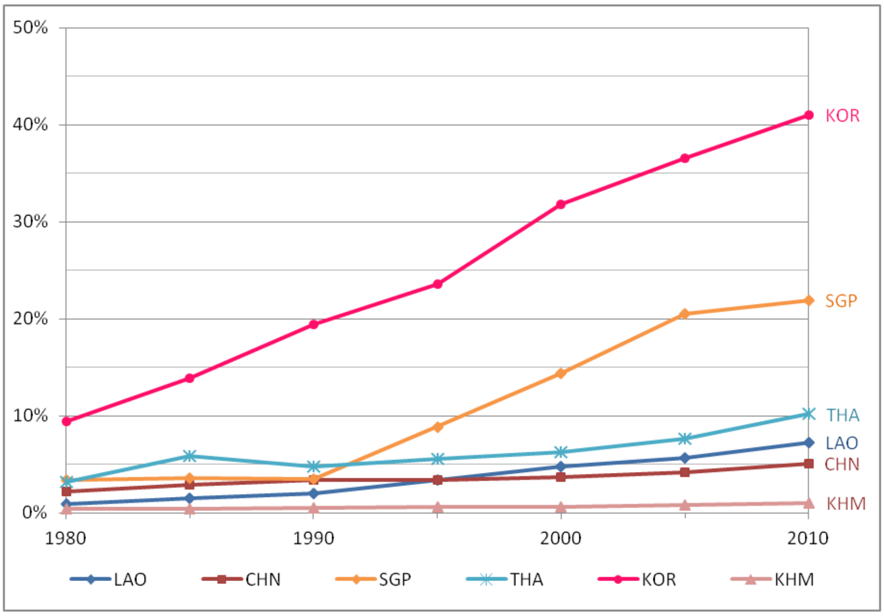
The arrival of young age groups in ageing countries like EU and USA tends to increase their savings rate (+0.6% and +0.3% of GDP, respectively). However, we also see a drop in savings rate in origin country due to the departure of working-age population (but not younger and older people). At the global level, the loss is greater than the increase (-0.1% of world GDP). Then, the global investment envelope decreases, while the share of EU and USA in this envelope increases. Therefore, investment lowers everywhere else.

3.2 Human capital accumulation and female participation

Beyond demography, we must address shocks related to investment in human capital. Education catch-up over the past 50 years has been very diverse among regions and has been one of the main drivers of the difference in per-capita income performances across countries. For estimation purposes, we estimated catch-up speed by geographical regions. However, this average speed fails to encompass the diversity of situations, depicted for instance in the graph below. Our shocks to MaGE try to frame educational convergence and represent lower and upper bounds of catch-up by the mean of a standard catch-up measure: half-life time. Half-life time is the time a country will take (at constant educational frontier) to reduce its difference with the leader by half.

As an illustration of the observed increase in education levels in emerging countries, we show in Figure 8 the evolution in educational attainment in some Asian countries over the period 1980-2010. The pattern is quite different across countries. The achievements observed in Korea and Singapore fuelled productivity gains and help elevating income levels in this country. By contrast, China remains at low levels, which has driven so far its comparative advantage mainly towards low segments of value added, if not towards low value added products.

Figure 6 – Share of tertiary educated population in Asia, 1980-2010



Note: KOR stands for Korea, SGP for Singapore, THA for Thailand, LAO for Laos, CHN for China and KHM for Cambodia

In the high scenario, as shown in Table 12, the catching up is accelerated (reduction of the half-life of convergence by 50%). Even if the assumption is made that such investment in education is to be observed worldwide, its impact will be concentrated on countries being far from the (moving) educational frontier. In the USA or Japan, the increase in the percentage of the population completing a degree in the tertiary education is respectively 3 and 2 p.p. The impact is larger for the EU (+6 p.p.), due to the differentiated levels currently observed in member countries. The impact is large also in Latin America (+7 p.p.). In China gains in relative terms are less important, though the absolute number of educated people is indeed very large, which is important for world growth overall. China gains 4 p.p. in the tertiary education and more than 1 p.p. in secondary. In contrast, most of the gains are concentrated on the secondary education in the poorest countries (+ 8 p.p. in Sub-Saharan Africa). In India both levels of education are benefitting (+ 5 p.p. each). The low scenario is pointing to symmetric results, though attenuated as a result of the assumption made (half time increased by half). Detailed results are shown in Appendix 2.

Table 12 – Secondary and Tertiary education, % of population, 2035

	Secondary			Tertiary		
	Reference	low	high	Reference	low	high
United States of America	99	-0.1	+0.1	64	-1.8	+3.1
Japan	97	-0.1	+0.2	64	-1.3	+2.2
European Union	93	-0.7	+1.3	38	-2.7	+5.7
Brazil	71	-1.8	+3.9	17	-2.4	+7.2
Russian Federation	98	-0.1	+0.2	63	-1.6	+2.8
India	66	-2.3	+5.2	12	-1.5	+5.2
China	86	-0.7	+1.4	14	-1.3	+4.0
Latin America	74	-1.9	+4.4	25	-2.6	+7.2
Middle east and North Africa	72	-2.1	+4.4	25	-2.6	+6.9
Sub-saharian Africa	40	-2.7	+7.9	5	-0.7	+2.5
Rest of Asia	62	-2.5	+5.8	17	-1.4	+4.3
Rest of the World	94	-0.7	+1.2	46	-2.8	+5.4
Total world	71	-1.7	+4.1	20	-1.6	+4.5

Another important pattern of labour markets is female participation. It ranges from 37% (India) to 54% (USA) or even 57% (China).[10] Any convergence in the participation rates to the highest level would impact labour force and its skill composition. Two opposite effects compete. First, more educated women tend to participate more to the labour force. However, this statement is true only for women older than 25. For the younger age groups (15-19 and 20-24), longer studies decrease participation to the labour force. If the former (resp. latter) effect is greater, then the overall impact on labour force will be positive (resp. negative). In our baseline scenario, we consider that there is some form of convergence, based on historical evidence. We do not make a "high" case here, whereby women participation would increase even more. The "high" case is identical to the baseline. In contrast, in the "low" case we constrain women participation to be constant after 2010. This has an unexpected outcome for ageing economies, whereby women participation is expected to decrease naturally, just for demographic reason. By constraining this mechanism not to play in the future, the low scenario actually increases women participation wrt the reference scenario e.g. in Europe or Russia. The impacts of our scenario are shown in Table 13.

[10] Female participation is actually the highest in Sub-Saharan Africa (63%).

Table 13 – Female participation to the labour force, % of female population, 2035

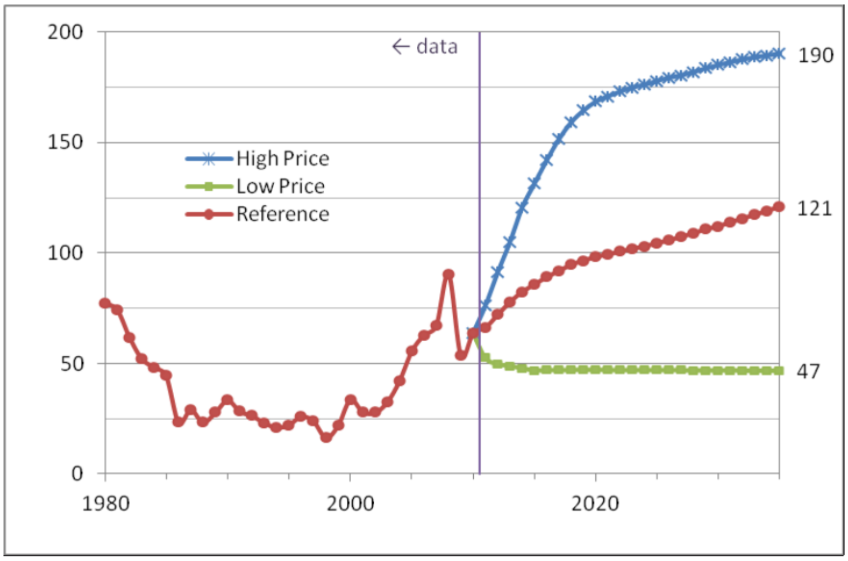
	Ref	low
United States of America	56	-1.5
Japan	47	-2.3
European Union	43	+2.1
Brazil	54	+5.5
Russian Federation	51	+3.0
India	37	-5.9
China	57	-1.7
Latin America	46	+3.9
Middle east and North Africa	30	-4.3
Sub-saharian Africa	63	+1.7
Rest of Asia	50	-0.8
Rest of the World	53	+2.4
Total world	49	-1.1

3.3 Energy price and technical progress in energy use

The next shock to be considered is about energy price, using EIA scenarios (Figure 7). It will induce substitutions and technical progress (although the link between energy price and productivity is not integrated in our model), such that the energy intensity of GDP will be reduced in case of high prices. We observe how much this phenomenon cushions the impact of energy prices for different countries in Table 14. The reference scenario is shown in column 1, where values are energy intensity expressed in barrels of oil equivalent (boe) per 1,000 US dollar of GDP, in 2035. Energy productivity can be observed independently but it does not include the possible substitution with labour and capital. We therefore present results rather in terms of energy intensity of GDP (E/Y). In general, lower productivity will lead to higher energy intensity.

In column 2 and 3, we have the change in energy intensity measured in the same unit. We firstly observe that the world economy will be much more energy efficient under the high price scenario. For oil producing countries, this effect is reinforced by the oil rent boosting growth and thus facilitating the convergence in terms of energetic efficiency. The largest gains to be expected would appear in Sub-Saharan Africa and in Russia. Japan, Europe or even the Unites States are expected to achieve less efficiency gains on this front, though from extremely low initial energy intensity in Japan and Europe.

Figure 7 – Observed energy price and EIA scenarios 1980-2050 (constant 2005 USD)



Source: EIA

Energy use is determined by energy price and the induced adjustment of the economies towards less intensive technologies in case of high energy prices. Beyond this "economic" adjustment, an autonomous strand of technical progress in the energy domain is to be considered. Major technological breakthrough, or societal changes, may occur in the next two decades, leading to a dramatic increase in the energetic efficiency of our economies. Such changes are not embedded in past data and thus absent from our econometric estimations. They can be introduced in the projections as exogenous shocks.

Results in terms of energy intensity are shown in Table 14, along with the impacts of energy price scenarios. As in the previous case, columns 4 and 5 show the result of our assumptions on energy price on energy use efficiency, measured in boe per 1000USD of GDP. Although this time countries are not impacted homogeneously, world average order of magnitude is the same as for scenarios on energy price.

Regarding technological progress, we assume in the Low scenario, a 50 % increase (compared to our reference scenario) in energy efficiency in high income countries at the 2050 horizon, but no change for other countries. Under the High scenario, we assume a 50% increase in energy efficiency for low and mid income countries at the 2050 horizon, but no change for other countries.

Table 14 – Energy intensity, 2035, barrel per $1,000 of GDP: different scenarios for energy price

		Impact of energy price		Impact of techno.progr.	
	Ref	low	high	low	high
United States of America	0.92	-0.06	+0.13	-0.18	+0.00
Japan	0.65	-0.04	+0.09	-0.12	+0.00
European Union	0.72	-0.05	+0.10	-0.12	-0.01
Brazil	1.30	-0.09	+0.20	+0.00	-0.25
Russian Federation	2.83	-0.32	+0.59	+0.00	-0.54
India	2.28	-0.14	+0.32	+0.00	-0.44
China	2.21	-0.13	+0.31	+0.00	-0.42
Latin America	1.22	-0.11	+0.21	-0.00	-0.23
Middle east and North Africa	1.43	-0.19	+0.35	-0.08	-0.19
Sub-Saharan Africa	2.51	-0.23	+0.44	+0.00	-0.48
Rest of Asia	1.76	-0.12	+0.26	-0.10	-0.23
Rest of the World	1.03	-0.08	+0.17	-0.15	-0.04
Total world	1.36	-0.11	+0.22	-0.09	-0.17

3.4 Total factor productivity

An important mechanism associated with our scenario is about technological progress in the various regions of the world, which can vary according to our scenarios. These changes may be driven by autonomous technological developments of countries or by the international technology transfers. We consider in the Low scenario a 50% drop in the TFP growth rate for low and middle income countries, compared to our baseline scenario, and respectively a 25% for high-income countries. In the High scenario, we assume a 50% increase in the TFP growth rate for low and middle income countries, and respectively only a 25% increase in the growth rate of TFP for high-income countries.

Table 15 – TFP growth rate, 2012-2035

	TFP growth		
	Ref	low	high
United States of America	0.98	-0.25	+0.25
Japan	1.71	-0.34	+0.30
European Union	1.33	-0.29	+0.30
Brazil	1.65	-0.77	+0.68
Russian Federation	3.91	-1.80	+1.54
India	3.26	-1.50	+1.28
China	4.19	-1.89	+1.56
Latin America	1.76	-0.83	+0.75
Middle east and North Africa	1.54	-0.60	+0.67
Sub-Saharan Africa	2.28	-0.95	+0.85
Rest of Asia	2.32	-0.37	+0.37
Rest of the World	1.66	-0.22	+0.26
Total world	1.58	-0.13	+0.25

3.5 International capital mobility

The last factor of production is capital. Capital is depreciating at a constant rate in our model, consistently with the specification used in MIRAGE. Regarding gross investment, two drivers have to be taken into account. First, savings are driven by demography (already discussed) and income per capita. Second, the difference between domestic savings and domestic investment is driven by international mobility of capital. This is what we will now shock. We have two opposite cases here: in the low case countries are returning to capital autarky, while in the high case they all converge to the highest degree of capital mobility observed (with no direct gains for low and middle-income countries). Low mobility has a positive impact for surplus countries (India, Russia or China).

Under the high mobility assumption, we reduce the Feldstein-Horioka correlation coefficient for OECD countries: the correlation between domestic savings and domestic investment is lower for OECD countries, and takes the value estimated for non-OECD countries which remains unchanged. The total amount of savings (which equals world investment) remains almost unaffected by this change, whereas the allocation of investment between countries is modified. As the correlation is reduced in OECD countries, investment in these countries diminishes for a given amount of savings. In turn, investment is increasing in non-OECD countries, where it is associated with lower TFP. At the world level, this induces a negligible decrease in overall GDP, while developed countries suffer a -0.2% loss in GDP compensated by a gain of a similar magnitude for developing countries (see Appendix for details).

Table 16 – Investment rate, 2035, percentage of GDP

	Averageinvestment rate		
	Ref	low	high
United States of America	15.3	-0.73	-2.36
Japan	20.7	-0.15	-3.02
European Union	17.4	-0.07	-2.54
Brazil	17.6	-1.71	+2.33
RussianFederation	21.2	+3.70	+6.32
India	20.7	+1.08	+4.39
China	32.2	+0.35	+6.78
Latin America	18.8	-0.36	+0.39
Middle east and North Africa	21.0	+2.05	+3.71
Sub-saharianAfrica	16.6	-0.36	+2.73
Rest of Asia	23.4	+0.56	+1.55
Rest of the World	19.9	+0.82	-2.01
Total world	18.8	+0.20	-0.66

3.5 Combining the different assumptions of the two scenarios in MaGE

We now implement jointly all the assumptions in two scenarios simulated with MaGE. Results shown in Table 17, for GDP growth now take into account all relations and feed-backs between variables in the MaGE model. Table 26 shows the results in per capita terms.

The first panel of Table 17 is showing annual growth rates for the regions used in MIRAGE in column (1), and the difference between each scenario and the reference case shown in columns (2) and (3). China is posting a 6% average growth rate to 2035. This is the highest figure among regions considered. The high scenario corresponds to 2.7 percentage points (p.p.) additional growth and symmetrically -2.7 p.p. for the low scenario. This symmetry is not observed systematically, depending of the composition of the region. We observe that the two scenarios are much contrasted for developing economies, with a range of 3.7 p.p. growth between the two scenarios, but not so for the developed economies (resp. 0.6 p.p.). The second panel is showing the level of the GDP in column (4), at 2005 US $ exchange rate and prices. Deviations in percentage terms from this 2035 level are indicated in columns (5) and (6). We observe that our scenarios, combining different assumptions, are indeed much contrasted. World GDP would be 33% larger (15% smaller) in the high (low) scenario, compared to the reference case.

Table 17 – GDP projections under the high and low scenarios

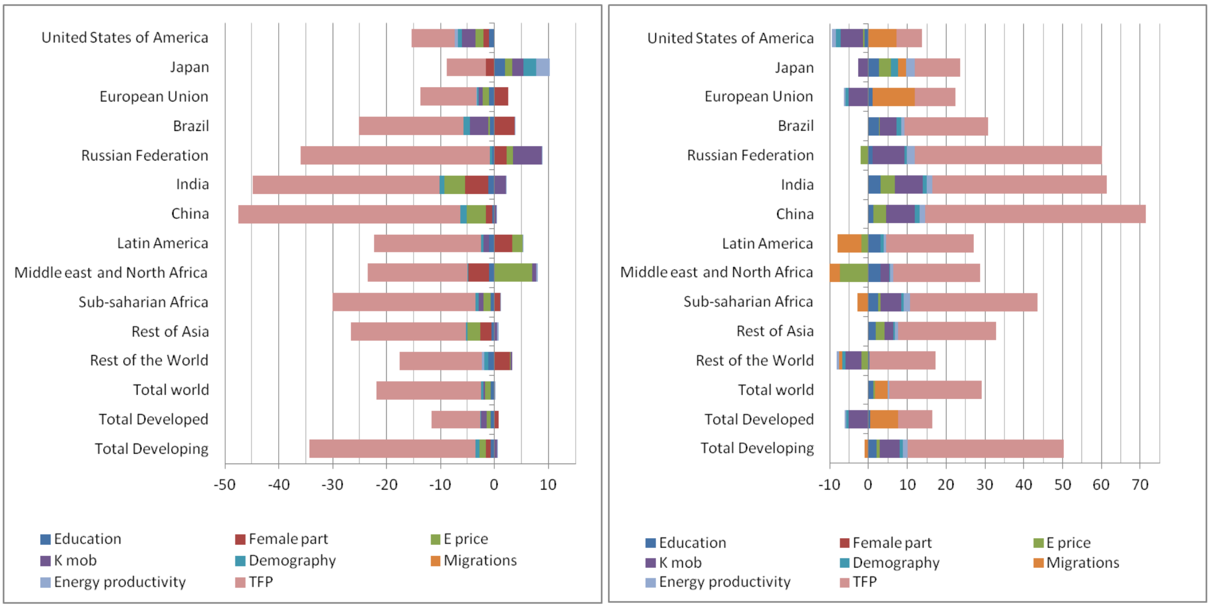
	GDP growth			GDP in 2035			Share of world GDP		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ref	low	high	Ref	low	high	Ref	low	high
United States of America	1.74	-0.12	+0.44	20562	-2.75	+10.49	20.3	+2.99	-3.40
Japan	1.53	-0.12	+0.20	6749	-2.63	+4.53	6.7	+0.99	-1.42
European Union	1.43	-0.02	+0.80	20458	-0.37	+19.81	20.2	+3.55	-1.97
Brazil	2.97	-1.01	+1.31	2299	-20.31	+33.78	2.3	-0.14	+0.02
RussianFederation	4.13	-1.51	+2.34	2481	-28.55	+66.66	2.5	-0.38	+0.63
India	5.96	-2.33	+2.48	5450	-40.10	+70.23	5.4	-1.58	+1.52
China	6.07	-2.70	+2.76	17217	-44.79	+80.48	17.0	-5.93	+6.12
Latin America	3.34	-0.79	+0.76	4674	-16.22	+18.38	4.6	-0.05	-0.50
Middle east and North Africa	3.47	-0.57	+0.79	5440	-11.86	+19.05	5.4	+0.21	-0.55
Sub-saharianAfrica	5.09	-1.43	+1.68	2727	-27.04	+43.99	2.7	-0.37	+0.23
Rest of Asia	3.98	-0.91	+1.37	7154	-18.24	+35.05	7.1	-0.25	+0.12
Rest of the World	2.69	-0.07	+0.63	6039	-1.61	+14.99	6.0	+0.96	-0.80
Total world	2.84	-0.74	+1.27	101251	-15.24	+32.73	100.0		
Total Developed	1.64	-0.04	+0.52	52842	-0.95	+12.57	52.2	+8.80	-7.93
Total Developing	4.72	-1.67	+2.01	48409	-30.84	+54.73	47.8	-8.80	+7.93

Source: Authors calculations

Note: column (4) is in billion US$ of 2005. Columns (1), (5) , (6) and (7) are in percent and columns (2), (3), (8), (9) in percentage points.

Due to the intrinsic link between all the factors that are shocked by our scenarios, it is not possible to exactly determine the relative impact of each shock. We could however observe the impact of each variable shocked at a time on GDP in 2060 to have an insight. Results are shown in Figure 8.

Figure 8 – Contributions from scenarios on individual variables to GDP level in 2060.



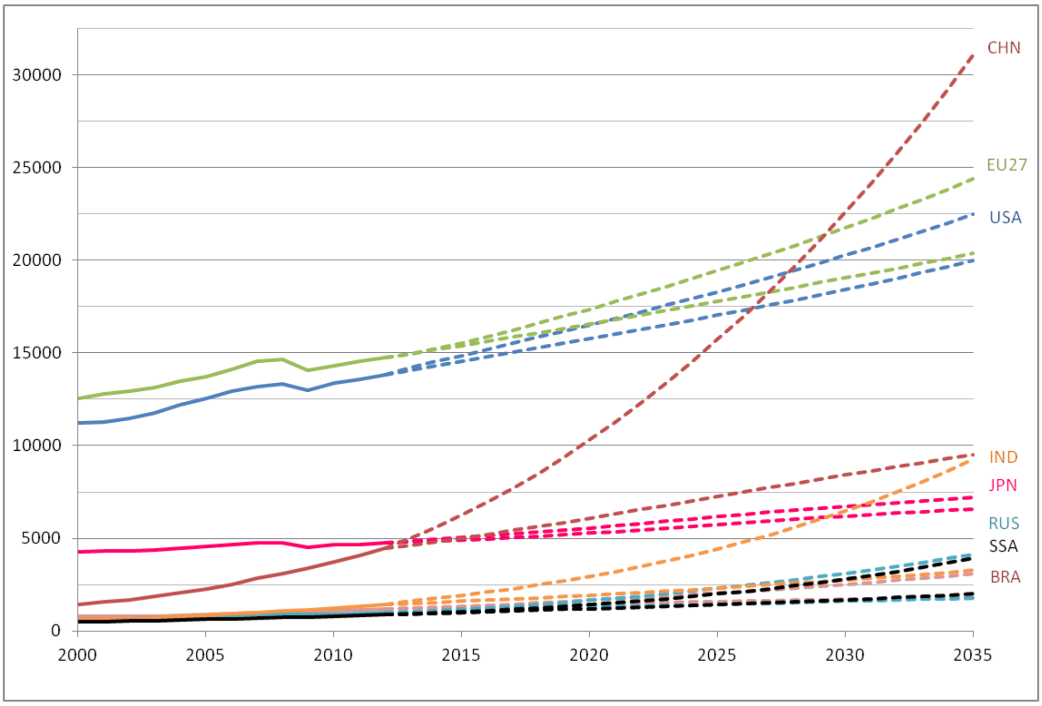
From the independent shocks we can infer that TFP is the main contributor to GDP changes in our differentiated scenarios, along with capital mobility, energy price, female participation or migrations. For the USA and European Union for instance, migrant inflows account for around the same extra

GDP as TFP gains in the "High" scenario. Although one at a time, demography, education or energy productivity seem to remain marginal, their sum is not negligible and they contribute more as a catalyser: education fuels TFP, energy productivity inflates the benefits of a low energy price, and demography drives savings.

4. Contrasted world trade patterns at the 2035 horizon

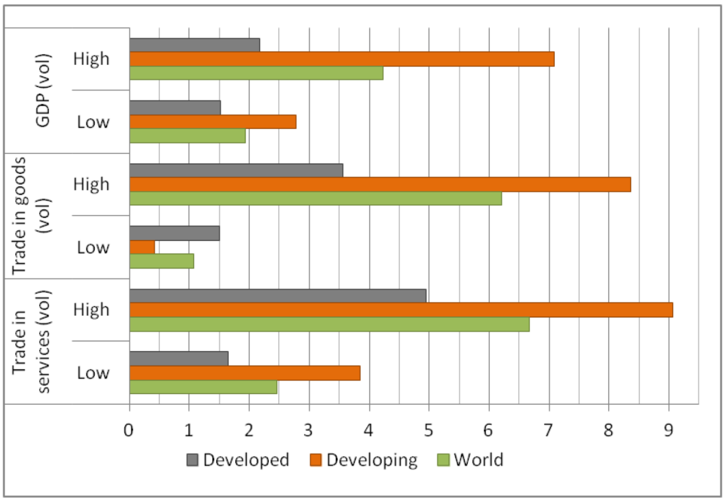
We now present the results of the two scenarios simulated in MIRAGE. The GDP trajectories introduced in the CGE in volume, shown in Figure 9, are quite contrasted as discussed in the previous section. This is indeed the purpose of our choice of opening the Pandora box of growth projections. The upper (dotted) curve corresponds to the high scenario for each country. China, according to Table 25, will reach a US$ 17,217 GDP in 2035 in the reference scenario and 80.5% more under the high scenario, hence the 31,073 GDP in 2035 for the upper dotted curve. The interpretation is symmetric (low scenario) for each country and each low dotted curve. This graph confirms that the range of outcomes in terms of GDP is very large for developing countries, compared to developed ones. The largest range of possible is for China. China is overcoming the US by 2030 under the high scenario, contrasting with the low scenario. Similarly, India will overcome Japan at the same horizon under the high scenario only. Our objective in this section is accordingly to describe the implications in terms of world trade patterns of such extreme assumptions.

Figure 9 – GDP in the two scenarios, 2000-2035, billion 2005 USD



World trade patterns are fundamentally shaped by gravity-like determinants. We expect the volume of world exports to be determined by changes in GDP, comparative advantages and trade costs. The overall picture is shown in Figure xx. Under the high scenario, developing economies will have buoyant exports of goods, growing at a 8 % rate annually. This figure will be even larger for services. This contrasts with the low scenario where GDPs are growing at a slower pace, in particular for the developing world, and where trade costs (tariffs or transaction costs) are increasing. The low scenario is particularly penalising for goods: goods must be transported and face a tariff war, while services are only confronted to regulations, the latter being assumed constant in the low scenario. Finally, developing countries' exports would be very much affected by the combination of assumptions on transaction costs, tariffs and growth assumed under the low scenario.

Figure 10 – GDP (volume) and exports (volume, incl. intra) growth rates, 2012-2035



Source: MIRAGE, authors' calculation
Note: average annual growth rates (percent)

The annual growth rates shown for exports of goods and GDP in Figure 10, suggest that trade to income elasticity will be very different in the two scenarios and in the two regions of the world economy. We show the computed trade elasticity in Table 18. In the high scenario the elasticity is 1.5 at the world level. This elasticity is low, compared to historical standards in particular if we compare with the decade where many Global Value Chains were put in place: the elasticity was 2.8 during the 1900s'. We are back in our projection to the values observed in the 1960's. Under all circumstances the elasticity will be higher for developed economies, trading increasingly with a faster growing developing world. Finally, under the low scenario, we will have (slow) growth without trade in the developing world (elasticity of 0.4), while trade and income would have the same path for developed economies.

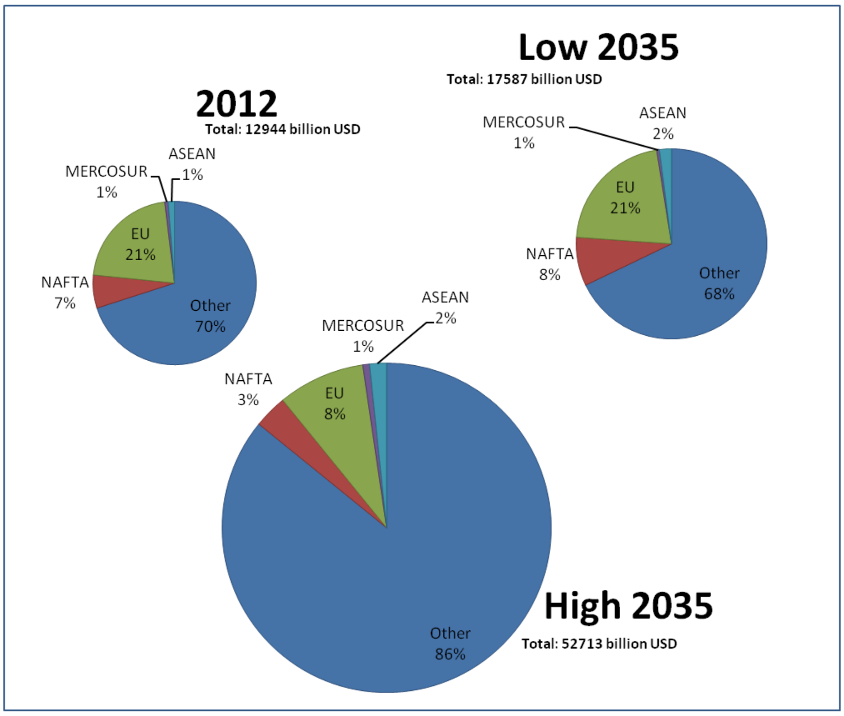
Table 18 – Trade to income elasticity (goods),2012-2035

	High	Low
Developed	1.78	1.00
Developing	1.19	0.38
World	1.49	0.69

Source: MIRAGE, author's calculation
Note: elasticity computed on the exports.

The next question regarding trade patterns is the share of intra-regional trade in world trade. As a result of the gravity forces shaping world trade, we expect South-South trade to grow faster. But South-South trade is not necessarily driven by the presence of FTAs, as the level of market integration currently signed in the South is too low to have significant impact. This contrasts with integrated regions like the EU, and to a lesser extent NAFTA. Finally, the EU and the NAFTA manage to keep their initial share of world trade at the 2035 horizon, notwithstanding a 35% increase in the volume of world exports. In contrast, in the high scenario, most of the growth is in developing economies, shifting the gravity centre of international trade to the South. World trade would quadruple in volume, EU exports would increase by 55%, but the EU share would dramatically decrease. The same pattern is observed for the NAFTA (with a 52% increase in exports). FTAs in the South do not deliver, as ASEAN and Mercosur keep their share constant in all scenarios. Such reduction of the share of regional trade in world trade in the high scenario could well be reversed, would ambitious and new FTAs signed, as the ones under negotiation in the Pacific or to a lesser extent at the Transatlantic level.

Figure 11 – Share of intra-regional FTAs exports in world trade (volume, incl. Intra)



Source: MIRAGE, authors' calculation.

Alternative growth paths for the world economy will be conducive to different export specialisation of countries. In the two scenarios contemplated here, accumulation of human as well as physical capital accumulation will be different. This will shape countries' comparative advantages. A good illustration of this mechanism is provided by the Chinese specialisation, as shown in Figure XX. The high scenario will further increase the Chinese specialisation in the electronic sector, as opposed to textile. In the low scenario, with less physical and human capital per worker, China will keep its specialisation in textile and increase it specialisation in other manufacturing, while progressively losing ground in electronics. What suggests this result is that specialisation of countries is not fully pre-determined when one consider seriously the wide range of possible outcomes in terms of medium term growth.

Figure 12 – Share of sectors in China total export (volume)

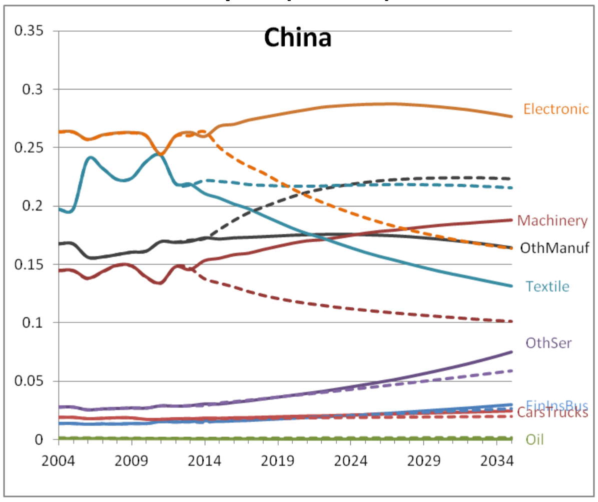
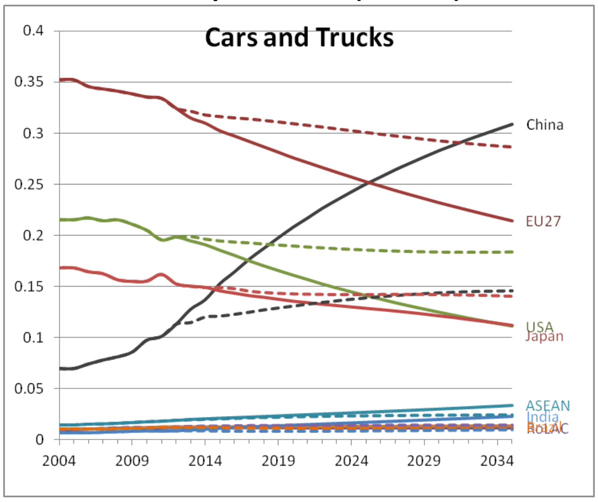
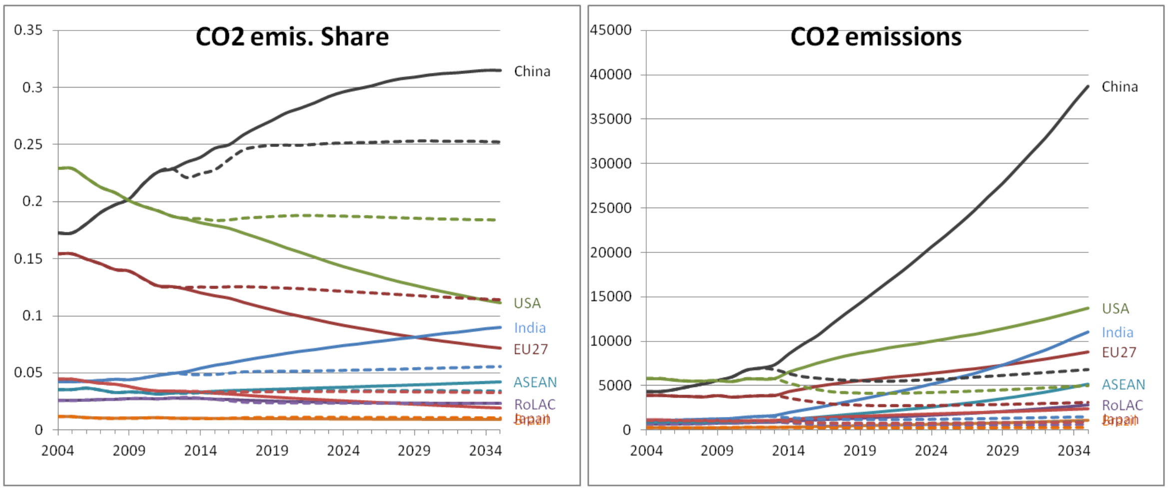


Figure 13 – Regional shares in worldCars and Trucks production (volume)



Such contrasted scenarios in terms of country specialisation will indeed profoundly impact the shape of world production in broad sectors. This is exemplified in Figure xx for the car industry. We observe the Chinese production of cars will rapidly overcome the European one in the high scenario, which won't happen in the low scenario. The same conclusion pertains to the comparison of China and the US in this sector. In contrast, the Japanese car industry will be overcome by China under all scenarios.

Figure 14 – CO_2 emissions (Percentage and $MtCO_2$)



Finally, as economic activity is the main determinant of greenhouse gas emissions, the potential shapes for world CO_2 emissions are heavily impacted by our two scenarios, both in terms of amounts and in terms of repartition. Our "Low" scenario would almost freeze the contribution of main CO2 emitters around 2020, with China stabilizing at 25% of world emissions, ahead of the USA (18%) and EU (12%). On the contrary, a sustained growth would lead India to becoming more emissive than the EU, while the share of China would reach more than 30% of world emissions. In terms of amounts, it becomes clear that, despite the improvements in energy productivity introduced in our "High" scenario, the emissions path would not be sustainable without introducing massive technological breakthrough or investment in renewable energies.

Conclusion

This paper aimed to develop a comprehensive methodological framework for projecting world trade patterns at the medium or long-run horizon, and to do so with an open-minded approach as regards scenarios for the world economy. We investigated the determinants of past developments of trade to build sound baseline assumptions and we used contrasted scenarios encompassing a large range of potentialities. The combination of MaGE, a growth model, with MIRAGE a dynamic multisectoral CGE model of the world economy proved fruitful. Our results point to the necessity of carefully building baseline scenarios when evaluating policies in dynamic general equilibrium. Given the large amount of uncertainty around future paths for the global economy we shed the light on, and provided the important role of key assumptions in terms of modelling, our results firstly call for transparency, replicability and inter-operability of such modelling framework. In order to make general equilibrium inference as reliable and transparent as possible we urge to opening the Pandora's box of growth and trade patterns projections.

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Appendix

AppendixA: Trade War data

Table A2 – Post-Tokyo round tariffs by sector

Table II. Post-Kennedy Round Base Rate Tariffs on Industrial Products by Sector in the Major Industrialized Countries (Percent; Weighted by Own-Country Imports, Excluding Petroleum)

	ALA+	ATA	BLX	CND+	DEN	FIN	FR	GFR	IRE	IT	JPN+	NL	NZ	NOR	SWD	SWZ	UK	US	ALL
Textiles	21.5	18.7	9.5	18.9	12.1	24.1	9.8	10.3	10.7	7.5	3.3	11.8	14.2	16.2	10.9	8.2	9.2	14.4	10.7
Wearing Apparel	61.8	36.3	16.7	25.4	16.4	37.2	16.7	16.8	16.4	16.6	13.8	16.8	58.7	22.8	14.4	15.5	16.9	27.8	20.7
Leather Prod	25.7	9.1	4.1	8.2	3.6	12.6	3.3	5.1	5.4	1.7	3.0	5.2	15.3	6.6	4.8	2.8	2.8	5.6	4.5
Wood Products	13.6	4.8	3.2	5.8	4.4	0.5	3.3	3.9	3.2	1.0	0.3	3.6	11.7	2.0	0.9	5.0	4.0	3.6	2.7
Paper, Pap Prod	7.1	15.9	9.3	11.8	10.8	8.0	7.6	7.1	10.9	3.7	2.1	8.4	20.9	2.9	3.0	6.6	6.6	0.5	5.8
Print & Publ	1.8	2.4	2.4	5.7	4.4	1.8	3.4	3.3	2.4	2.7	0.2	3.5	1.1	4.3	0.2	0.9	3.3	1.1	2.9
Chemicals	5.8	8.1	11.6	7.9	11.9	3.1	10.9	11.6	10.7	11.8	6.2	11.9	10.0	8.1	6.3	1.1	11.4	3.8	9.4
Rubber Products	13.8	14.6	6.2	12.2	6.7	13.9	5.2	5.7	5.6	4.0	1.5	6.1	9.5	7.3	6.5	2.0	4.0	3.6	5.8
Nonmet Min Prod	11.6	8.9	5.2	9.5	6.7	3.8	7.0	5.4	6.0	3.3	0.6	4.4	13.8	2.8	3.1	3.5	3.2	9.1	5.8
Iron & Steel	10.8	6.2	6.1	6.7	7.2	5.7	6.6	6.3	7.5	4.7	3.3	7.1	6.0	2.2	4.7	2.1	6.3	4.7	5.8
Nonfer Metals	5.3	4.5	1.9	2.0	8.1	1.2	3.1	2.3	8.0	2.2	1.1	4.3	9.3	1.1	0.9	4.3	2.0	1.2	2.0
Metal Products	24.1	19.3	7.7	14.1	7.9	9.6	7.8	8.0	7.7	8.0	6.9	7.8	29.7	6.3	5.3	3.8	8.0	7.5	9.0
Nonelec Mach	14.2	10.8	6.4	6.1	6.4	8.7	6.4	6.6	6.1	6.5	9.1	6.4	28.1	8.8	4.9	1.5	6.4	5.0	6.7
Elec Machinery	21.6	18.7	9.6	12.9	9.3	11.0*	9.8	10.2	9.5	9.9	7.4	10.0	21.0	8.6	7.0	2.0	10.0	6.6	9.6
Transp Equip	22.1	24.5	11.1	2.4	8.5	6.0*	10.3	9.9	12.0	10.7	6.0	10.9	27.6	3.5	8.2	6.7	9.3	3.3	7.7
Misc Manufact	13.0	13.7	5.2	8.8	10.0	18.1	9.6	9.1	11.2	9.4	6.0	8.7	20.5	8.9	6.1	1.5	4.9	7.8	7.8
All Industries	17.0	15.4	8.2	7.3	9.0	9.6	8.3	8.7	9.4	7.3	3.9	9.2	18.9	6.9	6.4	3.9	7.3	6.5	7.8

* Estimated from incomplete data.
+ Prevailing rates, which include unilateral reductions in post-Kennedy round tariff rates.
Source: based on data supplied by Office of U.S. Trade Representative.

Source: Deardorff and Stern (1983)

Table A3 – Weighted average applied tariff, First available year

Zone	Corresp. region	Tariff	Year
Brazil	Brazil	37.96	1989
China	China	36.41	1992
ASEAN	East Asia (developing)	13.53	1996
RoEurope	Europe and Central Asia (developing)	8.91	1996
India	India	76.28	1990
Korea	Korea	16.91	1988
RoLAC	Latin America (developing)	14.57	1996
Mexico	Mexico	13.03	1991
MiddleEast	Middle-East and North Africa (developing)	25.74	1996
NorthAfr	Middle-East and North Africa (developing)	25.74	1996
RoW	Middle Income	13.23	1996
Russia	Russian Federation	7.52	1993
SouthAfr	South Africa	13.42	1988
RoAfr	Sub-Saharan Africa (developing)	13.33	1996
Turkey	Turkey	5.37	1993

Source: WDI

Appendix B: Country classification

code	name	Inc. class	zone	Dvd.
AGO	Angola	M	SSA	0
ALB	Albania	M	ROW	0
ARE	United Arab Emirates	H	MENA	0
ARG	Argentina	M	SAM	0
ARM	Armenia	M	ROW	0
AUS	Australia	H	ROW	0
AUT	Austria	H	EU27	1
BDI	Burundi	L	SSA	0
BEL	Belgium	H	EU27	1
BEN	Benin	L	SSA	0
BFA	Burkina Faso	L	SSA	0
BGD	Bangladesh	L	ROAS	0
BGR	Bulgaria	M	EU27	1
BHR	Bahrain	H	MENA	0
BHS	Bahamas, The	H	SAM	0
BLR	Belarus	M	ROW	0
BLZ	Belize	M	SAM	0
BOL	Bolivia	M	SAM	0
BRA	Brazil	M	BRA	0
BRB	Barbados	H	SAM	0
BRN	Brunei Darussalam	H	ROAS	0
BTN	Bhutan	M	ROAS	0
BWA	Botswana	M	SSA	0
CAF	Central African Republic	L	SSA	0
CAN	Canada	H	ROW	1
CHE	Switzerland	H	ROW	1
CHL	Chile	M	SAM	0
CHN	China	M	CHN	0
CIV	Cote d'Ivoire	M	SSA	0
CMR	Cameroon	M	SSA	0
COG	Congo, Rep.	L	SSA	0
COL	Colombia	M	SAM	0
CPV	Cape Verde	M	SSA	0
CRI	Costa Rica	M	SAM	0
CZE	Czech Republic	H	EU27	1
DEU	Germany	H	EU27	1
DJI	Djibouti	M	SSA	0
DNK	Denmark	H	EU27	1
DOM	Dominican Republic	M	SAM	0
DZA	Algeria	M	MENA	0
EGY	Egypt, Arab Rep.	M	MENA	0
ESP	Spain	H	EU27	1
EST	Estonia	H	EU27	1
ETH	Ethiopia	L	SSA	0
FIN	Finland	H	EU27	1
FJI	Fiji	M	ROW	0
FRA	France	H	EU27	1
GAB	Gabon	M	SSA	0
GBR	United Kingdom	H	EU27	1
GEO	Georgia	M	ROW	0
GHA	Ghana	L	SSA	0
GIN	Guinea	L	SSA	0
GMB	Gambia, The	L	SSA	0
GNB	Guinea-Bissau	L	SSA	0
GRC	Greece	H	EU27	1
GTM	Guatemala	M	SAM	0
GUY	Guyana	M	SAM	0
HKG	Hong Kong, China	H	ROAS	0
HND	Honduras	M	SAM	0
HTI	Haiti	L	SAM	0
HUN	Hungary	H	EU27	1
IDN	Indonesia	M	ROAS	0
IND	India	M	IND	0
IRL	Ireland	H	EU27	1
IRN	Iran, Islamic Rep.	M	MENA	0
ISL	Iceland	H	ROW	1
ISR	Israel	H	MENA	0
ITA	Italy	H	EU27	1
JOR	Jordan	M	MENA	0
JPN	Japan	H	JPN	1
KAZ	Kazakhstan	M	ROW	0
KEN	Kenya	L	SSA	0
KGZ	Kyrgyz Republic	L	ROAS	0
KHM	Cambodia	L	ROAS	0
KOR	Korea, Rep.	H	ROAS	0
KWT	Kuwait	H	MENA	0
LAO	Lao PDR	L	ROAS	0
LBN	Lebanon	M	MENA	0
LCA	St. Lucia	M	SAM	0
LKA	Sri Lanka	M	ROAS	0
LSO	Lesotho	M	SSA	0
LTU	Lithuania	M	EU27	1
LUX	Luxembourg	H	EU27	1
LVA	Latvia	M	EU27	1
MAR	Morocco	M	MENA	0
MDA	Moldova	M	ROW	0
MDG	Madagascar	L	SSA	0
MDV	Maldives	M	ROW	0

MEX	Mexico	M	SAM	0
MLI	Mali	L	SSA	0
MLT	Malta	H	EU27	1
MNG	Mongolia	M	ROAS	0
MOZ	Mozambique	L	SSA	0
MRT	Mauritania	L	SSA	0
MUS	Mauritius	M	SSA	0
MWI	Malawi	L	SSA	0
MYS	Malaysia	M	ROAS	0
NER	Niger	L	SSA	0
NGA	Nigeria	M	SSA	0
NIC	Nicaragua	M	SAM	0
NLD	Netherlands	H	EU27	1
NOR	Norway	H	ROW	1
NPL	Nepal	L	ROAS	0
NZL	New Zealand	H	ROW	1
OMN	Oman	H	MENA	0
PAK	Pakistan	M	ROAS	0
PAN	Panama	M	SAM	0
PER	Peru	M	SAM	0
PHL	Philippines	M	ROAS	0
PNG	Papua New Guinea	M	ROW	0
POL	Poland	M	EU27	1
PRT	Portugal	H	EU27	1
PRY	Paraguay	M	SAM	0
QAT	Qatar	H	MENA	0
ROM	Romania	M	EU27	1
RUS	Russian Federation	M	RUS	0
RWA	Rwanda	L	SSA	0
SAU	Saudi Arabia	H	MENA	0
SDN	Sudan	M	MENA	0
SEN	Senegal	L	SSA	0
SGP	Singapore	H	ROAS	0
SLB	Solomon Islands	M	ROW	0
SLE	Sierra Leone	L	SSA	0
SUR	Suriname	M	SAM	0
SVK	Slovak Republic	H	EU27	1
SWE	Sweden	H	EU27	1
SWZ	Swaziland	M	SSA	0
SYR	Syrian Arab Republic	M	MENA	0
TCD	Chad	L	SSA	0
TGO	Togo	L	SSA	0
THA	Thailand	M	ROAS	0
TJK	Tajikistan	L	ROW	0
TTO	Trinidad and Tobago	H	SAM	0
TUN	Tunisia	M	MENA	0
TUR	Turkey	M	MENA	0
TZA	Tanzania	L	SSA	0
UGA	Uganda	L	SSA	0
UKR	Ukraine	M	ROW	0
URY	Uruguay	M	SAM	0
USA	United States	H	USA	1
VCT	St. Vincent and the Grenadines	M	SAM	0
VEN	Venezuela, RB	M	SAM	0
VNM	Vietnam	L	ROAS	0
VUT	Vanuatu	M	ROW	0
YEM	Yemen, Rep.	L	MENA	0
ZAF	South Africa	M	SSA	0
ZMB	Zambia	L	SSA	0

Labels for zones and income groups:

Label	Zone	Developed / Developing
EU27	European Union	All developed
MENA	Middle-East and North Africa	All developing
SSA	Sub-Saharan Africa	All developing
USA	United States of America	Developed
JPN	Japan	Developed
CHN	China	Developing
IND	India	Developing
BRA	Brazil	Developing
RUS	Russian Federation	Developing
ROAS	Rest of Asia	Developing
SAM	Latin America	Developing
ROW	Rest of the World	All developing excepted Switzerland, New Zealand, Iceland, Norway, Australia and Canada
H	High income (WB)	
M	Medium income (WB)	
L	Low income (WB)	

Appendix C: Direct impact of homogeneous shocks in MaGE

Table C1 – Secondary and Tertiary education scenarios, 2035, percentage of active population

	Secondary			Tertiary		
	Reference	low	high	Reference	low	high
United States of America	99	-0.1	+0.1	64	-1.8	+3.1
Japan	97	-0.1	+0.2	64	-1.3	+2.2
European Union	93	-0.7	+1.3	38	-2.7	+5.7
Brazil	71	-1.8	+3.9	17	-2.4	+7.2
Russian Federation	98	-0.1	+0.2	63	-1.6	+2.8
India	66	-2.3	+5.2	12	-1.5	+5.2
China	86	-0.7	+1.4	14	-1.3	+4.0
Latin America	74	-1.9	+4.4	25	-2.6	+7.2
Middle east and North Africa	72	-2.1	+4.4	25	-2.6	+6.9
Sub-Saharan Africa	40	-2.7	+7.9	5	-0.7	+2.5
Rest of Asia	62	-2.5	+5.8	17	-1.4	+4.3
Rest of the World	94	-0.7	+1.2	46	-2.8	+5.4
Total world	71	-1.7	+4.1	20	-1.6	+4.5

Table C2 – Female participation in 2035

	Ref	low
United States of America	54	-0.1
Japan	50	-4.9
European Union	43	+2.6
Brazil	54	+5.5
Russian Federation	51	+3.0
India	37	-5.9
China	57	-1.7
Latin America	46	+3.9
Middle east and North Africa	30	-4.3
Sub-Saharan Africa	63	+1.7
Rest of Asia	50	-0.8
Rest of the World	52	+2.9
Total world	49	-1.0

Table C3 – Impact of female participation on GDP growth

	GDP growth		GDP in 2035		Share of world GDP	
	Ref	low	Ref	low	Ref	low
United States of America	1.69	+0.00	20358	+0.01	20.1	-0.02
Japan	1.63	-0.17	6895	-3.73	6.8	-0.26
European Union	1.41	+0.14	20355	+3.11	20.1	+0.60
Brazil	2.97	+0.17	2300	+3.79	2.3	+0.08
Russian Federation	4.13	+0.10	2482	+2.26	2.5	+0.05
India	5.96	-0.21	5452	-4.43	5.4	-0.24
China	6.07	-0.06	17221	-1.21	17.0	-0.22
Latin America	3.34	+0.14	4676	+3.23	4.6	+0.14
Middle east and North Africa	3.47	-0.18	5442	-3.84	5.4	-0.21
Sub-Saharan Africa	5.09	+0.05	2728	+1.08	2.7	+0.03
Rest of Asia	3.98	-0.10	7158	-2.09	7.1	-0.16
Rest of the World	2.66	+0.16	5991	+3.70	5.9	+0.21
Total world	2.84	+0.01	101056	+0.11	100.0	
Total Developed	1.62	+0.05	52631	+1.13	52.1	+0.53
Total Developing	4.72	-0.05	48425	-0.99	47.9	-0.53

Table C4 – Impact of energy price on GDP growth

	GDP growth			GDP in 2035			Share of world GDP		
	Ref	low	high	Ref	low	high	Ref	low	high
United States of America	1.69	-0.02	+0.03	20358	-0.53	+0.60	20.1	+0.05	-0.01
Japan	1.63	-0.03	+0.04	6895	-0.73	+0.80	6.8	+0.00	+0.01
European Union	1.41	-0.03	+0.03	20355	-0.57	+0.65	20.1	+0.04	-0.00
Brazil	2.97	-0.01	+0.01	2300	-0.23	+0.28	2.3	+0.01	-0.01
Russian Federation	4.13	+0.05	-0.09	2482	+1.06	-2.07	2.5	+0.04	-0.07
India	5.96	-0.18	+0.16	5452	-3.86	+3.61	5.4	-0.17	+0.16
China	6.07	-0.17	+0.15	17221	-3.60	+3.35	17.0	-0.49	+0.46
Latin America	3.34	+0.09	-0.09	4676	+1.92	-1.96	4.6	+0.12	-0.12
Middle east and North Africa	3.47	+0.30	-0.35	5442	+6.91	-7.51	5.4	+0.42	-0.44
Sub-Saharan Africa	5.09	-0.06	+0.02	2728	-1.23	+0.53	2.7	-0.01	-0.00
Rest of Asia	3.98	-0.11	+0.10	7158	-2.45	+2.26	7.1	-0.12	+0.11
Rest of the World	2.66	+0.05	-0.04	5991	+1.02	-0.96	5.9	+0.11	-0.09
Total world	2.84	-0.03	+0.03	101056	-0.76	+0.65	100.0		
Total Developed	1.62	-0.02	+0.02	52631	-0.41	+0.49	52.1	+0.18	-0.08
Total Developing	4.72	-0.05	+0.04	48425	-1.14	+0.83	47.9	-0.18	+0.08

Table C5 – Energy intensity in the reference and in the "high" case

Energy intensity, 2035, barrel per $1000 of GDP

	Ref	high
United States of America	0.92	-0.18
Japan	0.65	-0.12
European Union	0.72	-0.14
Brazil	1.30	-0.25
Russian Federation	2.83	-0.54
India	2.28	-0.44
China	2.21	-0.42
Latin America	1.22	-0.23
Middle east and North Africa	1.43	-0.27
Sub-Saharan Africa	2.51	-0.48
Rest of Asia	1.76	-0.33
Rest of the World	1.03	-0.20
Total world	1.36	-0.26

Note: the low scenario is equal to the reference by assumption

Table C6 – Impact on GDP of a 50% increase in energy efficiency

	GDP growth		GDP in 2035		Share of world GDP	
	Ref	high	Ref	high	Ref	high
United States of America	1.69	+0.02	20358	+0.46	20.1	-0.07
Japan	1.63	+0.01	6895	+0.30	6.8	-0.03
European Union	1.41	+0.02	20355	+0.35	20.1	-0.09
Brazil	2.97	+0.03	2300	+0.70	2.3	-0.00
Russian Federation	4.13	+0.09	2482	+1.91	2.5	+0.03
India	5.96	+0.06	5452	+1.42	5.4	+0.03
China	6.07	+0.06	17221	+1.38	17.0	+0.10
Latin America	3.34	+0.03	4676	+0.67	4.6	-0.01
Middle east and North Africa	3.47	+0.04	5442	+0.84	5.4	+0.00
Sub-Saharan Africa	5.09	+0.07	2728	+1.65	2.7	+0.02
Rest of Asia	3.98	+0.05	7158	+1.07	7.1	+0.02
Rest of the World	2.66	+0.02	5991	+0.54	5.9	-0.01
Total world	2.84	+0.03	101056	+0.79	100.0	
Total Developed	1.62	+0.02	52631	+0.40	52.1	-0.20
Total Developing	4.72	+0.05	48425	+1.21	47.9	+0.20

Note: the low scenario is equal to the reference by assumption

Table C7 – UN scenarios for the world population according (2035)

	Ref	low	high
United States of America	373	-6.3%	+6.3%
Japan	117	-5.8%	+5.8%
European Union	513	-6.2%	+6.2%
Brazil	223	-7.8%	+8.1%
Russian Federation	134	-6.9%	+7.0%
India	1580	-7.5%	+7.7%
China	1382	-6.8%	+6.9%
Latin America	452	-7.7%	+7.8%
Middle east and North Africa	544	-7.5%	+7.5%
Sub-Saharan Africa	1320	-6.4%	+6.4%
Rest of Asia	1238	-7.6%	+7.7%
Rest of the World	193	-6.7%	+6.8%
Total world	8068	-7.0%	+7.1%

Table C8 – Impact of GDP of homogeneous demographic scenarios, 2012-2035

	GDP growth			GDP in 2035			Share of world GDP		
	Ref	low	high	Ref	low	high	Ref	low	high
United States of America	1.69	-0.05	+0.05	20358	-1.16	+1.16	20.1	-0.02	+0.02
Japan	1.63	-0.05	+0.05	6895	-1.12	+1.11	6.8	-0.01	+0.00
European Union	1.41	-0.05	+0.05	20355	-1.11	+1.12	20.1	-0.01	+0.01
Brazil	2.97	-0.06	+0.06	2300	-1.30	+1.34	2.3	-0.01	+0.01
Russian Federation	4.13	-0.03	+0.03	2482	-0.59	+0.63	2.5	+0.01	-0.01
India	5.96	-0.04	+0.05	5452	-0.96	+1.02	5.4	+0.00	-0.00
China	6.07	-0.06	+0.06	17221	-1.28	+1.32	17.0	-0.04	+0.04
Latin America	3.34	-0.03	+0.03	4676	-0.71	+0.77	4.6	+0.02	-0.01
Middle east and North Africa	3.47	-0.02	+0.03	5442	-0.50	+0.56	5.4	+0.03	-0.03
Sub-Saharan Africa	5.09	-0.03	+0.03	2728	-0.68	+0.73	2.7	+0.01	-0.01
Rest of Asia	3.98	-0.03	+0.03	7158	-0.64	+0.68	7.1	+0.03	-0.03
Rest of the World	2.66	-0.06	+0.06	5991	-1.33	+1.34	5.9	-0.02	+0.02
Total world	2.84	-0.05	+0.05	101056	-1.05	+1.07	100.0		
Total Developed	1.62	-0.05	+0.05	52631	-1.16	+1.16	52.1	-0.06	+0.05
Total Developing	4.72	-0.04	+0.04	48425	-0.93	+0.98	47.9	+0.06	-0.05

Table C9 – Impact on GDP of assumptions on capital mobility, 2012-2035

	GDP growth			GDP in 2035			Share of world GDP		
	Ref	low	high	Ref	low	high	Ref	low	high
United States of America	1.69	-0.07	-0.20	20358	-1.58	-4.35	20.1	-0.30	-0.85
Japan	1.63	-0.01	-0.19	6895	-0.14	-4.20	6.8	-0.00	-0.28
European Union	1.41	-0.01	-0.19	20355	-0.28	-4.28	20.1	-0.03	-0.84
Brazil	2.97	-0.16	+0.18	2300	-3.55	+4.06	2.3	-0.08	+0.10
Russian Federation	4.13	+0.24	+0.34	2482	+5.37	+7.83	2.5	+0.13	+0.20
India	5.96	+0.09	+0.30	5452	+2.02	+6.74	5.4	+0.11	+0.37
China	6.07	+0.01	+0.28	17221	+0.32	+6.33	17.0	+0.07	+1.10
Latin America	3.34	-0.05	-0.00	4676	-1.01	-0.00	4.6	-0.04	+0.01
Middle east and North Africa	3.47	+0.03	+0.09	5442	+0.73	+2.00	5.4	+0.04	+0.11
Sub-Saharan Africa	5.09	-0.05	+0.20	2728	-1.01	+4.40	2.7	-0.02	+0.12
Rest of Asia	3.98	+0.02	+0.08	7158	+0.48	+1.84	7.1	+0.04	+0.14
Rest of the World	2.66	+0.05	-0.13	5991	+1.10	-2.97	5.9	+0.07	-0.17
Total world	2.84	-0.00	-0.01	101056	-0.10	-0.12	100.0		
Total Developed	1.62	-0.03	-0.20	52631	-0.59	-4.33	52.1	-0.26	-2.20
Total Developing	4.72	+0.02	+0.20	48425	+0.43	+4.46	47.9	+0.26	+2.20

Appendix D: Additional results

Figure D1 – Share of sectors in total export (volume)by region under the two scenarios

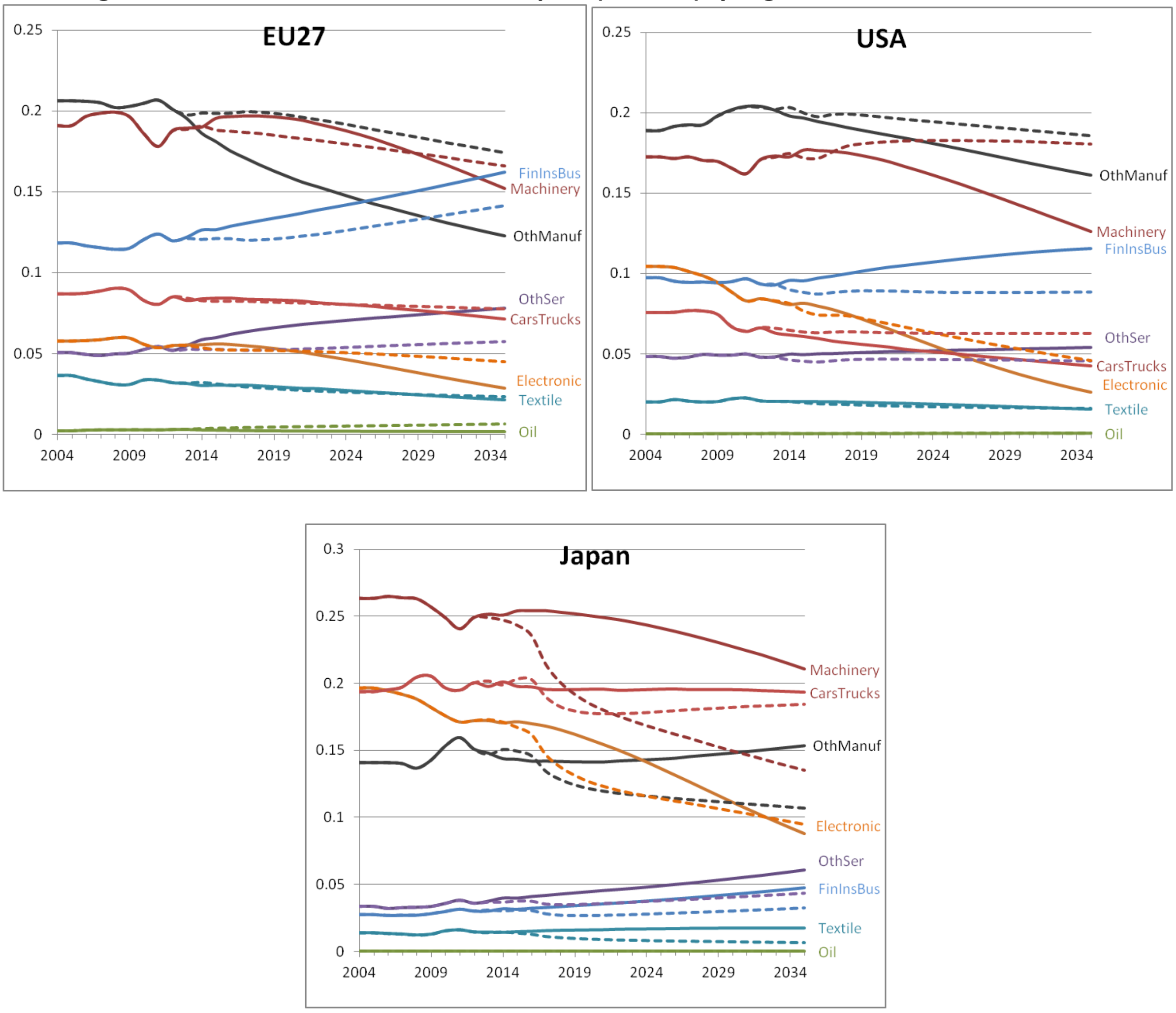

Figure D2 – Regional shares in world production (volume) by sector