Modeling the Impact of Technical Change on Emissions Abatement Investments in Developing Countries

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ABSTRACT. The cost of greenhouse gas (GHG) mitigation over time depends on both the rate of technical change in leading-edge technologies and the diffusion of knowledge and capabilities throughout international markets. This paper presents a framework developed by the U.S. Environmental Protection Agency (EPA) and RTI International (RTI) for incorporating technical change in non-CO2 GHG mitigation projections over time. An engineering (bottom-up) approach is used to model technical change as a set of price and productivity factors that change over time as a function of technology advances and the location of developing countries relative to the technology efficiency frontier. S-shaped diffusion curves are generated, which demonstrate the maturity of the market for a given technology in a given region. The framework is demonstrated for coal mine methane mitigation technologies in the United States and China, but it is applicable for the full range of technology adoption issues.

Key words: technology transfer, diffusion, climate change

JEL Classification: O33

1. Introduction

Edwin Mansfield was an early pioneer in the description of the diffusion of industrial technology. His work on the diffusion of robotics and flexible manufacturing systems highlighted the importance of the firm's perceived adoption costs, rate of return, and risk associated with technology investments (Mansfield, 1989, 1993). Mansfield's early work set the stage for more sophisticated econometric analysis (Geroski, 2000). However, all these efforts build on the principle that technical information diffuses throughout a population, reducing costs, and generates S-shaped adoption paths over time. Information lowers the cost (and risk) of adoption by reducing the leaning curve and increasing the effectiveness of new technologies. This paper follows Mansfield's work, applying these principles to the adoption of emissions abatement technologies in developed and developing countries. The paper develops a bottom-up engineering approach for modeling technology change that provides insights into the factors underpinning the S-shaped diffusion curves observed in the empirical and qualitative literature.

The diffusion of information and technical change are key drivers in the adoption of abatement technologies. This is particularly important in developing countries where the diffusion of new technologies and supporting infrastructures significantly affect the installation and maintenance costs of emerging technologies. The availability of cost-effective abatement options over time depends on both the rate of technical change in newer mitigation technologies and the rate of diffusion of established mitigation practices and technologies. New technologies follow a life cycle where early installation and operating costs are high but then decrease for later installations as methods are refined. Technical improvements lead to reductions in capital and labor

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costs and increase the reduction efficiency of mitigation options. In addition, knowledge spillovers and the expiration of patents lead to increased competition that lowers market prices.

Analyses of historical data have shown that inter- and intra-firm diffusion of new technologies typically follows a gradual S-shaped process. Griliches' (1957) early work on the diffusion of hybrid corn shows that the rate at which a new technology is being used slowly increases at first, then increases more rapidly, and then continues to increase but at a decreasing rate, forming an S-shaped curve. Griliches characterized the observed pattern as a logistic curve. Mansfield (1968) also found that a logistic S-shaped curve fit the diffusion of diesel locomotives in the U.S. railroad industry. In addition, Mansfield found that although the shapes of most diffusion curves may be similar, the length of time associated with the diffusion process can vary significantly across different industries and technologies.

The S-shaped diffusion can theoretically be motivated by decreasing cost and/or information models. One popular explanation of S-shaped curves is the epidemic model of information diffusion (Geroski, 2000). Similarly Rogers (1995) motivates the S-shaped diffusion curve in terms of innovators, early adopters, takeoff adoptions, and late adopters. He describes diffusion as a social process where early adopters reduce the uncertainty for later adopters of the innovation. In this way, the communication of knowledge and experience from peers is equally important as the dissemination of knowledge through consensus guidelines and academic publications.

In a related fashion, technology adoption plays an important role in the timing of potential emissions reductions. Expensive installations by early adopters serve to demonstrate the technology, lowering the perceived risk for following adopters. In addition, early adopters develop solutions for integrating new technologies into legacy systems, hence lowering costs to later adopters. In this way, it is the heterogeneous cost and benefit characteristics of individual sources that determine the rate of adoption, with entities in the tails of the distributions significantly affecting the timing of adoption by "mainstream" or "typical" entities.

This paper presents a framework developed by the U.S. Environmental Protection Agency (EPA) and RTI International (RTI) for incorporating technical change into the marginal cost of methane gas mitigation projections over time. An engineering-economic (bottom-up) approach is used to model technical change as a set of price and productivity factors that change over time as a function of specific technology life cycles and the location of countries relative to a technology efficiency frontier. The framework is demonstrated for coal mining emission reduction technologies in China, but it is applicable for the full range of technology adoption issues.

2. Introducing technical change into marginal abatement cost analysis

Marginal abatement curves (MACs) are an important input into the modeling of global climate change and policy alternatives to reduce greenhouse gas (GHG) emissions. Similar to marginal cost curves, MACs express the quantity of emissions a country might be willing to abate at a given carbon price.

MACs commonly describe the adoption potential of a single or suite of emission reduction technologies. As shown in Figure 1, MACs present emissions reductions (on the horizontal axis) as a function of the price of carbon (on the vertical axis). As the market value of abatement (expressed as tons of carbon equivalent [TCE][1]) increases, more abatement options become economically viable. Analysts and policy makers use these curves to assess the impact of potential carbon taxes or emissions trading programs.

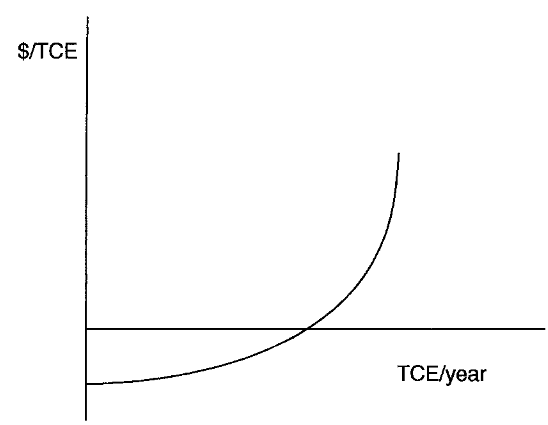

Figure 1. Marginal abatement curves (MACs).