INTERTEMPORAL EMISSION PERMITS TRADING IN UNCERTAIN ELECTRICITY MARKETS

Fan Zhang, Harvard University, Phone +1 857 928 5876 E-mail: Fan_Zhang@ksgphd.harvard.edu

Overview

Cap-and-trade emission permit systems that allow permits to be traded across compliance periods (intertemporal emissions trading or bankable emission permit trading) are witnessing growing regulatory interest as a cost-effective way to reduce total emissions. The U.S. sulfur dioxide (SO_2) emission trading program is one of the first, and by far the most extensive application of bankable emission permit trading. Under Title IV, firms are not only allowed to transfer allowances for emissions of SO_2 between facilities, but also to bank them for use in future years. The implementation of Title IV happens to have coincided with electricity restructuring which introduced dramatic uncertainty into the electricity market. In this paper, I explore the effects of increased electricity price volatility on firms' emissions trading behavior. I also revisit the oftern considered regulatory insturmetns choice between taxes and quotas and discuss implications for climate policy.

This paper makes two specific contributions. First, I introduce uncertainty into the intertemporal emissions trading model, which is theoretically more interesting and empirically more relevant. In this model, a firm decision regarding permit trading is an *ex ante* choice in the sense that optimal emissions and permit banking decisions depend not only on current output and input prices, but also on expectations of future prices. Second, I empirically test the theoretical prediction. To the best of my knowledge, this is the first study that quantitatively estimates the effects of uncertainty on emissions trading based on actual market data. Although the analysis is conducted in the context of the U.S. SO_2 allowance trading program, the model is flexible enough to be extended to other intertemporal trading initiatives, such as the global carbon trading, for which uncertainty is a prevalent feature in many of the policy parameters.

The paper is organized as follows: Section 2 provides background on the U.S. SO_2 allowance trading program; Section 3 analyzes the impact of electricity restructuring on the allowance market; Section 4 develops a firm model of intertemporal emissions trading and derives the relationship between emissions banking and uncertainty; Section 5 and 6 present the empirical and numerical models and the estimation results. Section 7 concludes the paper.

Methods

1. Stochastic Dynamic optimization
2. Econometric Analysis
3. Numerical Simulation

Results

I prove analytically that the permit price, as well as firm's marginal abatement costs, are convex functions of the electricity price. Assuming risk neutrality and a competitive permit market, a mean-preserving increase in electricity price volatility would decrease *ex ante* emissions, and increase industry-level allowance banking. The results hold with or without perfect competition in the electricity market.

Empirical analysis shows that a one-percent increase in electricity price volatility measured by annualized standard deviation of percentage price change is on average associated with a 0.88% decrease in annual emission rate. Overall, electricity restructuring may explain 8-11% of the total amount of banked allowances during Phase I of the SO_2 trading program.

Numerical simulation suggests that high uncertainty may generate substantial initial compliance costs, thereby deterring new entrants and reducing enomic efficiency; sharp emission spikes are also more likely to occur under high uncertainty scenarios. When a pollutant creates convex flow damage, the dispproprotionate distribution of emissions could dramatically increase health hazards.

Conclusions

A tradable quota system that allows banking creates incentive for early carbon emissions abatement and generates substantially greater environmental benefits than a tax schedule.

To estabalish a robust and effective banking regime, a hybrid approach that combines a tradable quota system with safety measures such as restricting the intertemporal trading ratio and/or applying discount to banked peremits is suggested. For SO_2 allowance trading, the government may also consider incorporating multiple polluting industries into a national trading program so that uncertainties facing one industry can be diversified, and the importance of building up a bank to buffer unexpected price strikes can be reduced.

References

Abel,A.B. "Optimal Investment Under Uncertainty." *American Economic Review*, March 1983, 73(1), pp.228-33.

Abel,A.B. "A Stochastic Model of Investment, Marginal q and the Market Value of the Firm." *International Economic Review*, June 1985, 26(2), pp.305-22.

Arimura, T.H. "An Empirical Study of the SO2 Allowance Market: Effects of PUC Regulations." *Journal of Environmental Economics and Management*, 2002, 44, pp.271-89.

Ellerman, A. D. and Montero,J-P. "The Declining Trend in Sulfur Dioxide Emissions: Implications for Allowance Prices." *Journal of Environmental Economics and Management*, 1998, 36(1), pp.26-45.

Ellerman A.D. and Montero,J-P. "The Efficiency and Robustness of Allowances Banking in the U.S. Acid Rain Program." Working Paper 05-005, MIT Center for Energy and Environmental Policy Research, 2005.

Hoel, M. and Karp, L. "Taxes and Quotas for a Stock Pollutant with Multiplicative Uncertainty." *Journal of Public Economics*, 2001, 82, pp.91-114.

Feng, H. and Zhao, J. "Alternative intertemporal permit trading regimes with stochastic abatement costs." *Resources and Energy Economics*, 2006, 28, pp.24-40.

Kling, C. and Rubin, J. "Bankable Permits for the control of environmental pollution." *Journal of Public Economics*, 1997, 64, pp.101-115.

Leiby, P. and Rubin, J. "Intertemporal Permit Trading for the Control of Greenhouse Gas Emissions." *Environmental & Resource Economics*, 2001, 19(3), pp. 229-256.

Pindyck, R.S. "A Note on Competitive Investment Under Uncertainty." *American Economic Review*, March 1993, 83(1), pp.273-77

Pizer, W.A. "Combining Price and Quantity Controls to Mitigate Global Climate Change." *Journal of Public Economics*, 2002, 85, pp.409-434

Rubin, J.D. "A model of intertemporal emission trading, banking and borrowing." *Journal of Environmental Economics and Management*, November 1996, 31(3), pp.269-86

Smith, A.E., Platt, J. and Ellerman, A.D. "The Costs of Reducing Electric Utility SO2 Emissions may not be as low as You Might Think." Working Paper 98- 010, MIT Center for Energy and Environment Policy Research, 1998.

Schennach,S.M., "The Economics of Pollution Permit Banking in the Context of Title IV of the 1990 Clean Air Act Amendments." *Journal of Environmental Economics and Management*, 2000, 40,pp.189-210.

Stevens, B. and Rose, A. "A Dynamic Analysis of the Marketable Permits Approach to GlobalWarming Policy: A Comparison of Spatial and Temporal Flexibility." *Journal of Environmental Economics and Management*, 2002, 44(1), pp.45-69.

Stranlund, J.K. Costello, C., et al. "Enforcing Emissions Trading when Emissions Permits are Bankable." *Journal of Regulatory Economics*, 2005, 28(2), pp.181-204.

Weitzman, M. "Prices vs. Quantities." *Review of Economic Studies*, 1974, 41, pp.447-491

Yates, A. J. and Cronshaw, M. B. "Pollution Permit Markets with Intertemporal Trading and Asymmetric Information." *Journal of Environmental Economics and Management*, 2001, 42(1),pp.104-118