参考資料１

「IPCC 第 3 作業部会報告書 気候変化 2001 緩和対策」
6.5.3 技術変化に与える代替政策の効果

※ 資料１「環境税の技術、産業構造等に与える影響について」２頁の関連資料

6.5.3 The Effects of Alternative Policy Instruments on Technological Change

In the long run, the development and widespread adoption of new technologies can greatly ameliorate what, in the short run, sometimes appear to be overwhelming conflicts between economic well being and environmental quality. Therefore, the effect of public policies on the development and spread of new technologies may be among the most important determinants of success or failure in environmental protection (Kneese and Schultze, 1975).

To achieve widespread benefits from a new technology, three steps are required (Schumpeter, 1942):

- invention, the development of a new technical idea;
- innovation, the incorporation of a new idea into a commercial product or process and the first marketplace implementation thereof; and
- diffusion, the typically gradual process by which improved products or processes become widely used.

Rates of invention, innovation, and technology diffusion are affected by opportunities that exist for firms and individuals to profit from investing in research, in commercial development, and in marketing and product development (Stoneman, 1983).

Governments often seek to influence each of these directly, by investment in public research, subsidies to research and technological development, dissemination of information, and other means (Mowery and Rosenberg, 1989). Policies with large economic impacts, such as those intended to address global climate change, can be designed to foster technological invention, innovation, and diffusion (Kemp and Soete, 1990). For the impact of R&D policies on technology development and transfer, see the IPCC Special Report on Technology Transfer (IPCC, 2000).

To examine the link between policy instruments and technological change, environmental policies can be characterized as market-based approaches, performance standards, technology standards, and voluntary agreements. All these forms of intervention have the potential to induce or force some amount of technological change, because by their very nature they induce or require firms to do things they would not otherwise do. Performance and technology standards can be explicitly designed to be “technology forcing”, mandating performance levels that are not currently viewed as technologically feasible or mandating technologies that are not fully developed. The problem with this approach can be that while regulators typically assume that some amount of improvement over existing technology will always be feasible, it is impossible to know how much. Standards must either be made not very ambitious, or else run the risk of being ultimately unachievable, which leads to great political and economic disruption (Freeman and Haveman, 1972). However, in the case of obstructed technology, regulators know quite well the technology improvements that are feasible. Thus, although the problem of standards being either too low or too ambitious remains a possibility, it does not make standards inherently incapable of implementing some portion of the available technology base, and to do so cost-effectively on the basis of cost–benefit tests.

6.5.3.1 Theoretical Analyses

Most of the work in the environmental economics literature on the dynamic effects of policy instruments on technological change has been theoretical, rather than empirical, and the theoretical literature is considered first. The predominant theoretical framework involves what could be called the “discrete technology choice” model. In this, firms contemplate the use of a certain technology that reduces the marginal costs of pollution abatement and that has a known fixed cost (Downing and White, 1986; Jung *et al.*, 1996; Malueg, 1989; Milliman and Prince, 1989; Zerbe, 1970).

While some authors present this approach as a model of innovation, it is perhaps more useful as a model of adoption. The adoption decision is one in which firms face a given technology with a known fixed cost and certain consequences, and must decide whether or not to use it; this corresponds precisely to the discrete technology choice model. Innovation, on the other hand, involves choices about research and development expenditures, with some uncertainty over the technology that will result and the costs of developing it. Models of innovation allow firms to choose their research and development expenditures, as in Magat (1978, 1979), or incorporate uncertainty over the outcome of research (Biglaiser and Horowitz, 1995; Biglaiser *et al.*, 1995).

Several researchers have found that the incentive to adopt new technologies is greater under market-based instruments than under direct regulation (Downing and White, 1986;

Jung *et al.*, 1996; Milliman and Prince, 1989; Zerbe, 1970). This view is tempered by Malueg (1989), who points out that the adoption incentive under a freely allocated tradable permits system depends on whether a firm is a buyer or seller of permits. For permit buyers, the incentive is larger under a performance standard than under tradable permits.

Comparisons among market-based instruments are less consistent. Downing and White (1986), who consider the case of a single (sole) polluter, argue that taxes and tradable permit systems are essentially equivalent. On the other hand, Milliman and Prince (1989) find that auctioned permits provide the largest adoption incentive of any instrument, with emissions taxes and subsidies second, and freely allocated permits and direct controls last. Jung *et al.* (1996) consider heterogeneous firms, and model the "market-level incentive" created by various instruments. This measure is simply the aggregate cost savings to the industry as a whole from adopting the technology. Their rankings echo those of Milliman and Prince (1989).

On the basis of an analytical and numerical comparison of the welfare impacts of alternative policy instruments in the presence of endogenous technological change, Fischer *et al.* (1998) argue that the relative ranking of policy instruments depends critically on firms' ability to imitate innovations, innovation costs, environmental benefit functions, and the number of firms that produce emissions. Finally, the study includes an explicit model of the final output market, and finds that it depends upon empirical values of the relevant parameters whether (auctioned) permits or taxes provide a stronger incentive to adopt an improved technology.

Finally, recent research investigates the combined effect of the pollution externality and the positive externality that results from learning-by-doing with mitigation technologies. Since the benefit from learning occurs after the learning has taken place, a dynamic analysis is needed. Some analyses shown that dynamic efficiency (discounted least cost, aggregated over time) requires that the incentive for emissions-mitigating innovations be set higher than the penalty on emissions, especially if account is taken of "leakage". This is in contrast with the conclusions of comparative static analysis upon which most environmental policy analysis is grounded (e.g., Baumol and Oates, 1988), under which the two incentives should be equal in all time periods (for a formal analysis, see Read (1999, 2000)).

6.5.3.2 Empirical Analyses

Empirical analyses of the relative effects of alternative environmental policy instruments on the rate and direction of technological change are limited in number, but those available focus on technological change in energy efficiency, and thus are potentially of direct relevance to global climate policy. These studies can be considered within the three stages of technological change introduced above–invention, innovation, and diffusion. It is most illuminating, however, to consider the three stages in reverse order.

Beginning, then, with empirical analyses of the effects of environmental policy instruments on technology diffusion, Jaffe and Stavins (1995) conducted econometric analyses of the factors that affected the adoption of thermal insulation technologies in new residential construction in the USA from 1979 to 1988. They examined the dynamic effects of energy prices and technology adoption costs on average residential energy-efficient technologies in new home construction. The effects of energy prices can be interpreted as suggesting what the likely effects of taxes on energy use would be, and the effects of changes in adoption costs can be interpreted as indicating what the effects of technology-adoption subsidies would be. They found that the response of mean energy efficiency to energy price changes was positive and significant, both statistically and economically. Interestingly, they also found that equivalent percentage cost subsidies would have been about three times as effective as taxes in encouraging adoption, although standard financial analysis suggest they ought to be about equal in percentage terms. This finding does, however, offer confirmation for the conventional wisdom that technology adoption decisions are more sensitive to up-front cost considerations than to longer-term operating expenses.

In a study of residential conservation investment tax credits, Hassett and Metcalf (1995) also found that tax credit or deductions were many times more effective than “equivalent” changes in energy prices–about eight times as effective in their study. They speculate that one reason for this difference is that energy price movements may be perceived as temporary. The findings by Jaffe and Stavins (1995), and by Hasset and Metcalf (1995) are consistent with other analyses of the relative effectiveness of energy prices and technology market reforms in bringing about the adoption of lifecycle cost-saving technologies. Up-front subsidies can be more effective than energy price signals (see, e.g., Krause *et al.*, 1993; Howarth and Winslow, 1994; IPSEP, 1995; Eto *et al.*, 1996; Golove and Eto, 1995; IPCC, 1996, Executive Summary, p. 13). A disadvantage of such non-price policies relative to administered prices is that they have to be implemented on an “end-use by end-use” or “sector by sector” basis in a customized fashion. Also, an effective institutional and regulatory framework needs to be created and maintained to evaluate and ensure the continued cost-effectiveness of such policies.

This and other research on energy efficiency programmes also highlights a major difference in the way energy price signals and technology subsidies function. The technology adoption response to taxes may include a secondary increase in the demand for energy services. This secondary effect takes two forms: a direct effect that results from the increased utilization of energy-using equipment and capital stocks, and an indirect effect from increased disposable income. Studies of such demand effects suggest that the combined effects are generally not sufficient to offset more than a minor portion of emissions reductions.

In addition, technology subsidies and tax credits can require large public expenditures per unit of effect, since consumers who would have purchased the product even in the absence of the subsidy will still receive it.

Some recent empirical studies suggest that the response of relevant technological change to energy price changes can be surprisingly swift. Typically, this is less than 5 years for much of the response in terms of patenting activity and the introduction of new model offerings (Jaffe and Stavins, 1995; Newell *et al.*, 1999; Poppe, 1999). Substantial diffusion can sometimes take longer, depending on the rate of retirement of previously installed equipment. The longevity of much energy-using equipment reinforces the importance of taking a longer-term view towards energy-efficiency improvements–on the order of decades.

An optimal set of policies would be designed in such a way as to achieve two outcomes simultaneously: release any obstructed emission and cost-reduction potentials from already available technologies through various market reforms that try to reduce market distortions (see IPCC, 2000), and induce the accelerated development of new technologies. This approach allows significant carbon abatement over the near-term by diffusing existing technologies, while at the same time preparing new technologies for the longer term.