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Impact of fragmented emission reduction regimes on the energy market and on CO_2 emissions related to land use: A case study with China and the European Union as first movers

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ABSTRACT

In recent years, an approach based on voluntary pledges by individual regions has attracted interest of policy-makers and consequently also climate policy research. In this paper, we analyze scenarios in which the EU and China act as early-movers in international climate policy. Such a situation risks leakage between regions with ambitious emission reduction targets and those with less ambitious targets via fossil-fuel markets, displacement of heavy industry and land-use consequences. We examine some of these factors using the IMAGE model. While IMAGE does not include all mechanisms, we find the leakage rate to be relatively small, about 5% of the emission reductions in the EU and China. The far majority occurs via the energy market channel and the remainder through land-use change. Reduced oil prices due to less depletion forms the key reason for this leakage impact.

1. Introduction

Many studies have argued that an economically optimal climate policy should be based on an international regime in which a wide range of different countries participate [1–3]. Current climate negotiations, however, seem not to be leading in that direction. Instead, as part of the Copenhagen Accord and the Cancun Agreement, an alternative system based on voluntary pledges has emerged, at least temporarily. The pledges indicate that countries have very different ambitions with respect to mitigation action [4]; in fact, a large number of countries do not participate in emission reduction [5]. Although the pledge-based approach has advantages in terms of ease of implementation, a disadvantage is that policies of individual countries can become much less effective[1], one reason being that the total volume of emissions targeted by the policies is considerably lower than it would be if there were universal commitment. Moreover, differences between countries in the efforts made to achieve emission reduction may trigger various interactions between countries, for instance via the energy markets, including the relocation of economic activities to non-participating countries and the enhanced energy demand in non-participating countries in response to lower fossil fuel prices [4–8].

In the literature, these interactions are often referred to as leakage, as they may weaken the effectiveness of the climate policies of individual countries. Examples of leakage include the relocation of economic activities to non-participating countries and the enhanced energy demand in non-participating countries in response to lower fossil fuel prices. Climate policies can, however, also result in ‘negative leakage’, i.e. emission reductions in non-participating countries such as induced technology learning [9].

In the AMPERE project, various consequences of fragmented international climate policies are studied based on a scenario-

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Table 1
Scenarios discussed in this paper.

Brief name	Description and main characteristics
Base	Scenario assumes that no climate policies are implemented and is based on the assumptions of the OECD Environmental Outlook [12] in which population[a] and GDP[b] are both harmonized.
RefPol	Fragmented regime: a weak policy scenario with regional emissions reduction targets for 2020, based on the Copenhagen pledges, followed by a constant regional greenhouse gas intensity improvement in line with the 2020 pledges (Appendix B), this scenario is used as a reference scenario.
450	All regions immediately adopt a 450 ppm target and technology targets.
RefP-CEback	Fragmented regime with EU27 and China as first mover. After 2030, weak climate policy is discontinued.
450P-CE	Fragmented regime in which the rest of the world joins EU27 and China in 2030 by adopting the carbon tax of the 450 scenario.

[a] Population is harmonized by using the medium population scenario of the UN 2010 Medium Term Projection [13].
[b] The GDP projections were constructed following a method developed in the RoSE project [14].

based model comparison exercise [10]. The scenarios compare coordinated policy regimes to regimes in which the EU and/or China are the first to move ahead toward more ambitious policies. Among the different world regions, it is the EU that has most clearly expressed its ambition by aiming for an emission reduction by 80% by 2050 (to achieve a 2 °C reduction target), and to consider action even if international agreement is not reached. China's long-term policies are less clear, but the country has committed to supporting international climate policy. Together, the EU and China currently account for about a third of global CO_2 emissions. In this context, it is interesting to consider what the impacts would be of a scenario in which either the EU or China—or both—would implement ambitious climate policies, whereas other countries would implement modest policies.

In this paper we analyze how a situation in which international climate policies are fragmented and the EU and China are first movers, influences greenhouse gas emissions outside the EU and China in the energy system and in relation to land use. To do so, we use the IMAGE integrated assessment model. The analysis focuses on the following questions:

- How do the policy regimes impact global greenhouse gas emissions?
- How do these policies impact the greenhouse gas emissions change in the energy and land use system — both directly and indirectly?

Below, we first describe the methodology and scenario experiments (Section 2). In Section 3 we report the results. Finally, in Section 4 we summarize the conclusions.

2. Methodology

2.1. The IMAGE integrated assessment framework

The IMAGE integrated assessment model examines the possible development of global environmental problems based on different assumptions about socio-economic development and policy [11]. The model consists of several coupled models that describe the energy and land-use system and also represent components of the Earth's natural system, such as climate and natural vegetation. Most of the subcomponents of IMAGE are simulation models, i.e. a set of rules determines the future developments of, for instance, the energy system and land use.

In the energy system, different technologies compete for a share in investment flows on the basis of their relative costs. The focus of the model is on describing long-term dynamics. Long-term decisions in the energy system are assumed to be governed by the relative costs of various technologies. These long-term costs are assumed to be determined by two processes: depletion and technology dynamics, which in turn are driven by production (cumulative or otherwise). The model also describes international trade of fossil/bio-fuels, by taking account of the relative costs (including transport costs) in different supply regions.

An important feature of the IMAGE model is that it is also able to describe changes in land use. Key inputs in the land-use model are the demand for production of food, feed, bio-energy, and animal products. Assumptions on technology and management and on the impact of local climate and soil conditions on yields are used to determine the land requirement and allocate it to a $0.5° \times 0.5°$ grid cell. The need to meet an additional demand for products from agriculture leads to additional CO_2 emissions from land-use change.

A key component of the mitigation strategies in the IMAGE model is bio-energy. This energy is used in the energy system in the form of solid bio-fuels in the industrial, power, and hydrogen sectors, and in the form of liquid bio-fuel in other end-use sectors (particularly transport) and the production of feedstock. In the power sector, in the industrial sector, and also in hydrogen production, bio-energy use can be combined with CCS, providing the option of so-called negative emissions. In IMAGE, bio-energy is assumed to be produced from crop residues and dedicated crops. The potential for the latter is based on the land model used in IMAGE: bio-energy can be produced on abandoned agricultural land and extensive grassland. Costs depend on the yields in each grid cell, regional income levels (as a proxy for labor costs), and changes in the level of technology.

There are three possible interactions between regions in the context of climate policy. First of all, the regions are interconnected via fossil fuel trade markets. Reduced fossil fuel consumption in countries that are implementing climate policy is likely to depress international prices for fossil fuel, because it slows down the depletion of reserves. This may, however, boost fossil fuel consumption in non-participating regions. Second, technological learning is assumed to be shared across regions. Therefore, strong mitigation activities in some regions may reduce the costs of non-fossil technologies. Third, participation is likely to impact the bio-energy markets, as countries may opt

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