



Economic analysis of a low carbon path to 2050: A case for China, India and Japan[☆]

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ABSTRACT

This article studies the economic implications that different global GHG emission mitigation policies may have in the major Asian economies, namely, China, India, and Japan. The analysis covers the period 2010–2050 and is performed by means of a recursive dynamic computable general equilibrium model (GEM-E3). Four scenarios are investigated: the three standard AME scenarios, and a fourth scenario with a GHG emission reduction path compatible with the 2 °C target, reducing global GHG emissions in 2050 by 50%, relative to 2005. The scenarios are compared with the already adopted and announced policies of the respective countries, in the context of the Copenhagen pledges for 2020 and their long-term objectives in 2050. We further discuss the role of energy efficiency measures and zero-carbon power technologies in order to reach the long-term 2 °C target. We find that postponing significant emission reductions may not accrue an economic benefit over time whereas it may increase some risks by possibly overstressing the reliance on zero-carbon technologies.

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1. Introduction

The UNFCCC 2009 Copenhagen Accord (UNFCCC, 2009) on climate policy states that deep cuts in global greenhouse gas (GHG) emissions are needed “so as to hold the increase in global temperature below 2 degrees Celsius”. Meeting this 2 °C target will require reducing world GHG emissions by 50% globally in 2050,¹ with major transformations in global energy and economic systems. Countries such as the EU, US and Japan have announced or are debating domestic reductions in the range of 80–95% compared to 1990. The EU has recently put forward a roadmap detailing the transition scenario that the EU could follow from now to 2050 in order to reduce its GHG emissions by 80% (European Commission, 2011a,b).

Achieving a 50% reduction of global GHG emissions by 2050 will require substantial reductions in the major Asian economies as well. This article explores the economic implications of such global transition

scenarios for the three largest Asian GHG-emitters' countries² (China, India and Japan), which are among the top world six largest emitters,³ and which are projected to account for 35% of world GHG emissions in 2050.

The assessment has been made in the context of a broader modeling exercise within the Asian Modelling Forum (AME) of the Energy Modelling Forum (EMF) (see Calvin et al., 2011). This article considers four global climate policy scenarios until 2050, with two scenarios compatible with the 2 °C target. All four scenarios assume a single carbon price for the world. The first three scenarios are the ‘standard’ scenarios of the AME: a low, middle and a high carbon price path until 2050, called respectively, the CO₂ Price \$10 scenario, CO₂ Price \$30 scenario, and CO₂ Price \$50 scenario (Calvin et al., 2011). The CO₂ Price \$50 scenario can reach the 2 °C target. The fourth scenario, called hereafter E1*, is also compatible with the 2 °C target, and is derived from the E1 scenario in the ENSEMBLES project.⁴ The E1* scenario assumes a 50% reduction of global GHG emissions by 2050 (vs. 2005).

[☆] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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¹ There is a debate whether the 50% GHG reduction should be compared to 1990 or to 2005. A global GHG reduction of 50% in 2050 compared to 2005 is considered to give a 50% chance to stay below the 2 °C target, whereas a global GHG reduction of 50% in 2050 compared to 1990 is a ‘likely’ 2 °C scenario with a probability of 66% to stay below the 2 °C threshold (UNEP, 2010).

² Studies assessing the economic adjustment in these countries include for China e.g. Chen (2005) and Hübler (2011).

³ In 2007 the share of world CO₂ emissions for China was 22.8%, 5% for India and 4.3% for Japan, according to the CDIAC (<http://cdiac.ornl.gov/>). The other three largest CO₂ emitters in the world are US (with a share of 19.9%), the EU (14%) and Russia (5.5%). The statistics account for the CO₂ emissions from the burning of fossil fuels and cement manufacture and do not include emissions from land use such as deforestation.

⁴ <http://www.ensembles-eu.org/>.

This article has two main objectives. Firstly, we compare the emission pathways of the four scenarios with the Copenhagen pledges in 2020 and to which extent the pathway is compatible with a 50% chance of staying below 2 °C warming (IPCC, 2007). Further, we focus on the macroeconomic consequences of the scenarios in 2020 and 2050, assessing the effects on GDP, carbon value and economic sectors, and on the role played by energy efficiency and zero-carbon technologies.

The analysis uses the computable general equilibrium (CGE) GEM-E3 global model (Capros et al., in press), which for the purpose of this study includes an energy efficiency module, a bottom-up module for the power generation sector, and the electrification of the transport sector.⁵ These extensions allow us to better represent the structural shift of the energy sector towards 2050 both in the reference as in the low carbon scenarios.

Improvements in energy efficiency may play a key role in attaining ambitious GHG emission reduction targets, representing potentially up to half of the overall reduction in emissions (e.g. Russ et al., 2009). Yet in a CGE model such energy efficiency improvements usually are captured by price-induced factor substitutions and by energy efficiency improvements that are incorporated in the reference, which do not change when a policy is implemented. This version of the GEM-E3 model allows for additional energy efficiency improvements in a policy context with more ambitious climate targets. In particular agents are able to use part of their budget to obtain higher energy productivity, however the decision on the amount of money spent for energy productivity is specified exogenously. As these additional energy efficiency improvements incur a cost, they are not windfall gains.

The second extension consists of the integration of a bottom up representation of the power generation sector into the CGE model. The power generation sector has a key role in the overall adjustment towards a less carbon intensive economy. Identifying in a discrete way the different power generation technologies is crucial for a consistent evaluation of the overall energy cost. The deployment of power technologies in GEM-E3 has been calibrated to the results of the PRIMES model and the POLES global energy model for similar scenarios (Dowling and Russ, 2012).

Finally, the electrification of the transport sector is expected to play a key role for long-term GHG emissions abatement. Given the current high dependence of transport on oil and the required large reductions in fossil fuel consumption, a major process of electrification of the transport system is necessary. This is modeled in GEM-E3 with an increasing demand of electricity from the transport sector, leading to higher electricity prices, and therefore having economy-wide effects.

The article has four main sections, in addition to this introduction. In the next section the main features of the GEM-E3 global model are presented. Sections 3 and 4 detail the assumptions for the reference and the climate scenarios, respectively. Section 5 deals with the main results and their interpretation. Section 6 concludes.

2. The GEM-E3 model

The computable general equilibrium GEM-E3 model covers the interactions between the economy, the energy system and the environment (Capros et al., 2010, in press). The world version⁶ of GEM-E3 is based on the GTAP 7 database (base year 2004) with the major world economies and main geographical regions⁷ linked through endogenous bilateral trade. The version used for this study incorporates labor market imperfections. The labor market accounts for involuntary unemployment with

⁵ A different version, not including these modules, was used for the policy analyses done in European Commission (2009, 2010, 2011b).

⁶ See www.gem-e3.net. There are two versions of GEM-E3, Europe and World. They differ in their geographical and sectoral coverage, but the model specification is similar. The European version covers the EU countries (all EU except for Luxemburg, Malta and Cyprus) and the rest of the world (in a reduced form), and is based on EUROSTAT data.

⁷ The regions/countries represented in this version are China, India, Japan, EU27, USA, Canada, Russian Federation, Brazil, Rest of Annex I, and Rest of the World.

efficiency wages based on Shapiro and Stiglitz (1984), and introduced in a CGE environment following Annabi (2003).

The model is recursive-dynamic, driven by the accumulation of capital and equipment with the amount of capital fixed within each period. Investment decisions of the firms in the current period affect the stock of capital and, hence, the production possibilities in the next period. Technological progress is exogenous and explicitly represented in the production functions.

The economic agents optimize their objective functions (utility for households and cost for firms) and determine separately the supply or demand of capital, energy, environment, labor and other goods.

The production of the firms is modeled with a nested constant elasticity of substitution (CES) neo-classical production function, using capital, labor, energy and intermediate goods. Although, the model allows for different market clearing mechanisms and alternative market structures, this study assumes perfect competition. Labor is immobile across national borders.

The consumers decide endogenously on their demand of goods and services following a two stage budgetary process. In the first stage, the household income is allocated between consumption of goods and services (both durables and non-durables), leisure and savings. In the second stage, households allocate their consumption expenditure to the different consumption purposes. The model identifies both durable and non durable goods. Households obtain utility from consuming a non-durable good or getting the service from using a durable good. The consumption of a durable good is directly linked to the consumption of a non-durable good, e.g. fuel for the use of transport equipment.

The demand of goods by the consumers, firms (for intermediate consumption and investment) and the public sector constitutes the total domestic demand. This total demand is allocated between domestic goods and imported goods, using the Armington specification (Armington, 1969). Government behavior is exogenous.

The model includes the energy-related and non-energy related emissions of carbon dioxide (CO₂), other GHG such as methane (CH₄), nitrous oxide (N₂O) sulfur hexafluoride (SF₆), hydrofluorocarbon (HFC), and perfluorocarbon (PFC). There are four mechanisms of emission reduction explicitly specified in the model: (i) substitution between fuels and between energetic and non-energetic inputs, (ii) emission reduction due to a decline in production and consumption, (iii) purchasing abatement equipment according to marginal abatement curves, and (iv) energy efficiency measures.

The GEM-E3 World model version used in this study includes a scenario for the electrification of transport as well as modules for Energy Efficiency and Bottom-up Power Technologies in order to get a more realistic representation of the energy system up to 2050.

2.1. Bottom-up power technologies

The simplified modeling approach of the energy system in a standard CGE model has been improved by linking a bottom-up module for power technologies with the top-down model core. The version of the GEM-E3 model used in the current study adopts the hard-link^{8,9} approach. The aggregated energy sector data in the Input Output (IO) table is disaggregated with engineering bottom-up data, and it is used to calibrate¹⁰ the GEM-E3 models' CES production functions. The required bottom-up engineering information are generation costs, share of transmission and distribution costs to total cost of electricity production

⁸ The modeling approach is based on Boehringer (1998), McFarland et al. (2004), and Sue Wing (2006).

⁹ Boehringer and Rutherford (2008) distinguish between two approaches to link bottom-up with top-down models: The hard-link approach integrates both bottom-up and top-down features in a single modeling framework, whereas with the soft-link or decomposition approach bottom-up and top-down models are run independently of each other and are fed into each other.

¹⁰ The cost estimates on capital, labor, and fuel inputs are used directly as the CES share parameters.

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