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Introducing detailed land-based mitigation measures into a computable general equilibrium model

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ABSTRACT

We propose a new climate change mitigation assessment method focusing on agriculture, forestry, and land-use change sectors by coupling the computable general equilibrium (CGE) model with a bottom-up type technology model. The CGE model covers the entire economic market, but includes a rough description of mitigation measures, whereas the bottom-up type technology model takes into account abatement cost and mitigation effects of individual mitigation measures, but only focuses on a few sectors. The coupled framework enables us to connect relevant conditions and to complement the shortcomings of each model. As a test, we applied our method to Indonesia, which has set a national greenhouse gas emissions reduction target for 2020. A large proportion of Indonesia's greenhouse gas emissions are from the land-use sector. We assessed the differences in modeling behaviors between the CGE models with and without coupling the bottom-up type model. The two primary findings were: 1) consumption loss estimated by the coupled CGE (1.2%) was larger than the loss estimated by the uncoupled model (0.5%), because the emission reduction estimated by the bottom-up model was less than the standalone CGE's estimate; and 2) consumption loss caused by achieving the reduction target by 2020 in Indonesia strongly depends on the assumption of mitigation costs and available land area for the emission reduction measures.

1. Introduction

The International Panel on Climate Change (IPCC) recently reported, with medium evidence and high agreement, that the greenhouse gas (GHG) emissions from agriculture, forestry, and other land-use (AFOLU) sectors could change substantially in terms of transformation pathways, with significant mitigation potential from agriculture, forestry, and bioenergy mitigation measures (IPCC, 2014). Similarly, Weyant et al. (2006) conducted a comprehensive analysis on climate change mitigation, and reported that non-energy sectors and non-CO_2 GHGs may have great mitigation potential and can play an important role in future climate change. On a national scale, several countries have made pledges to reduce their emissions in the near future and have submitted their own emission reduction targets under the Copenhagen Accord (UNFCCC, 2009). In addition, developing countries have been establishing Nationally Appropriate Mitigation Actions towards a multi-sectoral GHG mitigation framework. For some countries, the AFOLU sectors account for substantial emission mitigation potential (Hasegawa and Matsuoka, 2015; Jilani et al., in press; Nguyen et al., 2014). Therefore, assessing the abatement costs and economic impacts of mitigation measures is essential for national decision-making.

There are currently two approaches for assessing climate change mitigation potential. First, integrated models are effective tools for comprehensively analyzing mitigation scenarios by incorporating agricultural, forestry, and land-based emission reduction. For example, several studies have combined the Integrated Model to Assess the Global Environment (IMAGE) with an abatement cost model, and examined how abatement costs and environmental impacts differ between a long-term multi-gas mitigation strategy and a CO_2-only strategy for climate stabilization targets (Lucas et al., 2007; Strengers et al., 2007; van Vuuren et al., 2006). In addition, the Global Change Assessment Model fully integrates the energy, agriculture, and land-use systems, and is therefore a state-

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of-art approach for assessing climate change mitigation in all sectors (Wise et al., 2009). Second, a computable general equilibrium (CGE) model has been proposed as an approach for dealing with land-use within an entire economic system (Fujimori et al., 2014a; Golub et al., 2013; Golub and Hertel, 2012; Gurgel et al., 2007; Ronneberger et al., 2008; Sohngen et al., 2009). The CGE model can account for inter-temporal change in carbon stocks accumulated over a long time, which is a challenge when assessing land-use (Sohngen et al., 2009). However, both above approaches; integrated models and CGE models still rely on simplified descriptions of mitigation measures for agricultural and land-use sectors, leaving room for improvement in terms of the descriptions of the mitigation measures.

Here, we propose a new method for assessing climate change mitigation scenarios by coupling a CGE model and a bottom-up type model, and incorporating detailed mitigation measures in the agriculture, forestry, and land-use sectors. We tested the model applying it to Indonesia. Specifically, we examined the differences in modeling behavior between the coupled and uncoupled CGE model under a carbon-constrained scenario. To clarify the influences of assumptions of the abatement costs and applicable area used for implementing land-use mitigation measures, which are largely uncertain, to macroeconomic impacts under the carbon-constrained scenario, we also performed a sensitivity analysis of modeling behavior. Indonesia serves as a good example for examining the model's coupling activity, as it accounts for some of the highest levels of GHG emissions globally and a large portion of the GHG emissions is from land-use changes (Ministry of Environment (MoE), 2010). Recently, under the Copenhagen Accord, the Indonesian government pledged to reduce total GHG emissions by 26% to BaU levels unilaterally, and to 41% with sufficient international support (UNFCCC, 2009).

2. Methods

2.1. Modeling framework

Fig. 1 shows the coupling scheme of the AIM/CGE (Fujimori et al., 2012) and a bottom-up type model, named the AFOLU model (Hasegawa and Matsuoka, 2015). The scheme enables us to complement the shortcomings of each model and to connect the relevant conditions to produce an assessment of macroeconomic impacts under various emission scenarios. The CGE model covers the entire economic market and provides estimates of macroeconomic impacts caused by climate change mitigation, but relies on a rough description of mitigation measures by aggregating them. In contrast, the AFOLU model takes into account the abatement cost and mitigation effects of individual mitigation measures, and thereby estimates the overall cost and effects, but can only focus on individual sectors. Relevant conditions and data were translated several times between the models until convergence, as described below in detail. Population, GDP, emission constraint, consumer preference, and crop yields were input into the CGE model. Outputs of the CGE model included GHG emissions, carbon price, and consumption loss. Parameters entered into the AFOLU model included carbon price, agricultural production, harvested crop area, and land area, whereas outputs included abatement cost, reduced emissions, and area used for mitigation measures.

2.2. Coupling procedure

Data for the entire studied period were transferred between the models. The first loop was run for a case without emission constraints (BaU case), while subsequent loops analyzed cases with emission constraints [Counter Measure (CM) case].

The coupling procedure consisted of six steps:

1. The CGE model estimated agricultural production, harvested area of crops, and land-use area for the BaU case.
2. Using the output data, the AFOLU model estimated baseline emissions for the BaU case.
3. Using the baseline emissions estimated by the AFOLU model, the CGE calibrated emission coefficients and developed scenarios of agricultural production, crop harvested area, land-use area, prices of carbon, capital, energy and commodities, and wage. Hereafter, this loop is referred to as "CGE-only" to compare the results between the coupled and uncoupled models.

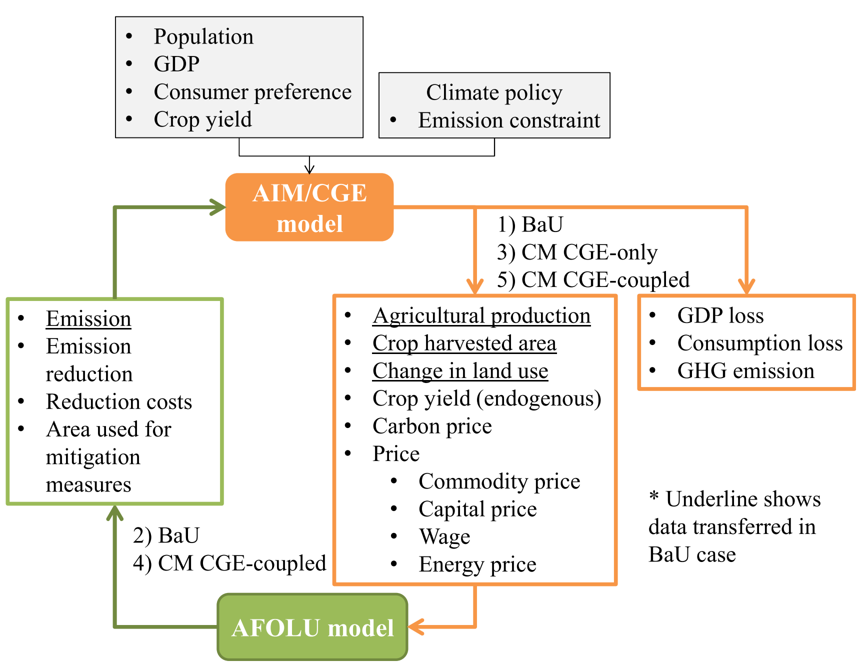

Fig. 1. Coupling scheme of the AIM/CGE and AFOLU models.

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