# MODELLING GLOBAL MACROECONOMIC IMPACTS OF A CARBON CONSTRAINED ENERGY SYSTEM USING ETSAP-TIAM MSA

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## Overview

This abstract presents work on global energy systems model scenario development to understand the macroeconomic impacts to the regional economies as a result of climate change mitigating, energy system development pathways. The Global ETSAP-TIAM partial equilibrium energy systems model is used in conjunction with the new multi-region Macro stand-alone (MSA) general equilibrium model.

## Methods

TIMES (The Integrated MARKAL-EFOM System) is a techno-economic model generator for local, national or multi-regional energy systems, which provide a technology-rich basis for estimating energy system dynamics over a long-term, multi period time horizon. TIMES computes a time varying inter-temporal partial equilibrium in inter-regional energy markets. The objective function maximises total surplus. This is equivalent to minimising the discounted total energy system cost while respecting environmental, technical and scenario constraints.

TIAM; the TIMES Integrated Assessment Model, couples a climate module with a global TIMES model to assess climate change energy system scenarios. It is developed within the IEA-ETSAP community.

MACRO Stand Alone is an inter-temporal general equilibrium model which maximises utility for a representative regional producer agent. It enables the assessment of general macro-economic implications of changes to the energy system, such as climate constrained scenarios. The model formulation consists of a Cobb-Douglas production function with substitution between an aggregated good of capital and labour with energy.

ETSAP-TIAM is typically solved using exogenous macroeconomic conditions with elastic demands to endogenously approximate consumer behaviour and demand response. However, *ETSAP-TIAM-MSA* solves giving pareto optimal solutions, maximising welfare, and gives least-cost energy system technology choice development pathways for given environmental, economic or technical constraints. This approach gives better estimation of inter-temporal regional generic consumer welfare response to energy system cost, energy demand response, and thus energy system development. This provides an estimate of the impact to GDP of energy system costs increases.

## Results

The energy system's sensitivity to key macroeconomic parameters is assessed and resultant energy systems presented. Key sensitive parameters are the Negishi Weights which initially constrain income distribution in proportion to cumulative discounted regional GDP, and iteratively evolve in response to interregional trade. Energy trade value has significant impacts on welfare when carbon constrained scenarios are considered.

The trade surplus of oil exporting countries is undermined in carbon constrained scenarios, and resultantly they observe a significant loss in GDP beyond 2040. Carbon constraints from large consumers of coal such as China become binding beyond 2040 where the cost to the Chinese economy is in the range of 2-4% GDP in comparison to the reference case. Further capital formation constraints on the welfare optimisation limit developing countries, including Other Developing Asian (ODA) countries, ability to invest in mitigation technologies and thus their overall welfare (GDP) becomes vulnerable in carbon constrained scenarios. Significant demand destruction occurs with an elastic response to reducing overall primary coal requirements. Lastly, regions Canada and Australia, that have the resource potential and capital to invest in carbon mitigation and sequestration, such as large scale reforestation or emission storage in depleted oil and gas fields, see positive effects on welfare and GDP growth.

## Conclusions

The integrated analysis of both changes to the energy system and the resultant macro economy provides feedback to energy service demands. This feedback provides estimates and insight into potential loss in consumption, GDP and by proxy other macro-economic impacts as a result of carbon constraints to the global energy system.