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Climate change scenarios and Technology Transfer Protocols

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ABSTRACT

We apply a specific version of MERGE-ETL, an integrated assessment model, to study global climate policies supported by Technology Transfer Protocols (TTPs). We model a specific formulation of such a TTP where donor countries finance via carbon tax revenues, the diffusion of carbon-free technologies in developing countries (DCs) and quantify its benefits. Industrialized countries profit from increased technology exports, global diffusion of advanced technology (leading to additional technology learning and cost reductions) and reduced climate damages through the likelihood of greater global participation in a new international agreement. DCs experience increased welfare from access to subsidized technology, and profit from the reduction of damages related to climate change and expected secondary benefits of carbon abatement (such as reduced local and regional air pollution). The analysis identifies potential candidate technologies that could be supported under a TTP, and the impact of a TTP on economic development (including the flow of transfer subsidies) and global emissions. Although a TTP may encourage additional participation, such a proposal is only likely to be successful if an increased willingness to pay to avoid climate damages is accepted, first by the present and future generations of the industrialized world and later on, when sufficient economic growth is accumulated, by today's developing countries.

1. Introduction

The challenge of climate change demands a global response. However, securing international agreement on measures to address this challenge has proven to be an elusive goal over the past decade. It has not been possible to find agreement on an international regime for greenhouse gas (GHG) emission abatement that both achieves the necessary reductions and encourages participation in a way that recognizes responsibility and financial and technological capacity. To overcome this barrier, it is clear that new innovative ideas need to emerge in order to realize a successful post-Kyoto framework. One area where exists potential for novel approaches that may break negotiation deadlocks in the UNFCCC is in the treatment of technology, specifically technology transfer (Bazilian et al., 2008).[1]

Our technological systems, especially our energy and transportation systems, represent key factors that have driven economic growth since the industrial revolution. However, these systems also represent a key challenge to long-term sustainability and the successful mitigation of climate change, since they are the principal source of anthropogenic GHG emissions. Accordingly, technology and technological change in energy and transportation systems must play a major role in our response to climate change. To support such technological change and ensure that mitigation efforts are effective and politically acceptable globally, the necessary technologies need to be made available to those countries expected to undertake emissions abatement activities, which ultimately means all countries.

Technology Transfer Protocols (TTPs) are agreements for supporting the transfer to developing countries of the low- and zero-carbon technologies needed for an effective global response. In this way, they may also represent an attractive method of garnering support for a new international agreement. The technologies assumed to fall under a TTP in this study include renewable energy, fossil fuels with carbon capture and storage (CCS) and low-carbon systems producing alternative transportation fuels like synthetic fuels, biofuels and hydrogen. These technologies generally face technological, institutional or economic barriers and need support to emerge in the market place. We also include advanced generation IV nuclear breeder reactors as part of a TTP since they have zero emissions during operation, and also face significant barriers to deployment associated with high capital cost, waste disposal and proliferation. One would also expect a TTP to include energy conservation and efficient end-use technologies, but they are not included in our study.

TTPs are likely to produce a number of impacts in industrialized and developing countries (DCs). For instance, the subsidized transfer of technology and know-how DCs will increase their welfare,

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[1] As the report of Bazilian et al. gives an extensive literature review on technology transfer and protocols and discusses all the related policy issues we recommend consultation of this reference as a complementary introduction to the study.

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generating a positive feedback mechanism encouraging participation in an international abatement regime. For industrialized countries, the costs of supporting technology transfer will reduce economic welfare, but this will be partly offset by additional technology exports (manufactured in industrialized countries or in recipient countries under license). In addition, both developing and industrialized countries will benefit from the induced technological learning, resulting from the higher overall deployment of new technologies, which will reduce the global cost of achieving mitigation targets in a post-Kyoto agreement. Both groups of countries will also benefit from the reduction of damages related to climate change, and secondary benefits of GHG abatement arising from reduced local and regional pollution.

The study analyses a specific example of TTPs as an innovative cooperation mechanism where industrialized countries support the deployment and sharing of carbon-free technologies in developing and emerging economies to meet climate targets. Among the key factors in the design of TTPs is the question of how the mechanism of technology transfer and deployment is funded, and here we analyze various options of supporting transfer with revenue recycled from a carbon tax.

To assess the merits of a post-Kyoto agreement that encompasses TTPs, we applied a new version of MERGE-ETL incorporating a technology transfer mechanism to support carbon-free technology in DCs. Specifically, we have introduced an explicit representation of technology and capital transfer (see also Appendix). The objective is to understand how this may establish a diffusion of carbon-free technologies in the market place, reinforce climate change policies and reduce losses in welfare associated with mitigation efforts.

2. Methodology

We apply a modified version of MERGE5 (Manne and Richels, 2004a, b), referred to as MERGE-ETL, to analyze a range of global mitigation regimes incorporating TTPs. Key features of MERGE-ETL include a nine-region global disaggregation, a combined 'top-down' Ramsey-type economic and 'bottom-up' engineering modeling approach, a simple climate model with an optional damage function and international trade in a range of goods and resources. MERGE-ETL also accounts for technological learning with global spillovers (see below).

MERGE provides a normative representation of market development, assuming perfect competition and information, utility function continuity, and that world regions can be represented by a single agent. In addition, the level of technology detail enables only a generic representation of end-use energy efficiency (i.e., explicit end-use technologies are not represented) and price effects on demand.

Explicit energy supply technologies are included in MERGE-ETL. Electricity can be supplied using gas, coal, biomass and nuclear plants (both conventional and advanced designs[2]), or renewable energy, i.e. carbon-free non-exhaustible energy, namely hydropower, wind farms and solar photovoltaic devices. Carbon capture and storage (CCS) systems are available for natural gas combined cycle (NGCC), pulverized coal (PC) and integrated gasification (coal or biomass) combined cycle (IGCC). Non-electric energy can be supplied directly from fossil fuels (e.g. mainly via heat processes in the industrial and residential sectors, or in transport) or in producing some energy carriers or secondary fuels such as synthetic fuels (Fischer–Tropsch liquids, F–T) and hydrogen (H_2). Technologies for synthetic fuel production from either coal or biomass are included. Hydrogen may be produced by coal, natural gas, biomass, nuclear power or solar thermal plants (via sulfur–iodine thermo-chemical water splitting). CCS options are also available for some non-electric technologies, including FT liquids from coal and biomass and hydrogen production. Technologies included in the model and levelized production cost data are presented in Fig. 1, while the data sources are given in Magné et al. (2009). Fig. 1 illustrates the cost contribution of learning components, and the balance of the plant (BOP), fuel and operating and maintenance (O&M) costs. Clearly, there is uncertainty regarding future costs and performance of technologies, with the values in Fig. 1 representative of the literature.

The costs of energy resources (oil, gas and coal) are also reported in Fig. 1, with a total maximum potential of 18, 20 and 100 ZJ, respectively. A maximum potential of 250 TJ per year is assumed for biomass.

Technological learning in MERGE-ETL (see Kypreos and Bahn, 2003; Barreto and Kypreos, 2004; Kypreos, 2005a, b, 2007) is represented endogenously by two-factor learning curves (Magné et al., 2009). Two-factor learning curves, first introduced in Kouvaritakis et al. (2000), better translate cost reductions achieved through the various stages of technology development both via learning-by-doing (LbD) and via learning-by-searching (LbS). LbD is determined endogenously in MERGE as a function of cumulative experience with deployment of learning technologies, while LbS occurs through targeted investment in R&D. Further, the paradigm of technology clusters described in Seebregts et al. (2000) is applied, considering that development and adoption of technologies occur as a collective evolutionary process.

As a first approximation, and due to a lack of empirical estimates of the two-factor learning curve parameters,[3] we have chosen to classify the key components into two categories: mature (i.e. gasifier, gas turbine, advanced nuclear and wind) and speculative technologies (others). Both learning rates (for LbD and LbS) are set at 5% and 10% each for the mature and speculative key components, respectively. These learning rates are consistent with the range reported in the literature (see McDonald and Schrattenholzer, 2001), but it is important to appreciate that there are uncertainties about possible learning rates for speculative technologies.

To model technology transfer and TTPs, a new set of decision variables related to technology transfer have been introduced, along with a modified set of capital transfer and production balance equations. In summary, a new "subsidized activity" variable (SACT) defines the amount of electric or non-electric energy production in DCs (i.e., Non-Annex B regions of the Kyoto Protocol) to be supported via technology transfer payments (TTRX) from donor countries bounded by the tax revenue of donor regions. The subsidy is applied to the levelized investment cost of the learning components of carbon-free technologies in DCs (see Fig. 1 and also the Appendix).

3. The baseline

We first describe the baseline (BaU) development, which is based on the baseline scenario assumptions from the EU ADAM project (http://adamproject.info/) generated by the TIMER model (Van Vuuren, 2006). This baseline assumes higher economic

[2] MERGE-ETL incorporates a simple nuclear fuel cycle global sub-model (see Magné et al., 2009).

[3] Jamasb (2007) is an exception as he provides estimates for the learning rates of a variety of technologies in a comprehensive and harmonized way. Nonetheless, Jamasb reports statistically significant estimates for mature technologies contrary to more speculative technologies, for which learning rates estimation reveals less reliability due to insufficient quality of dataset. We thus chose not to use these estimates.