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Rethinking the Energy-Efficiency Gap: Producers, Intermediaries, and Innovation

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May 2013

http://ei.haas.berkeley.edu

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Abstract

The economic justification for energy efficiency policy primarily focuses on market failures and barriers that prevent energy consumers from undertaking privately profitable investments in efficiency. These consumer-oriented market imperfections are the subject of a substantial and growing body of research regarding human behaviour and economic incentives that influence the demand for energy-efficient technologies. But the literature has focused much less on the producers of energy efficient technologies, and intermediaries such as retailers, who supply technology choice sets for consumer adoption as a result of their competitive strategy (which includes decisions regarding research and development activities, supply chain management, risk management, marketing approaches, etc.).

This paper focuses on the question: How could supplier strategy issues help explain the observed "energy efficiency gap" between the privately optimal energy efficiency of goods and services and the actual energy efficiency of goods and services? We begin by providing background on the energy-efficiency gap and the different intellectual paradigms that have been brought to bear on it. Then we provide examples from the literature of apparent market imperfections on the supply side of energy-efficient technology development, including documentation of the concentration of the industries involved in the manufacture of appliances and other products that energy-efficiency policy efforts address. A central point of the paper is the observation that the efficiency gap is dynamic, changing over time and with the processes of innovation; the invention of new, more energy-efficient technologies can widen the gap, while the refinement and take-up of such technologies can narrow it. We conclude with a discussion of interventions on the supply side that could encourage a reduction in the energy-efficiency gap.

Introduction

A long-running conversation in the U.S. about "the energy-efficiency gap" continues to muddle the direction of the nation's energy-efficiency policy. The conversation is organized around the question: is there a gap between the optimal energy efficiency of goods and services and the energy efficiency of the goods and services that are actually consumed?

Studies by engineers and scientists beginning in the early 1980s (Meier, Wright et al. 1983) suggested that it was technically feasible to reduce energy consumption at costs that would provide net savings to society without diminishing the quality of the energy services being provided. A number of studies of this kind have been conducted over the years; a recent study of this kind that received wide attention was McKinsey & Co. (2009).

Some researchers have been sceptical of these studies because economic theory suggests that, absent market failures, a large gap between optimal energy efficiency and actual energy efficiency should not exist. There are a number of relevant papers in the literature; a recent one by Allcott and Greenstone (2012), while acknowledging the failure of the market to capture pollution externalities, argues that the efficiency gap is small.

The sceptical papers are mostly about the *demand side* of the energy-efficiency gap—in practice addressing the narrower question, does *consumer behaviour* – the behaviour of the ultimate user of energy – create a gap between the optimal energy efficiency of goods and services and the energy efficiency of the goods and services that are actually consumed?

When the problem is framed this way, policy responses tend to be framed in terms of actions to affect user behaviour. For the economist, the 'first best' policy option is to alter consumer incentives using mechanisms like energy taxes or cap-and-trade programs that raise the price of energy by internalizing the pollution externality. To the extent that first-best policies are judged to be politically infeasible, alternatives like subsidies to encourage energy-efficient choices, or regulations like codes and standards, are, in economic terms, a poor 'second best;' regulations are particularly undesirable, as they theoretically restrict consumer choice and, by corollary, reduce consumer welfare. Meanwhile, if one believes that consumers are failing to make optimal decisions because of market imperfections related to a lack of information or because consumers lack the ability to fully optimize while weighing their choices, then information programs or behavioural "nudges" (for example, making efficiency the default choice, see Thaler and Sunstein (2008)) could be economically justified as supplementing first-best policies.

This ordering of preferences for policy instruments by economists is not purely an academic issue, particularly in the U.S., which has a strong institution for reviewing proposed government actions on economic grounds in order to ensure that their social benefits exceed their private costs (for detail on the relevant U.S. institutions and enabling legislation/executive orders, see OECD 2009; Morrall 2010; Dudley 2012; Sunstein 2013). Here, it should suffice to say that the economic framing of the energy-efficiency gap is important to shaping the design and implementation of policies targeted at closing that gap.

But what if the energy-efficiency gap was regularly framed as a *supply-side* problem, such as a concern about whether problems in the *supply chain* create a gap between the energy-efficiency potential of goods and services and the adoption of energy-efficient goods and services? After all, in many instances consumer choices are constrained because it is not practical for manufacturers to produce a continuum of choices; suppliers can only provide a limited set of discrete choices within a range of prices, functionality and energy efficiency (see Blumstein, Goldstone et al. 2010). In addition, even when the choice set of energy users is not constrained, limitations related to the behaviour of actors in the supply chain may restrict consumer choices. For example, the construction of new buildings typically involves architects, engineers, contractors, bankers, building officials and others whose actions affect the possibilities for energy efficiency (see Lutzenhiser, Biggart et al. 2001).

When the efficiency-gap problem is framed to consider supply-side factors, the case for altering consumer incentives with emissions taxes or cap-and-trade programs is not fully persuasive. Supplier incentives to provide energy-efficient goods and services are, after all, not the same as consumer incentives to purchase energy-efficient goods and services. Strategies involving subsidies to encourage the production of energy-efficient products or standards to restrain the production of inefficient products could, for example, have lower social costs than taxes. This could be true if the increased demand for energy-efficient goods and services created by higher energy prices is counter balanced by other factors that influence supply, such as those discussed below. If these other factors weaken the transmission of the demand signal from the consumer to the supplier, the taxes necessary to achieve "optimal efficiency" might raise the price of energy above the social cost of consumption (that is, with externalities included), such that they become distortionary and politically infeasible.

This paper represents a first effort to frame the energy-efficiency gap from the supply side. We begin by providing background on the energy-efficiency gap and the different intellectual paradigms that have been brought to bear on it. Then we provide examples from the literature of apparent market imperfections on the supply side of energy-efficient technology development, including documentation of the concentration of the industries involved in the manufacture of appliances and other products that energy-efficiency policy efforts address. A central point of the paper is the observation that the efficiency gap is dynamic, changing over time and with the processes of innovation;[1] the invention of new, more energy-efficient technologies can widen the

[1] The language surrounding innovation in this paper tries to keep with definitions begun in Schumpeter (1942). "Invention" is the development of a new technical idea. "An invention is an idea, sketch, or model for a new device, process or system. It might be patented or not, it might lead to innovation or not" (Clarke and Riba 1998). "Innovation," in Schumpeter's rubric, refers to the first commercial implementation of a new invention into the marketplace, although this can be confusing when discussing the processes of innovation; whenever

gap, while the refinement and take-up of such technologies can narrow it. We conclude with a discussion of interventions on the supply side that can encourage a reduction in the energy-efficiency gap.

Background and Examples

The term "efficiency gap" seems first to have been introduced in the literature by Hirst (an engineer) and Brown (a geographer) in a paper in which they discuss reasons why "Only half of the potential for improving U.S. energy efficiency over the next 20 years is likely to be achieved, given current government policies and programs" (Hirst and Brown 1990). The term gained salience in a widely cited paper by the economists Jaffe and Stavins (1994). Jaffe and Stavins (1994), while tentative in its conclusions, is clearly sceptical about claims that a large efficiency gap exists.

Although Hirst and Brown (1990) mentions supply-side issues, it does not discuss the supply side in detail. Jaffe and Stavins give still less attention to the supply side. The authors suggest, at least implicitly, that lack of demand is the likely source of any supply problems. For example, Jaffe and Stavins suggest that observed high consumer discount rates are quite possibly just a reflection of true consumer preferences and further, that it is costly to learn how a technological improvement fits into one's home or firm or to learn about reliable suppliers. So, it seems appropriate to ask, are inadequacies in the supply of energy-efficient goods and services due only to lack of demand or, are there also problems that are specific to the supply side?

As far as we know, there are no systematic studies of supply-side problems that might contribute to the efficiency gap. However, in the literature there is anecdotal evidence, often collected for other purposes, that strongly suggests there are indeed important supply-side problems. In what follows we examine some of this evidence. We are particularly interested in the connections between supply-side problems and incentives for innovation.

Principal/Agent Problems

The incentives of the buyer of an energy-consuming product and the seller of that product are rarely perfectly aligned, particularly with respect to energy consumption. The buyer's desire for low energy costs for the product's operation must be transmitted to the seller through a demand signal for the product, but as we discuss below for several examples, principal/agent problems militate against this transmission, and are likely to be even bigger hindrances when these problems exist in non-competitive markets.

Pay-TV and Set-Top Boxes

Pay television (pay-tv) providers' primary business is the provision of information services, especially entertainment. Incidental to this business, pay-tv providers supply consumers with a variety of devices, generically known as set-top boxes (STBs). The average annual electricity consumption of set-top boxes for U.S. households with pay-tv is estimated to be 325kWh (Hardy, Phillips et al. 2012), or about 75% of the consumption of a new, U.S. standards-compliant refrigerator. Much of this energy consumption is the result of operating practices that require STBs to be continuously available for program updates—most STBs draw near-full power, even when they are not being actively used. Engineering estimates suggest that it is technically and economically feasible to reduce the electricity consumption of STBs by 30 to 50% (Hardy, Phillips et al. 2012). But pay-tv providers would have to change their products in order to make these savings a reality – for example, by reducing on-mode power levels, reducing sleep-mode power levels, reducing the amount of time STBs spend in higher-power modes, and shifting where recording and playback occur within the network (Hardy, Phillips et al. 2012) – and thus far, they have been reluctant to make such changes to improve energy efficiency.

In the broad sense of the term, this is a 'principal/agent' problem (IEA 2007). The principal, the consumer, wants to obtain a bundle of services from the agent, the pay-tv provider, which is both entertaining and efficient. The agent has less incentive to meet the energy efficiency aspect of the consumer's demand for services because the agent does not pay the energy bills.

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possible, we try to refer to "adoption" when referring to initial commercial implementation. Between invention and innovation are a number of modifications that can occur throughout the supply chain to improve the performance and reduce the cost of the new invention (see discussion of the sources of innovation in von Hippel (1988)). "Diffusion" refers to the widespread use of a commercial innovation and is often studied by researchers as a communication process through which future users become persuaded to adopt new technologies, in part due to information from previous users (Rogers 1995).

But in the textbook description of the problem (see, for example, Milgrom and Roberts 1992), a number of assumptions apply that relate to perfect competition. The principal can choose among many agents, the agent is expected to pursue a single clearly defined objective, and the principal has at least some control over the agent's incentives. None of these assumptions would appear to hold in the real world example of a householder as principal and a pay-tv provider as agent:

- Choice of agents—competition is limited (in many cases there is only one pay-tv provider), which means that the agent has more power to set prices and other attributes of a product for the principal to purchase
- Multiple objectives—the availability of desired television programs and other qualities related to the provision of entertainment clearly dominate the energy efficiency of the service
- The agent's incentive—to first order, the agent's incentive is to shift costs of operation to the principal and the principal has very little say in this arrangement

The above conditions create something of a worst-case principal/agent problem that makes it no surprise that pay-tv providers are able to resist changing their products to make them more energy efficient.

Landlord/tenant

The principal/agent problem that has probably received the most attention is that of the landlord and the tenant. Energy use in buildings is determined by a combination of the qualities of the building and its equipment, as well as the behaviour of building occupants. When the tenant pays the energy bill, the landlord does not have a direct incentive to provide the building with energy-efficient features. In the energy context this problem was identified at least as early as 1980 (Blumstein, Krieg et al. 1980). Although rental markets are often competitive (with exceptions in significant markets like New York City and San Francisco where rent-control exists, and the landlord incentives to provide energy-efficient properties are likely to be further reduced), the problems associated with misaligned incentives are compounded by the fact that rental property has many attributes including location, condition, aesthetic appeal, and size. Energy performance is rarely, if ever, the first thing that landlords advertise about their properties or that prospective tenants seek among a property's attributes. The problem is exacerbated by the fact that information about the qualities of a building that determine energy performance (for example, amount of insulation, furnace efficiency, etc.) is often difficult to obtain.

An ambitious attempt to examine the landlord/tenant problem is a study undertaken by the IEA (2007). This study looked at the commercial office sector in Japan, the Netherlands, and Norway, at residential space heating in the Netherlands, and appliances and equipment in the U.S. Much of the study is concerned with estimating the share of energy consumption that might be subject to inefficiencies because the building occupant, who pays for the energy, does not choose the building characteristics or equipment that affect energy performance. This is, of course, quite different from estimating the actual size of the efficiency gap that results from landlord/tenant problems. As a practical matter, data limitations make it very difficult to isolate the effects of the landlord/tenant problem from other factors, such as problems upstream in the supply chain (discussed below) that may contribute to the efficiency gap. Allcott and Greenstone (2012) attempt to estimate the efficiency gap that results from landlord/tenant problems on the basis of admittedly slender evidence: an estimate that about one third of U.S. housing stock is subject to landlord/tenant problems (see IEA 2007) and some data about the level of insulation in California rental property, as well as differences in ownership of Energy Star appliances between homeowners and renters. The paper finds that landlord/tenant problems likely account for roughly 1% of total residential consumption in the U.S., a not inconsequential amount, given the diffuse uses of energy and the variety of causes of inefficiency in those uses.

Actors in the building supply chain

Landlords, however, are only one of many actors involved in supplying buildings and building services. Very few of these actors have responsibility for paying the energy bill consequent on the operation of a building, and should, therefore, be a potential source of principal/agent problems regarding building energy efficiency.[2]

Lutzenhiser et al. (2001) provides a useful description of the actors in the supply chain for commercial buildings. They identify ". . . six major industry groups involved in [new] commercial building markets—providers of capital, developers, design and delivery firms, community/political/regulatory interests, real estate service providers, and users. . . . Developers orchestrate the development process and represent the interest of providers of capital. The nature of these interests will vary depending on whether the project is build-to-suit, build-to-hold, or build-to-sell. The building is produced by architects, engineers, and contractors in the design and delivery

[2] Note that depending on the structure of leases or other arrangements for occupancy, even users could be one of the actors that have little direct incentive for reducing energy costs.

group. Community/political/regulatory interests shape what can be built through zoning, codes, review, and other community processes. Real estate service providers offer marketing, sales, leasing, investment, management, and operations services and represent the interests of many market actors. Users are the firms and organizations that occupy the buildings." A variety of other groups (for example, product vendors, manufacturers and insurance providers) also influence the development process.

The link between these actors and the energy cost of operating buildings is tenuous, and the actions of upstream actors constrain the energy efficiency choices of those downstream. The focus of these actors, according to Lutzenhiser et al. (2001) is reducing risk and producing "reliable economic returns by using standard approaches and models that have worked well in the past." These factors militate against change in building supply.

Complications imposed by industry concentration

As mentioned above, the existence of market power dampens the responsiveness of suppliers of goods or services to consumer demand, as actors in a monopolistic or oligopolistic setting can more or less set prices and quality attributes. This section provides other instances of the difficulties posed by industry concentration for closing the energy-efficiency gap.

First mover disadvantage

In a concentrated industry a supplier may find that being the first to produce a new, more efficient technology is too risky. For a simple example, consider a duopoly: Both firms produce an inefficient consumer good, and both are capable of producing a more efficient good. Each knows that if it produces a more efficient good that is successful, then the other firm will also produce a more efficient good. Producing a more efficient good is initially costly (e.g., requires investment in new plant). So neither firm produces a more efficient good because producing a more efficient good will increase costs without creating a long-term competitive advantage. Note that this example does not require collusion, only knowledge about the capabilities of one's competitors.

How do stories like this play out in the real world? The answer is that they are hard to verify but the observed behaviour of firms in concentrated industries is sometimes consistent with this logic. For example, Kwoka (1984), in explaining a lack of innovation in the auto industry in the mid-1980s, writes, "When Alfred Sloan shaped General Motors in the 1920s, he operated on the belief that automobile customers wanted four things— 'comfort, convenience, power, and style.' GM launched annual style changes at that time, and as other firms sought to emulate its success, they too moved towards extensive style and model changes. In an oligopolistic setting, style changes were a safer outlet for rivalrous instincts than engineering and technological advances. Quality was nowhere on Sloan's list. Along with engineering and technological improvements, it was seen as too uncertain and too subtle to be an effective way" to produce competitive advantage through devices like marketing. **"**This view was nearly unanimously held by the few domestic automobile producers, based on Sloan's teachings" and reinforcement by decades of experience emphasizing style. "The American consumer had few realistic alternatives for most of this time, given the extent of concentration in the U.S. industry."

Price discrimination

Fischer (2005) presents a theoretical "model of a producer that uses energy intensity to help segment consumer demand and maximize prices. In this case, since low-income consumers always have lower willingness to pay, the monopolist's strategy is to charge a purchase price that extracts their entire surplus. Meanwhile, the monopolist offers them inefficiently high levels of energy intensity, in order to be able to charge high-income consumers more for the higher quality appliances. To that same end, the monopolist offers the consumers of the high-end products an efficient level of energy intensity—that is, all the energy efficiency for which they are willing to pay."

Houde (2012) uses a unique dataset to provide empirical evidence that such price discrimination occurs in an appliance industry (refrigerators), and occurs to a greater extent in a world in which a policy is in place that highlights top performing appliances (in this case, with Energy Star labels). He also shows, however, that contrary to typical expectations of the effects of market concentration on consumer welfare, consumers could actually benefit from the greater exercise of market power under Energy Star because "the presence of the certification leads to a greater diversity of products in equilibrium."

Suppression of new technology

Part of the lore about strategies that may be pursued to protect existing practices is that firms sometimes suppress 'disruptive' new technology. This might happen if a firm that owns an invention that has the potential to provide superior performance but would make an existing product obsolete chooses to sequester the invention instead of developing it. There is not a lot of evidence for this practice in the area of energy efficiency (although it is well-known in other industrial areas), but there is at least one lawsuit, known as *Alling v. Universal Manufacturing Corp* (see Chin 1998) in which an oligopolist was found to have acquired a patent license from an inventor for an electronic fluorescent light ballast with the intent of sequestering the invention. According to Chin, "the oligopolist was making an excellent profit on its existing energy-inefficient product—an electro-magnetic, carbon core ballast—and did not want to invest in developing the inventor's energy-saving electronic ballast until it had to. The licensee also did not want its few competitors to have this new technology or to introduce comparable, albeit possibly more expensive, new technology. Therefore, the licensee took the license from the inventor and shelved the invention for years. It also threatened its competitors that if they introduced their next generation products, it would introduce the invention it had licensed, which was better than its competitors' next generation innovations."

Closing the Efficiency Gap and Innovation

The discussion above highlights many instances in which it is likely that supply-side issues matter to the energy-efficiency gap. There is even more suggestive evidence in data regarding the energy intensity of the U.S. economy (that is, energy consumption per dollar of GDP).

As shown in Figure 1, U.S. energy intensity has declined steadily for the past three decades, due, at least in part[3], to the improved energy efficiency of goods and services. This is itself evidence, *a priori*, that there has been a persistent energy-efficiency gap, as an efficiency-based reduction in energy intensity means that a gap must have first existed between the technically and economically feasible potential for energy efficiency and actual practice. Further, the relationship between energy intensity and the energy-efficiency gap gives reason for hope when looked at through a supply-side lens. Thirty years ago, Meier, Wright, et al. (1983) estimated that the energy-efficiency gap – the difference between the potential for efficiency gains and realized energy savings – was on the order of 30 percent. By 2009, although U.S. energy intensity had declined by about 50 percent, the energy-efficiency gap was still on the order of 30 percent (see, e.g., McKinsey & Co. 2009). This implies not only that end-users adopted at least some of the more efficient goods and services that were available thirty years ago, but that the supply chain for efficient goods and services found ways to create new, more efficient products and services, whether through formal or informal invention or the application of such tacit knowledge as technical know-how.[4]

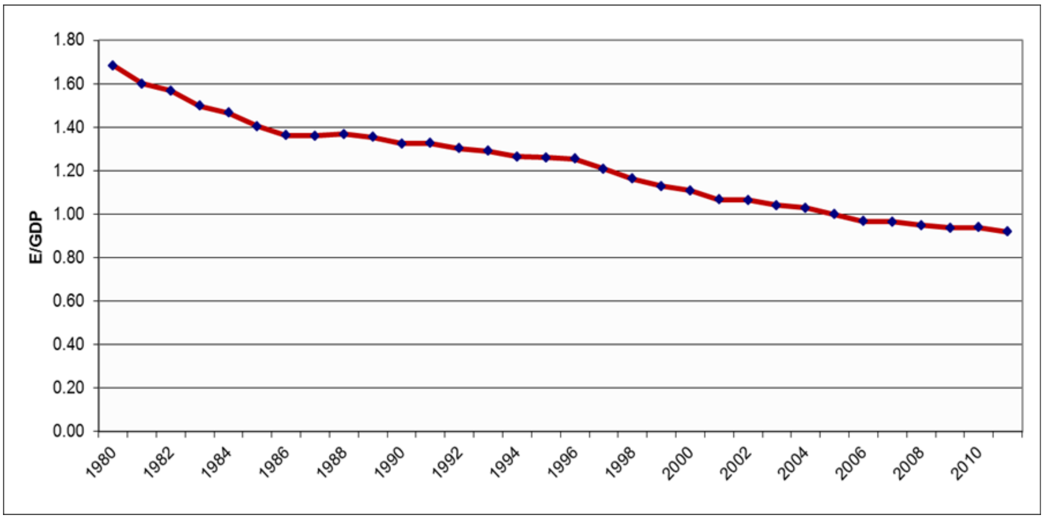

Figure 1: U.S. energy use per dollar of gross domestic product, 1980-2011 (index, 2005=1). Source: U.S. Energy Information Administration

[3] An Internet search for "energy intensity" reveals a large literature on the topic, much of which is concerned with separating efficiency improvements from other factors such as changes in the mix of outputs. A recent example is a paper by Metcalf (2008) that estimates that 75 percent of the decrease in US energy intensity was due to efficiency improvements.

[4] As an example, starting at the top of the chain, the invention could be a better light source, a better method for manufacturing the light source, better ways to use and control the light source, or better ways to install the light source.

The efficiency gap is clearly a dynamic phenomenon, changing over time and with the processes of innovation; the invention of new, more energy-efficient technologies can widen the gap, while the refinement and take-up of such technologies can narrow it. Closing the gap takes time and often involves significant costs—manufacturing processes and construction processes may need to be changed, obsolete equipment may need to be replaced, personnel may need to be trained or retrained, distribution channels may need to be established, and consumers may need to learn what works for them. The prospects for a sustainable world would be better if the rate of decline in energy intensity were faster—at least, for example, greater than the rate of growth of the economy.

This leads us to the policy question, should government attempt to increase the rate of innovation in the direction of energy efficiency (by this we include the full set of innovative activities involved in engineering energy-efficient goods and services) through supply-side interventions that are different from interventions that change the incentives for final consumers? The underlying market failure that these policies would address is that the returns to society from energy-efficient innovation are greater than the returns to the innovators for such innovation. At the same time, policies might be targeted to the specific restraints on innovation stemming from the supply-side issues discussed in the previous section.

We address this policy question below, first by examining possible supply-side interventions and then concluding with some further discussion of why supply-side interventions might be appropriate.

Intervention on the Supply Side

Industries develop in response to traditional forces of competitive rivalry, including: the threat of new entrants; the threat of substitute products; the determinants of supplier power; and the determinants of buyer power (Porter 1979; Porter 1980). Note that the structural conditions of industry are strongly determined by government actions, which: can form a barrier to entry or sometimes exit in an industry; can affect the relative positions of an industry's suppliers and buyers or perform the function of supplier or buyer; can affect the relative positions of substitutes vis-à-vis existing firms; and can affect rivalry among existing competitors (see discussion in Taylor, Fujita et al. 2012). But beyond government's structural effects on industry, it can also affect an industry's focus on the energy efficiency aspects of product design. Policy instruments that currently affect the energy efficiency of industry include top-performer labelling, public procurement, upstream subsidies, and minimum efficiency performance standards (MEPS), (for more information, see Nadel 2002; Gillingham, Newell et al. 2006). This section goes into more detail about previous uses of some of these policy instruments. We are particularly interested in the effects of these policies on innovation.

Top-performer labelling

As noted above, "efficiency targets" created by top-performer labels like Energy Star can serve as focal points for price discrimination in concentrated industries. But programs like Energy Star can also create targets for manufacturers that lead to the production of more energy-efficient products. Howard et al. (2012) describes coordinated efforts to improve the performance of televisions in which a market-leading strategy plays a

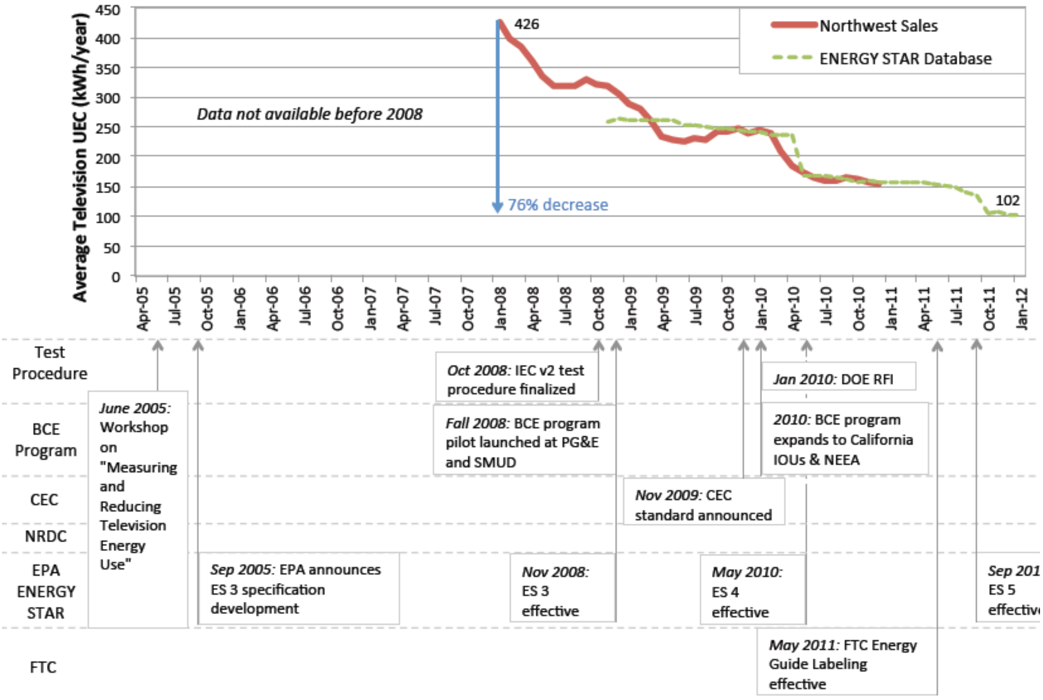

Figure 2: Correlation between Energy Star targets and television energy performance. Source: Howard, Baron et al. (2012).

prominent role. The production of televisions is highly competitive and the technology is changing rapidly with new models released on an annual cycle. Figure 2 shows a correlation between changes in Energy Star targets and the energy performance of televisions. According to Howard, Baron et al. (2012), “Manufacturers have been very responsive to the [Energy Star] specification, indicating that they place a large importance on meeting the Energy Star levels, which is also apparent from the rapid increase in market share of qualified televisions immediately following a new specification taking effect.”

Upstream subsidies

Wickes, Rasmussen et al. (2012) describes a program (80 PLUS) in which subsidies were offered to the manufacturers of desk-top computers to install more efficient power supplies. In 2004, the problem, according to Wickes, Rasmussen et al. (2012), was that, while research showed that power supplies with efficiencies of at least 80% could be produced with a small incremental cost, the typical efficiency of power supplies in desk-top computers was in the range of 45 – 65%. Wickes, Rasmussen et al. (2012) reports that it was not uncommon for desk-top manufacturers to say that end customers were not asking for energy-efficient desk-top computers and that the manufacturers of power supplies did not have the needed technology. At the same time, power supply manufacturers would say that desk-top manufacturers were not asking for or willing to pay the premium for the added level of efficiency for power supplies. In addition to subsidies, the 80 PLUS program attempted to address the efficiency gap through revision of the Energy Star specification and the development of a test procedure that manufacturers could use in specifying efficient power supplies, thereby breaking through this logjam. While it would be difficult to identify with precision the relative contributions of the various strategies in the 80 PLUS program and other unobserved factors, the efficiency of desk-top computers has now evolved in the desired direction—there is near universal compliance with the 80 PLUS specification.

Minimum Efficiency Performance Standards (MEPS)

In order to function effectively, top-performer labelling and MEPS require analysis of the overall distribution of products that are currently available in the marketplace, as well as of the upstream technology developments that have the potential to affect the product mix during the regular updating cycle for these instruments (Taylor, Fujita et al. 2012). Figure 3 provides an illustration of the importance of the time dynamic for both innovation and policy in the context of MEPS. In each time period in this figure, there is a distribution of products on the market with different efficiencies. A model product (in this case, a refrigerator) remains static regarding its energy efficiency performance while its competitor products and the related MEPS change over time. The model begins as a top performer in the initial time period t_0, during which standard$_0$ is set so that it will be applied in the next time period t_1 (the shaded area shows the share of the distribution of products that will be cut-off as laggard energy-performers when the standard comes into effect in the next time period). In time period t_1, the

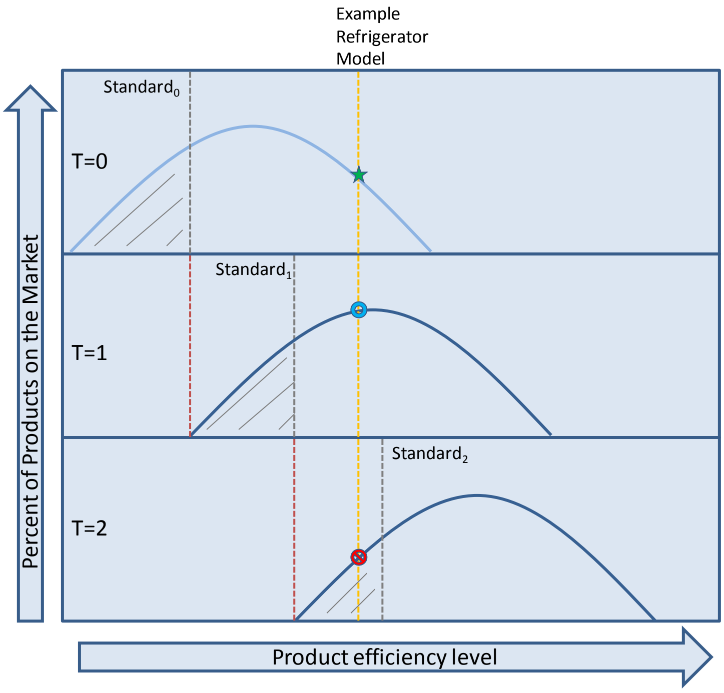

Figure 3: Illustration of the innovation dynamic in repeated standard-setting. Source: Taylor, Fujita et al. (2012)

model refrigerator becomes average for the new distribution of products while standard$_1$ is set to be applied in the next time period t_2. In time period t_2, the model refrigerator becomes a laggard energy-performer that will be cut off when standard$_2$ comes into effect in the next time period t_3 (not shown). In other words, if the model refrigerator does not change, it will eventually be banned by MEPS.

This dynamic is a driver of innovation for the manufacturers of the product in Figure 3, particularly if manufacturers conclude that it is credible that the MEPS will continue to tighten over repeated cycles. Note that policy-makers must undertake a delicate dance in the case of MEPS and innovation. If MEPS are set too lax, there will be less incentive for firms to focus a significant portion of their innovation efforts on the energy use – as opposed to other aspects – of their products, particularly in establishing brand differentiation (Taylor, Fujita et al. 2012). If MEPS are set too tight, there will be risks of "crowding out" innovative efforts on other aspects of a product as well as ending sales for certain products, both of which may reduce profits to the extent that overall innovation budgets are cut. Either scenario could result in a slower pace of advance in energy-efficient appliances than is societally optimal.

Conclusion

In the previous sections we have attempted to lay the groundwork for a different framing to the energy-efficiency gap, in which the supply side plays a central role. We began with a discussion of why a different approach is needed and followed with some examples from the literature of supply-side contributions to the efficiency gap. We then observed that the continuing decline in the energy intensity of the U.S. economy provides compelling evidence of a persistent energy-efficiency gap. We also observed that this gap is dynamic, changing over time and with the processes of innovation; for example, the invention of new, more energy-efficient technologies can widen the gap, while the refinement and take-up of such technologies can narrow it. Activities on the supply side are strongly implicated in both the widening and the narrowing of the gap. Finally we discussed some strategies for government intervention on the supply side.

Understanding the role of the supply side in both narrowing and widening the efficiency gap is important because of the potential importance of government intervention in affecting the rate and direction of technological change with regard to energy efficiency. Note that economic theory says that the rate of innovation is likely to be suboptimal when the returns to society from innovation are greater than the returns to the innovator—this is quite often the case, with this point particularly well-appreciated in the context of research and development expenditures by firms but less appreciated along the many actors in a supply chain. It stands to reason that if this is typical of even traditionally-defined industries, it is even more likely to be true in the case of energy efficiency, which can be considered an attribute of goods and services that has both low salience and high societal benefit. The rate of innovation in energy efficiency may also be suboptimal because a number of factors, some of which are discussed above, impede the transmission of consumer incentives for efficiency to the upstream actors in the supply chain.

Our cursory review of policy interventions that can affect the supply-side of the energy-efficiency gap suggests that there might be some relatively low-cost interventions that could indeed increase the rate of innovation. Absent an indisputable counterfactual (that is, what would have happened without an intervention), one can always argue that the observed progress would have occurred autonomously (see Blumstein 2010). Given the supply-side issues discussed above, as well as the positive externalities of the growth of new knowledge through directed research and development, we think that further analysis is warranted to better understand whether relatively low-cost measures like upstream subsidies and MEPS may be superior to energy taxes when addressing the energy-efficiency gap. Since any energy price increases are politically difficult, raising energy prices to levels that are high enough to achieve results similar to upstream subsidies and standards will be especially hard, because prices would probably have to be well above the cost of the relevant externalities of energy use, and thus distortionary as well as unpopular.

As is often the case with new approaches, we find ourselves still grappling with the clarity of our language and concepts, and searching for the best examples to illustrate the relevant problems and their solutions. We believe that the material we have presented here, however, is sufficient to justify more systematic efforts to study the supply-side of the efficiency gap, and we hope that evidence from other countries will enrich the picture of supply-side problems and strategies to deal with them.

Acknowledgements

This work was supported in part by a research contract from the California Energy Commission. The authors would also like to thank the Precourt Energy Efficiency Center for its support.

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