Macroeconometrics of the **G**lobal **E**conomy (MaGE)
Shared Socioeconomic Pathways

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Building on an initiative by the Intergovernmental Panel on Climate Change (IPCC), researchers of the climate change field have been conducting since 2010 an interdisciplinary exercise in order to identify the key elements that would impact the potential magnitude and cost of climate change mitigation over the 21st century. The outcome of these working groups has been the elaboration of five potential scenarios – denominated as Shared Socioeconomic Pathways (SSP) – meant to be a common basis for climate policy analyses.

Since the publication of the narratives describing the five SSP scenarios, different teams have contributed by producing quantitative evaluation. Among them, one of particular interest is the projections of population and education by the International Institute for Applied Systems Analysis – IIASA (KC et al. 2010).

Besides, recent work conducted at CEPII have lead to the elaboration of a set of tools to deal with long-term trade and development issues – the MaGE and MIRAGE models - which seemed natural candidates for an evaluation of the SSP scenarios. The present documentation aims at describing how MaGE contributes to the SSP modeling effort.

This scenario design have been made in the framework of a contract with the Institute for Prospective Technological Studies (IPTS) of the Joint Research Center of the European Commission. The research report by Fouré and Fontagné (2016) is available on CEPII website[1]. However, SSP scenarios results described in Fouré and Fontagné (2016) are based on MaGE 2.3, whereas the present release is version 2.4 (two major differences: energy price scenarios are from World Energy Outlook 2015 – was 2012 – and non-annual variables are now smoothed using cubic splines).

Contents

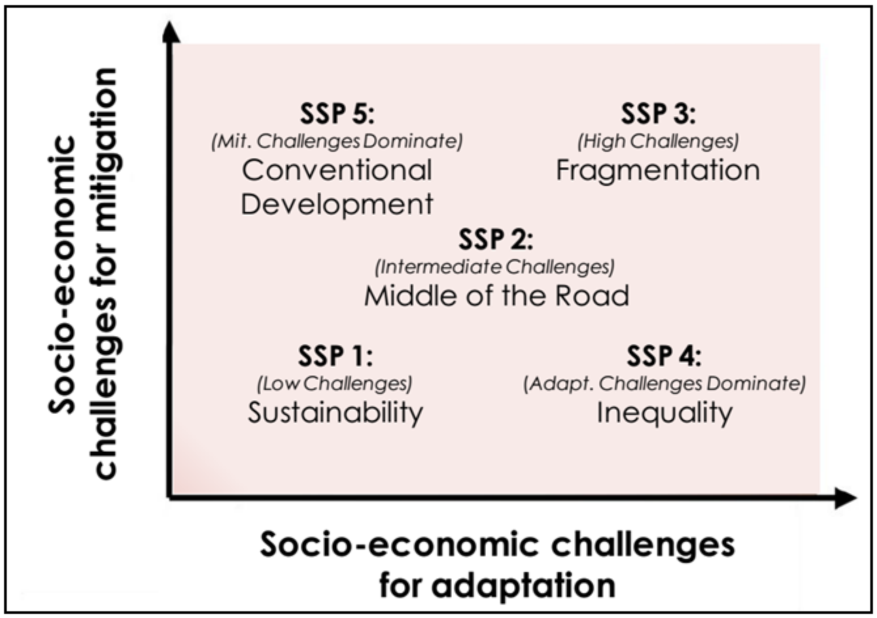
[1] http://www.cepii.fr/CEPII/fr/publications/reports/abstract.asp?NoDoc=8565

1 Background and narratives

Following the initiative by the International Panel on Climate Change (IPCC), launched in 2007, researchers from various fields have gathered to elaborate five scenarios representing the potential contexts in which the world could have to deal with climate change and CO2 mitigation. The outcome of these meetings is summarized in O'Neill et al. (2012), on which we will build our own interpretation of the narratives provided.

The 5 scenarios are articulated around two base directions: the socio-economic challenges for mitigation, and the socio-economic challenges for adaptation. Each of the scenarios includes a different mix of these challenges, as summarized in Figure 1.

Figure 1: Graphical representation of the five SSP scenarios



Source: O'Neill et al. (2012)

The following paragraphs describe in more detail the 5 scenarios. These descriptions are taken from O'Neill et al. (2012).

SSP1 – Sustainability This is a world making relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. Elements contributing to this are: a rapid development of low-income countries, a reduction of inequality (globally and within economies), a rapid technology development, and a high level of awareness regarding environmental degradation. Rapid economic growth in low-income countries reduces the number of people below the poverty line. The world is characterized by an open, globalized economy, with relatively rapid technological change directed toward environmentally friendly processes, including clean energy technologies and yield-enhancing technologies for land. Consumption is oriented towards low material growth and energy intensity, with a relatively low level of consumption of animal products. Investments in high levels of education coincide with low population growth. Concurrently, governance and institutions facilitate achieving development goals and problem solving. The Millennium Development Goals are achieved within the next decade or two, resulting in educated populations with access to safe water, improved sanitation and medical care. Other factors that reduce vulnerability to climate and other global changes include, for example, the successful implementation of stringent policies to control air pollutants and rapid shifts toward universal access to clean and modern energy in the developing world.

SSP2 – Middle of the Road In this world, trends typical of recent decades continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. Development of low-income countries proceeds unevenly, with some countries making relatively good progress while others are left behind. Most economies are politically stable with partially functioning and globally connected markets. A limited number of comparatively weak global institutions exist. Per-capita income levels grow at a medium pace on the global average, with slowly converging income levels between developing and industrialized countries. Intra-regional income distributions improve slightly with increasing national income, but disparities remain high in some regions. Educational investments are not high enough to rapidly slow population growth, particularly in low-income countries. Achievement of the Millennium Development Goals is delayed by several decades, leaving populations without access to safe water, improved sanitation, and medical care. Similarly, there is only intermediate success in addressing air pollution or improving energy access for the poor as well as other factors that reduce vulnerability to climate and other global changes.

SSP3 – Fragmentation The world is separated into regions characterized by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. Regional blocks of countries have re-emerged with little coordination between them. This is a world failing to achieve global development goals, and with little progress in reducing resource intensity, fossil fuel dependency, or addressing local environmental concerns such as air pollution. Countries focus on achieving energy and food security goals within their own region. The world has de-globalized, and international trade, including energy resource and agricultural markets, is severely restricted. Little international cooperation and low investments in technology development and education slow down economic growth in high-, middle-, and low-income regions. Population growth in this scenario is high as a result of the education and economic trends. Growth in urban areas in low-income countries is often in unplanned settlements. Unmitigated emissions are relatively high, driven by high population growth, use of local energy resources and slow technological change in the energy sector. Governance and institutions show weakness and a lack of cooperation and consensus; effective leadership and capacities for problem solving are lacking. Investments in human capital are low and inequality is high. A regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity. Policies are oriented towards security.

SSP4 – Inequality This pathway envisions a highly unequal world both within and across countries. A relatively small, rich global elite is responsible for much of the emissions, while a larger, poorer group contributes little to emissions and is vulnerable to impacts of climate change, in industrialized as well as in developing countries. In this world, global energy corporations use investments in R&D as hedging strategy against potential resource scarcity or climate policy, developing (and applying) low-cost alternative technologies. Mitigation challenges are therefore low due to some combination of low reference emissions and/or high latent capacity to mitigate. Governance and globalization are effective for and controlled by the elite, but are ineffective for most of the population. Challenges to adaptation are high due to relatively low income and low human capital among the poorer population, and ineffective institutions.

SSP5 - Conventional Development This world stresses conventional development oriented toward economic growth as the solution to social and economic problems through the pursuit of enlightened self interest. The preference for rapid conventional development leads to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation. Lower socio-environmental challenges to adaptation result from attainment of human development goals, robust economic growth, highly engineered infrastructure with redundancy to minimize disruptions from extreme events, and highly managed ecosystems.

2 Scope of MaGE

Of course, the complexity of these narratives cannot be perfectly represented in a macroeconomic model. Our set of tools can however build much differentiated scenarios upon these narratives. The first step in our interpreting the SSP narrative is identifying the scope of the mentioned variables, and the way it can enter in our model.

Building on the appendices from O'Neill et al. (2012), we separate the different variables between (i) those on which we can build exogenous scenarios in MaGE, (ii) those that are in fact outcomes of the model and (iii) the variables that are out of the scope of MaGE. The two first categories are presented in Table 1.

Table 1: From SSP narratives to MaGE scenarios

Topic	MaGE scenario	Outcome
Demographics	Fertility Mortality Migration Education	Population growth
Economy		Growth Across-regions inequality
Policies and institutions	Institutions	
Technology	Techno. development Energy intensity	Techno. transfers
Environment & Natural resources	Fossil constraints	

Along with these scenarios that we implement, some elements of the narratives cannot be included in our model. These are[2] urbanization, within-country inequality, international cooperation, environmental policy, energy technology change (towards renewable energy), land use, sector structure*, international trade*, agricultural productivity* and consumption structure*.

3 Quatifying assumptions

We develop several strategies, depending on the issue, in order to best represent our understanding of the SSP narratives and use all the capabilities of our model.

Demographics and education Our approach regarding demographics is hybrid, since all the dimensions cannot be directly encompassed using MaGE. Furthermore, other institutions have published detailed demographic scenarios, in particular the IIASA. These IIASA scenarios already include variation in mortality, fertility and migration, whereas MaGE can only deal with some migrations flows. We therefore chose to rely on IIASA projections for population.

Regarding education, two options were available: use IIASA projections or develop scenarios directly in MaGE. On the one hand, MaGE projections would have been more flexible, but on the other hand, IIASA include the impact of education on fertility. We then chose IIASA projections to keep a maximum consistency.

[2] A * denotes variables that can be handled with MIRAGE, see Fouré and Fontagné (2016)

Finally, total population has to be converted into active population. On this matter, MaGE provides the best framework by including variation in female participation to the labor force due to increases in education level.

Institutions The economic literature has studied institutions and their impact for long. For instance, Aron (2000) documents that institutions interfere in the accumulation of all production factors, and in particular by productivity improvements – both regarding innovation and catch-up to the technological frontier – and in capital accumulation. Quite often, as the author suggests, institutions are limited to productivity improvements, neglecting all other aspects. We will try to depart from this common assumption.

Although not explicitly specified, institutions differentials appear in MaGE in two ways. First of all, they are embodied in the fixed effects that are estimated in our econometric relationships (TFP, savings rate, female participation to the labor force and savings-investment relation). Second, institutions also appear in the Feldstein-Horioka relation, because we conduct two separate estimations on two different country groups (OECD countries vs. non-OECD countries). As a consequence, the estimated coefficients embody institutional differences between OECD members and other countries. Scenarios of institutional convergence can then be derived from these two ways.

However, quantifying the magnitude of the impact of institutions on our variables of interest is subject to judgment: to our knowledge the literature has not investigated the quantitative impact of institutions on other variables than TFP. Therefore, productivity improvements due to improvements in institutions efficiency will be derived from estimates from the literature – as described below – while we will have a simple normative definition of efficient institutions regarding other variables (savings rate, female participation and savings-investment relationship).

The link between productivity improvements and institutional environment has been quantified by Chanda and Dalgaard (2008). The impact of institutions – measured by the Governement Anti-Diversionary Policy (GADP) index – on the level of TFP is tackled using several estimation strategies (Ordinary Least Squares – OLS – and 2-Stage Least Squares – 2SLS – with instrumental variables). Endogeneity issues were finally not convincingly addressed and the results provide only orders of magnitude of the actual impact of institutions on TFP. Appendix A details how we converted these estimated coefficients into TFP level scenarios.

Regarding other relations that are impacted by institutional convergence, we will arbitrarily consider then institutions in OECD countries are more efficient than in non-OECD countries, and as a consequence, convergence towards more efficient institutions will only impact non-OECD countries, making them converge by 2100 to the average OECD institutions (both the fixed effects and other estimated coefficients converge).

Technology First of all, SSP narratives include scenarios on the technological frontier. This TFP frontier is present in MaGE, and is represented by the TFP level of Ireland and Denmark (these two countries share the leadership over our estimation period). Other countries converge towards the technological frontier conditionally on their education level. In projection, the baseline assumption in MaGE is that the TFP frontier continues to grow at its 1995-2008 average pace (around 1.5% annual growth). The amount of additional TFP for leader countries in SSP scenarios is however not easily determined, so we will consider scenarios where the TFP leader level of TFP growth is +/-50% of the baseline growth rate. The second issue about technology scenarios is energy productivity. We will consider a 50% increase in energy productivity by 2100.

Fossil constraints Fossil constraints in MaGE are materialized by oil price, whose trajectory binds the amount of energy use given the current level of energy-specific productivity. In MIRAGE, we can further differentiate the type of energy, and consider different prices for coal, oil and gas. The central scenario in both models corresponds to the medium projections of the International Energy Agency (IEA), taken from the World Energy Outlook (IEA 2012). Accordingly, high and low fossil resource prices scenarios will be derived from their counterparts in IEA projections.

Summary Table 2 summarizes the assumptions made to represent at best the five SSP narrative scenarios.

TABLE 2: MAGE SCENARIO ASSUMPTION

	SSP1 Sustainability	**SSP2 Middle of the Road**	**SSP3 Fragmentation**	**SSP4 Inequality**	**SSP5 Conventional**
Population			Provided by IIASA		
Education			Provided by IIASA		
Institutions	–	–	-30% TFP	OECD: +50% TFP; Non-OECD: -30%	+50% TFP ; Non-OECD: convergence of FE and coef.
TFP frontier	+50% frontier growth	–	-50% frontier growth	+50% frontier growth	+50% frontier growth
Energy productivity	–	–	–	–	+50% energy productivity
Fossil resource prices	–	–	–	High energy price	Low energy price

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Appendix A: Institutions and TFP level

Chanda and Dalgaard (2008) estimate the following relationship:

$$\log TFP_i = \beta_0 + \beta_1 INSTITUTIONS_i + \beta_2 OPENNESS_i + \beta_3 GEOGRAPHY_i + \varepsilon_i \tag{A.1}$$

where $INSTITUTIONS_i$ is measured – in their central case – by the GADP ("Government Anti-Diversionnary Policy") index. The estimated relationship (A.1) allows us to emasure the impact of a variation in institutions – for instance by an amount of σ between two periods 0 and 1, everything else being kept constant:

$$\log TFP_i^1 = \log TFP_i^0 + \beta_1 \times \sigma \tag{A.2}$$

And in levels:

$$TFP_i^1 = TFP_i^0 \times e^{\beta_1 \sigma} \tag{A.3}$$

Chanda and Dalgaard (2008) find the following results, when they include all the geographical controls:

$$0.88\ (OLS) \leq \beta_1\ 1.87(2SLS) \tag{A.4}$$

We assume that the variation of institutions we consider corresponds to a standard error of the GADP index distrubtion ($\sigma = \pm 0.21$). Using relation (A.3) yields:

$$\begin{cases} +20\% \leq \Delta TFP \leq +48\% & \text{if} \quad \sigma = 0.21 \\ -32\% \leq \Delta TFP \leq -17\% & \text{if} \quad \sigma = -0.21 \end{cases} \tag{A.5}$$

Then, our scenarios will correspond to +50% TFP for more efficient institutions, and -30% TFP for inefficient institutions.