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Energy Efficiency Challenges and Policies

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I. Introduction

As with virtually all economic problems, the economics of energy efficiency is at its heart a question of balancing of costs and benefits. For the individual energy user, this involves weighing the higher initial cost of purchasing more energy-efficient products with the expected benefits of future energy operating cost savings, among other considerations. For suppliers of energy-using products, decisions regarding energy-efficient innovations likewise depend on the expected profits from such technology development. Profits from innovation depend in turn on the expected demand for energy-efficient technologies and the degree to which firms can appropriate the value created by their innovations.

On both the demand and supply side of this market for energy-efficient technology there are potential market imperfections that can lead to under-investment in energy efficiency. This raises the possibility that corrective government policies could provide economic gains and provide net benefits after inclusion of all public and private implementation costs. The degree to which such opportunities exist in practice is the subject of significant debate. Environmental pollution associated with energy production—particularly carbon dioxide (CO₂) emissions from fossil fuels—represents an additional reason why private markets might under-provide energy efficiency if energy users do not face the cost of any resultant environmental harm.

II. Energy-efficient technological change

To understand the potential for public policy to affect energy efficiency, it is useful to understand the process through which technology evolves: invention, innovation, diffusion, and product use. *Invention* involves the development of a new idea, process, or piece of equipment. This activity typically takes place inside the laboratory. The second step is the process of technology *innovation*, in which new processes or products are brought to market. Another way of describing this stage is commercialization. The third step is *diffusion*, the gradual adoption of new processes or products by firms and individuals, who then also decide how intensively to *use* new products or processes.

Beginning at the end of the technological change process, research has consistently shown that diffusion of new, economically superior technologies is never instantaneous. An S-shaped diffusion path is typically used to describe the progress of new technologies making their way into the marketplace. The explanation for this typical path of diffusion that has most relevance for energy-conservation investments is related to differences in the characteristics of adopters and potential adopters. This includes differences in the type and vintage of their existing equipment, other elements of the cost structure (such as access to and cost of labor, material, and energy) and their access to technical information. Such heterogeneity leads to differences in the expected returns to adoption and, as a result, only potential adopters for whom it is especially profitable will adopt at first. Over time, however, more and more will find it profitable as the

cost of the technology falls, its quality improves, information about the technology becomes more widely available, and existing equipment stocks depreciate. The longevity of much energy-using equipment reinforces the importance of taking a longer-term view toward energy-efficiency improvements—on the order of decades.

Several studies have explored the effect of energy prices and technology adoption costs on energy-efficiency investments. From a policy perspective, the effect of higher energy prices can be interpreted as suggesting what the likely effects of taxes on energy use (and CO₂) would be, and the effects of changes in adoption costs can be interpreted as indicating what the effects of technology adoption subsidies would be. As one might expect, these studies have typically found that higher energy prices increase, and adoption costs decrease, the extent of adoption of energy-efficient technology (e.g. building insulation, more efficient home appliances, more efficient industrial motors).

An additional interesting finding in this line of research is that the adoption of these technologies is more sensitive to the cost of the equipment than it is to the expected cost of energy. This would seem to imply that a policy of subsidizing the purchase of new efficient equipment may be more effective than a policy of taxing resource use, for policies that should in theory create the same magnitude of economic incentive. This interpretation is subject to debate, however, and it is important to recognize some disadvantages of such subsidy approaches. First, unlike energy prices, adoption subsidies do not provide incentives to reduce utilization. Second, 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 (i.e., “free-riders”) still receive it. In addition, studies that have investigated directly the effect of income tax credits on energy-efficient technology adoption have found mixed results.

As with technology diffusion, studies have shown that increases in the price of energy have induced technological innovations in energy efficiency of commercialized products, such as household appliances (e.g., air conditioners, water heaters), automobiles, tractors, and jet aircraft. Moving back even further in the process of technological change to examine invention, other studies have analyzed U.S. patent data, finding that the rate of energy-conserving patent applications (e.g., for waste heat, heat pumps, solar energy, fuel cells) is significantly and positively associated with the price of energy.

III. Market failures and policy responses

At a conceptual level there are several reasons why technology diffusion will not, in general, occur at an economically efficient rate. Those market barriers that might justify a public policy intervention to overcome them are referred to in economics parlance as “market failures”. Normative economics teaches that in the presence of market failures, unfettered markets may not operate to produce outcomes that are socially optimal. When analysts speak of no-cost climate policies based on energy efficiency enhancement, they are often implicitly or explicitly assuming the presence of market failures in energy efficiency.

There are several sources of potential market failure that may affect energy-conserving technology adoption rates. Three of these relate to the availability of information, and the others relate to environmental externalities, and broader innovation and adoption externalities. Energy supply pricing and national security may also be an issue.

Inadequate information. First, information has important “public good” attributes: once created it can be used by many people at little or no additional cost. It may be difficult or impossible for an individual or firm that invests in information creation to prevent others who do not pay for the information from using it. It is well known that such public goods will tend to be underprovided by ordinary market activity. Second, if the act of adopting a new technology is, itself, a source of useful information for others, then the act of adoption creates a positive externality by providing information to others for which the adopter is unlikely to be compensated. Third, incomplete information can also foster “principal-agent” problems, as when a builder or landlord chooses the level of investment in energy efficiency in a building, but the energy bills are paid by a later purchaser or a tenant. If the purchaser has incomplete information about the magnitude of the resulting energy savings, the builder or landlord may not be able to recover the cost of such investments, and hence might not undertake them. This is another potential form of market failure.

Product testing and labeling, general and professional education programs, and energy audits are potential policies that have been used in practice to address these information problems. Minimum energy efficiency standards also address the information problem, in a sense, by removing the need for the purchaser to analyze the efficiency decision, at least at the lower end of the efficiency spectrum. In a sense, one can think of efficiency standards as economizing on the need for energy efficiency analysis by all individuals, since the government does it once for everyone. But the reality is that if the assumptions used in setting the standards are not appropriate for all purchasers, then overly stringent standards run the risk of leaving consumers worse off.

Environmental externalities. Economic analysis of environmental policy is based on the idea that the potentially harmful consequences of economic activities on the environment constitute an externality. All environmental policies, at their core, are designed to deal with this externality problem, either by internalizing environmental costs so that polluters will make efficient decisions regarding their consumption of environmental inputs, or else by imposing from the outside a level of environmental pollution that policy-makers believe to be more efficient than that otherwise chosen by firms. If energy-related environmental externalities are not fully addressed by environmental policy—for political or other reasons—the resulting level of energy efficiency will likely be too low. In other words, unless the environmental costs of energy are fully paid by producers and users, the price of energy will be too low and the incentive to use energy efficiently will be inadequate. Pollution control policy in the form of standards or incentive-based instruments such as green taxes or tradable permits are the most direct way to address such environmental externalities.

Innovation and adoption externalities. In addition to the externality associated with pollution, innovation and diffusion are both themselves characterized by externalities. A firm that develops or implements a new technology typically creates *benefits* for others, and hence has an inadequate incentive to increase those benefits by investing in technology. With respect to innovation, the positive externality derives from the public-good nature of new knowledge. While patents and other intellectual property rights institutions try to protect firms’ investments in innovation, such protection is inherently imperfect. Hence innovation creates positive externalities in the form of “knowledge spillovers” for other firms, and spillovers of value for the users of the new technology.

In addition, production costs tend to fall as manufacturers gain production experience in a process commonly called “learning-by-doing”. If this learning spills over to benefit other

manufacturers it can represent an additional externality. In any event, the existence of these innovation and adoption externalities suggests a rationale for public support of R&D *in general*, not for energy-efficient technology in particular. To make an argument particularly for energy-

efficient technologies in this regard, one would have to argue that spillovers related to these technologies were somehow greater than for technologies more generally in the economy. For instance, if political or other constraints do not allow for proper pricing of environmental externalities, such as global climate change, then there would tend to be an additional rationale for R&D specifically targeted at environmentally beneficial technologies.

IV. Differing perspectives on the ability of policy to cost-effectively capture potential energy efficiency

Although there is not much disagreement among analysts about the conceptual plausibility of the above market failures, there is significant disagreement about the size of the resulting economic inefficiencies and the ability of practicable policies to eliminate these inefficiencies at acceptable cost. In cases where implementation costs outweigh the gains from corrective government intervention, it will be more efficient not to attempt to overcome particular market failures.

What are the sources of these differing perspectives? More optimistic projections of cost-effective energy efficiency opportunities typically define optimal energy efficiency by minimizing the total purchase and operating costs of an investment, where energy-operating costs are discounted at a rate which may not correspond to the purchaser's point of view.

The problem with this approach is that it does not accurately describe all the issues which can influence energy-efficiency investment decisions. First, the importance of certain factors can vary considerably among purchasers, including the purchaser's discount rate, the investment lifetime, the price of energy, the purchase price, and other costs. For example, it may not make sense for someone who will only rarely use an air conditioner to spend significantly more purchasing an energy-efficient model; they simply may not have adequate opportunity to recoup their investment through energy savings.

In addition, there are typically costs of adoption that are not included in simple cost-effectiveness calculations. It is by no means costless to learn how a technological improvement fits into one's home or firm or to learn about reliable suppliers. Even after basic information about a technology has been disseminated, the purchase price of a new product is only a lower bound on its adoption cost. Another type of "hidden cost" is the possibility that qualitative attributes of new technologies may make them less desirable than existing, less efficient technologies. An obvious example is the difference in hue between florescent and incandescent lighting, and the delay in many florescent lights.

Moreover, most estimates do not account for changes over time in the savings that purchasers might enjoy from an extra investment in energy efficiency, which depends on trends and uncertainties in the prices of energy and conservation technologies. When making irreversible investments that can be delayed, the presence of this uncertainty can lead to a higher investment-hurdle rate. The magnitude of this "option-to-wait" effect depends on project-specific factors, such as the degree of energy-price volatility, the degree of uncertainty in the cost of the

investment, and how fast the prices of energy and conservation technologies are changing over time.

Finally, there is evidence that energy savings from higher efficiency levels have routinely been overestimated, partly because projections often are based on highly controlled studies that do not necessarily apply to actual, realized savings in a particular situation. For example, studies have found that actual savings from utility-sponsored programs typically may achieve only 50% to 80% of predicted savings. Another study found that the actual internal rate of return to residential energy conservation investments on insulation was about 10%, which is substantially below typical engineering estimates that the returns for such investments were 50% or more.

Requiring consumers to purchase appliances with a higher level of efficiency based on overly simplistic analysis will, in effect, impose extra costs on consumers. The result will be a higher level of energy efficiency, but decreased economic efficiency because consumers would be forced to bear costs that they had otherwise avoided.

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