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Integrated model for robust emission trading under uncertainties: Cost-effectiveness and environmental safety

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ABSTRACT

Emission trading scheme was devised to lower the cost of achieving greenhouse gas emission reductions: emissions are reduced where it is cheapest and emission certificates are then traded to meet the nominal targets for each participant. However, carbon markets, like other commodity markets, are volatile. They react to stochastic "disequilibrium" spot prices, which may be affected by inadequate policies, speculations and bubbles. The market-based emission trading, therefore, does not necessarily minimize abatement costs and achieve emission reduction goals. We introduce a basic stochastic trading model allowing analysis of the robustness of emission reduction policies under irreversibility, asymmetric information and other multiple anthropogenic and natural uncertainties. We illustrate functioning of the robust market with numerical results involving such countries as US, Australia, Canada, Japan, EU27, Russia, Ukraine, China. In particular, we analyze if knowledge about uncertainties may affect portfolios of technological and trade policies and how uncertainty characteristics may influence market prices and change the market structure.

1 . Introduction

The paper aims to analyze cost-effective and environmentally safe carbon trading systems operating under uncertainty about emissions and their abatement and monitoring cost functions, asymmetric information, and irreversibility. For analyzing robust emission trading schemes, we introduce an integrated multi-agent emission trading and reduction model under multiple natural and human-related uncertainties. The model pursues the goal that all trading parties jointly achieve individual emission targets at minimum costs by investing in emission abatement, uncertainty reduction and by redistributing the emission permits through trading. Safety constraints imposed on the trades require that the reported emissions plus uncertainty are below the targeted level (cap) with a given probability, therefore this creates incentives for parties to invest into uncertainty reduction prior to compliance. Proposed mutually beneficial bilateral trading scheme corresponds to a special distributed optimization method. The implementation of this trading scheme is discussed in Section 4 using a computerized multi-agent trading system avoiding irreversibility of real trades and asymmetric information of partners.

Emission cap and trade programs (de Jong and Walet, 2004; Kerr, 2000) are economic instruments for environmental regulations which become popular both among policy-makers and scientific communities (Stavins, 2010). These programs are now a key element in climate change policy negotiations establishing carbon prices as a "new currency" and emission permits as a new asset type (Kerr, 2000). In theory, the market price of tradable emission permits (allowances) should set up the marginal cost of emission reductions to meet the cap. In reality, the market prices exhibit periods of high volatility which may be a result of political decisions, information disclosure, speculations, uncertainties around emissions and

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emission reduction costs. For example, within two months, from January till April, 2006, carbon prices went down from €26/tCO_2 to €10/t CO_2 after the data for 2005 was verified and adjusted emission levels revealed (see Fig. 1, where EUA means European Union Allowances). Similarly, if not as abrupt, the recent crisis led to a dramatic decrease in carbon prices to about €13/t CO_2.

As studied by Potsdam Institute for Climate Impact Research (Roos, 2011), immaturity of the existing market policies triggered a major "dash for coal setting out on the construction of dozens of new coal plants. …". Also, in the Netherlands, "… CO_2 emission trading is a marginal consideration in the choice of fuel. Evidently, electricity producers are not too bothered about the price they pay for carbon emissions. The vast majority still favors coal, the worst carbon polluter. The reason is simple: the expected costs of emission rights are negligible compared to other investment outlays." The building of coal-fired plants now may lock-in energy decisions for about forty years (Stikkelman et al., 2010). Lessons learned from the existing emission trading (Betz and Sato, 2006) point out the need for environmental safety regulations in market instruments to smooth their performance (Cano et al., 2013).

In this paper, we propose a computerized multi-agent trading system (COMATS) which may function as a prototype of a real decentralized emission trading market under uncertainty without revealing the private information of parties about costs and emissions. The system may enhance real markets by analyzing conditions for strategic robust trades and stable market's performance avoiding potential irreversibility and "lock-in" equilibriums. COMATS is designed as a multicomputer network of traders and can be viewed as a device for decentralized collective regulation of trades towards their cost-effectiveness under safety constraints. The paper is organized as follows. Section 2 reviews the classical approach to emission trading and discusses its shortcomings in situations with uncertainty. In Section 3 the integrated stochastic multi-agent model is introduced and analyzed. Section 4 outlines the structure of the COMATS and summarizes important policy implications under uncertainties by using numerical results on trading involving such countries as US, Australia, Canada, Japan, EU27, Russia, Ukraine, China. In this section we show how the knowledge about uncertainties may affect structure of the market, e.g., turn buyer into seller, and how new participants may improve or destabilize market's performance. Conclusions are presented in Section 6.

2. Emission trading under uncertainties

A key issue for developing cost-effective and environmentally safe emission reduction schemes is the private character of information. If emission reduction costs are known, then the problem is reduced to the standard social cost minimization model subject to environmental safety targets. The asymmetric private information on emission reduction costs requires developments of special decentralized emission reduction processes which can be viewed as emission trading schemes. The paper analyzes this type of trading processes.

Emission trading as an economic instrument for environmental regulations has been analyzed e.g. by Dales (1968). The author assumed that environmental agency requires each regulated source to submit permits (also known as quotas, credits, or allowances), which are transferable. Each source reduces its emissions until the cost for one more unit of emission reduction is higher than to buy a permit. If the permit market is perfectly competitive, then marginal abatement costs will be equal to the permit price and therefore equal across all regulated sources. The equality of marginal abatement costs is a necessary condition for any given level of environmental quality to be achieved at the lowest overall cost, a condition known as cost-effectiveness. Putting a price on carbon was a crucial step towards market-based regulations of climate policies. Montgomery (1972) showed that market instruments may achieve their environmental objectives at lower information requirements than conventional command-and-control systems. Therefore, encouraged by economists (Stavins, 2010; Kerr, 2000; Baumol and Oates, 1975; Dales, 1968), the idea of carbon trading markets becomes increasingly popular for global climate change control. The theoretical conclusion of

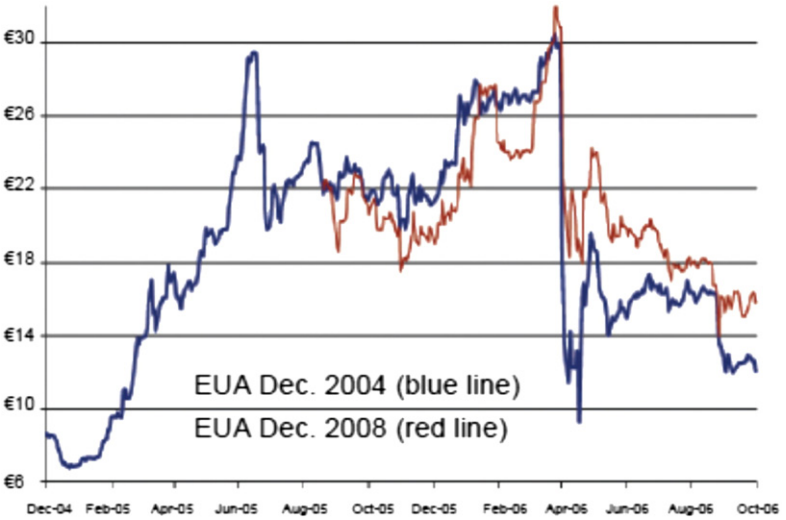

Fig. 1. Carbon prices (Source: www.pointcarbon.com, see also Betz and Sato, 2006).