THE COST-EFFECTIVENESS OF VOLUNTARY ENERGY EFFICIENCY PROGRAMS*

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1. Introduction

The European Union has set up ambitious objectives regarding future improvements in energy efficiency, and there exist today a wide array of different national policy instruments aiming to remove some of the barriers against cost-effective investment in energy efficiency. Many of these policy initiatives take the form of various types of voluntary agreements, in which often industrial firms may get tax cuts if they pursue given measures to improve their energy efficiency. Still, our understanding of these programs is so far limited (see, however, Anderson and Newell, 2002), and there exists a need to develop tools with which their impacts and cost-effectiveness can be evaluated. The purpose of this paper is therefore to conceptually analyze the cost-effectiveness of voluntary energy efficiency programs targeted at the industrial sector. This implies analyzing whether such programs induce behaviour leading to an outcome in which the achieved energy efficiency improvements take place where they are the cheapest.

In doing the above the paper draws on lessons from the economic welfare theory and behavioural economics literature (e.g., Sorrell et al., 2004) to discuss the scope for market failures in the industrial sector's energy use. We raise the issue of which policy objective energy efficiency programs are best suited for (e.g., carbon dioxide reduction, reduced energy need etc.), and in the paper a broad methodological framework for assessing the cost-effectiveness of voluntary energy efficiency programs is outlined. The focus lies on the presence of asymmetric information and bounded rationality, and the paper discusses how these factors may influence the cost-effectiveness of these types of programs. We also highlight the impact of the self-selection problem – i.e., the voluntary component of the program – on the program's cost-effectiveness.

In a second step this framework is employed empirically on the Swedish PFE program by using firm-level data provided by the Swedish Energy Agency. The PFE program provides energy-intensive companies the opportunity of a reduced tax on electricity use. In return they have to introduce and obtain certification for a standardized energy management system and carry out an energy audit. The latter is done to identify specific energy efficiency investment to be implemented in subsequent years if these have a pay-back time of less than three years. Similar programs exist in other countries (e.g., Denmark, United Kingdom), and the lessons drawn from the Swedish case should therefore be of general interest. The PFE program is still ongoing (Swedish Energy Agency, 2007), but with the data we have we can still discuss potential drawbacks and strengths of the *design* of the program.

The paper proceeds as follows. In section 2 we review some recent experiences of voluntary energy efficiency programs in Europe, and introduce the ongoing PFE program in Sweden. Section 3 provides a theoretical discussion of the cost-effectiveness of these types of programs, while section 4 comments on the potential cost-effectiveness of the PFE program. Section 5 concludes the paper.

* This paper has been prepared for the 31st IAEE International Conference, Istanbul, 18-20 June, 2008. Financial support from the Swedish Energy Agency (AES program) is gratefully acknowledged as are valuable comments from Staffan Jacobsson on earlier drafts of this work. Any remaining errors, however, reside solely with the authors.

2. Voluntary Energy Efficiency Programs in the European Industry Sectors

In order to increase energy efficiency – and reduce greenhouse gas emissions – voluntary agreements between the government and the energy intensive industries have been introduced in a number of European countries. These agreements are often used to offer industrial firms an alternative to, for instance, tax policies. If the firm enters the agreement the government provides either a tax break (e.g., reduced carbon dioxide tax) or a promise of relaxed environmental regulations in the future. In this section we briefly review some of the experiences of voluntary energy efficiency programs in Europe, and we also introduce the Swedish PFE program. Our review is not implied to be exhaustive, but it does highlight a number of key issues and problems in the use of these types of voluntary programs.

2.1 *The Use of Voluntary Energy Efficiency Programs in Great Britain, Holland and Denmark*

The British *Climate Change Programme*, which aims at reducing carbon dioxide emissions in the industry sector, is in part based on so-called “Climate Change Agreements” (CCAs). These were introduced in 2001 and imply that energy intensive industrial firms can sign a ten-year contract with the government to achieve either a more efficient use of energy or carbon emissions reductions. By signing such a contract the firm gains an 80 percent reduction in the so-called “climate change levy”, which constitutes a tax on (non-transport related) energy use. Not all companies can join this system; their production processes have to be energy intensive and they should be subject to intense international competition. During the first three years of the program, carbon dioxide emissions decreased by a total of 3.5 million tonnes, and about 70 percent of these reductions were achieved in the steel industry (British Government, 2004).

In Holland so-called Long-Term Agreements (LTAs) have been used for the manufacturing industry since the early 1990s. The nature of the agreements differs across sectors, but a number of general requirements must be met by each sector who wishes to enter a LTA. The sector must, for instance, be fairly homogenous in terms of products and processes and it should represent a major consumer of energy. Each sector must also be represented by a well-established industry organization. Each LTA has been preceded by an assessment of the potential for energy savings in the sector, and this assessment has formed the basis of a long-term energy efficiency plan for the entire sector. During the period 1989-2000 the goal was to reduce energy intensity by 19 percent, and by 1997 an 18 percent average reduction had been achieved but with substantial differences in outcomes across sectors (Farla and Blok, 2002). The Dutch experience with LTA has raised concerns about how to monitor realized energy efficiency improvements, and about trade-offs between material intensity and energy efficiency improvements (Ibid.). The results from Rietbergen et al. (2002) also indicate that “only” about 25-50 percent of the total reduction in energy use during the 1990s can be attributed to the LTAs.

Voluntary agreements have also been used between the Danish Energy Agency and the energy intensive industry in Denmark. These three-year agreements have aimed both at achieving energy efficiency improvements but also to reduce emissions of carbon dioxide, and they can be signed either by individual companies or by a group of companies. The main reason for permitting also “collective” agreements is the desire to minimize the system’s administrative costs. The most important incentive to enter an agreement is a reduction in the carbon dioxide tax. In 1997 about 45 percent of total industrial energy use was covered by these voluntary agreements. A typical Danish agreement then had the following three facets:

- the energy use of each participating company must be assessed by an external consultant, who is paid by the company (but at a subsidized rate).
- the identification of profitable energy saving investments – i.e., those with a payback time of 4-6 years – which have to be pursued by the company. The companies are entitled to the carbon tax reduction even if no profitable energy savings investments can be identified.
- a requirement that the company has to implement an energy management system.

This Danish system has in part been quite cost-ineffective, primarily due to the administrative costs involved in financing the energy use assessment process, but these costs are also substantially lower for the collective agreements (Johannsen, 2002).

Moreover, there arises quite often a problem of asymmetric information (see also section 3). Specifically, the external consultants tend to have a rather generic knowledge about energy efficiency improvements, while the company representatives know much more about the specific production process of the company. For this reason it has been difficult to induce investments involving alterations of the production process through the agreements, and the consultants have “only” been able to identify measures such as the substitution of new pumps, fans and ventilation systems for old ones (Ibid.). Johannsen (2002) stresses also that this limited knowledge among the consultants leads to high search costs:

”On the impact side, numerous case studies [...] show that, due to the consultants’ lack of knowledge about specific production technologies used in the plants, many of the audits (in particular the second or third audit in the same production plant) only lead to the identification and implementation of few and relatively small investment projects, i.e., the additional CO₂ emission reduction directly derived from the audit is limited.” (p. 136)

This illustrates that the marginal cost of carbon dioxide reduction increases quickly with the number of consultancy hours used to analyze the companies’ energy use patterns. Krarup and Ramesohl (2002) confirm that the voluntary agreements used in Holland and Denmark have led to significant reductions in energy use and carbon dioxide emissions but at a comparatively high cost.

2.2 The Swedish Program for Improving Energy Efficiency in Energy-intensive Industries (PFE)

On 1 July 2004, due to the adoption of the EU’s Energy Tax Directive, a tax of 0.005 SEK per kWh on industrial process-related electricity was introduced.¹ The Directive gives, however, the energy-intensive companies that are subject to the tax, the opportunity of reduced taxation on their electricity consumption if they take action to improve their energy efficiency. As an instrument to promote this, the program for improving energy efficiency (PFE) came into force in January 2005. The aim of the program is partly to increase the efficiency of energy use among companies that consume large amounts of electricity. Participation is voluntary and companies which applied before 31 March 2005 were entitled to a tax reduction backdated to 1 July 2004 (Swedish Energy Agency, 2005).

The Swedish Energy Agency is the supervising authority, and decides thus whether a company may participate in PFE. Most notably, only energy-intensive companies can participate and a company is defined as energy intensive if it meets at least one of the following criteria: (a) the cost of energy in the company amounts to at least 3 percent of the value of the output; and (b) the company’s energy, carbon dioxide and sulphur taxes amount to at least 0.5 percent of the added value.

The program period starts on the date at which the company is accepted for participation and lasts for five years. During the first two years the company has to introduce and obtain certification for a standardized energy management system (EMS), and carry out an energy audit and analysis in greater depth than the one described in the EMS. In addition, the audit and analysis within the PFE-program must be carried out from a system perspective and must cover both the short and the long term. It must also include measures to improve electricity efficiency. The purpose of the energy audit and analysis is to enable the company to monitor its energy consumption and identify measures to improve the efficiency of its electricity consumption. The company will prepare a list of the measures to be implemented in subsequent years, and these should have a pay-back time of less than three years. The list is to be submitted to the Swedish Energy Agency. During the first two years the company also has to introduce standard procedures for the procurement of high-consumption electrical equipment. As a consequence, as new equipment is being bought, the company will give greater preference to energy-efficient products. Finally, the company has to introduce procedures for project planning.

When a company has participated in PFE for two years, it must submit its first report to the Swedish Energy Agency to demonstrate how the program requirements have been met. During the following three years the company should implement the identified measures and continue to apply the energy management system, as well as the procedures for purchasing and project planning. They also have to demonstrate the effect of the purchasing procedures on the company and assess the effects of

¹ Manufacturing companies in the metallurgy, electrolysis and chemical reduction sectors are exempted from the tax.

the project planning procedures. In the end of the programme period the company must submit its final report. In this report the company should analyze its actual electricity consumption during the period and the actual impacts of the measures. If the company has achieved an improvement in electricity efficiency which broadly speaking is equivalent to the improvements that would have been achieved if the tax had been imposed, then the company will have fulfilled its obligations under the program.

About 1150-1300 companies have had the opportunity to participate in PFE, and they represent a total electricity consumption of about 42 TWh (2002). In the beginning of 2007, 117 companies participated in the program, together consuming roughly 30 TWh, and 98 of these have sent in their first report to the Energy Agency. According to the reports they are planning to carry out almost 900 different measures to reduce their electricity consumption and these actions shall be carried out during the following three years at an estimated cost of SEK 1 billion. The measures planned by the participants are estimated altogether to reduce electricity consumption by at least 1 TWh per year.² At an average price of electricity of 0.50 SEK per kWh this corresponds to yearly cost reductions of about SEK 500 million. In addition, the companies are granted a yearly tax relief of about SEK 150 million (Swedish Energy Agency, 2007).

2.3 Summarizing Comments

The above experiences of voluntary agreements in Europe – including the ongoing Swedish program – raise a number of questions related to the cost-effectiveness of the policy. Cost-effectiveness implies that the policy objective is met at minimum costs to society, and this requires both a proper assessment of the actual objective to be met as well as of how efforts are allocated across, for instance, firms and sectors. The next section 3 provides a conceptual discussion of the evaluation of the cost-effectiveness of these types of programs, and highlights the question of which policy objective (e.g., energy efficiency, carbon reduction) the assessment should rest on. We also pay attention to potential market imperfections and to the voluntary aspects of the program, which will tend to influence the allocation of policy-induced energy efficiency and/or carbon dioxide reduction efforts across different firms and sectors. In section 4 we revert to the Swedish PFE program, and illustrate how the theoretical insights can be used to shed some light on the potential cost-effectiveness of this program.

3. The Economics of Voluntary Energy Efficiency Programs

3.1 The Case for Market Failures in Industrial Energy Use

From a policy point-of-view energy efficiency is often promoted for several reasons, including security-of-supply and not the least greenhouse gas reductions. In its *Green Paper on Energy Efficiency* the European Commission (2005) concludes that:

“Energy saving is without doubt the quickest, most effective, and most cost-effective manner for reducing greenhouse gas emissions, as well as improving air quality, in particular in densely populated areas. It will therefore help Member States in meeting their Kyoto commitments.” (p. 5)

This is very unlikely to be generally true, primarily since promoting energy efficiency will only provide incentives for reduced energy use and not, for instance, for fuel substitution. In other words, such policy instruments will deny market actors the flexibility to choose the cheapest climate policy compliance measures available. Newell (2000) provides support for this view:

“Energy-efficiency improvements certainly can be relevant for climate policy; however, it is also important to remember that primary fuels differ substantially in terms of their GHG emissions per unit of energy consumed. Policies focused on energy use rather than GHG emissions run the risk of orienting incentives and efforts in a direction that is not cost-effective. In particular, policies focused on energy efficiency ignore the other important way in which GHG emissions can be reduced – namely by reducing the carbon content of energy. [...] Economists generally prefer to focus policy instruments directly at the source of a market failure. Policies focused on carbon emissions – such as tradable carbon permits or carbon fees – will provide incentives for conserving particular fuels in proportion to the fuels’ GHG content.” (p. 17)

² Approximately half of the efficiency improvements arise from production-related processes while the other half arises from auxiliary systems within the companies (Swedish Energy Agency, 2007).

For this reason it is useful to identify those market failures that motivate policy intervention targeting increased energy efficiency *per se*, thus beyond those measures already taking place in the private market. Jaffe and Stavins (1994) identify a number of such market failures.

First, new information often possesses substantial public good characteristics and therefore leads to important positive spillover effects. This means that a single firm cannot generally reap the entire benefits of its investment in new knowledge, and it does therefore not have enough incentives to undertake such activities. An important policy lesson from this is that even if policies to correct for environmental externalities are in place, the level of investment in new knowledge may be suboptimal (and too low). However, although the social benefits of such information activities are higher than the private ones, it must be acknowledged that this is the case for many such activities throughout the entire economy (including many energy projects). Moreover, for different reasons the presence of *asymmetric information*, implying that one actor holds information but faces too few incentives to transfer this to other actors although this would increase overall economic efficiency. One example is the principal-agent problem where the principal (e.g., the CEO) is unable to perfectly monitor the agents' (e.g., the engineers) performance and introduce enough incentives for the agent to pursue all profitable energy saving projects.

While the above assumes perfectly rational (i.e., profit-maximizing) firms, we need also to pay attention to the potential bounded rationality of firms. The latter implies that individuals within firms will economize on scarce cognitive resources by utilizing routines and rules of thumb and will tend to make satisfactory decisions rather than expend time and effort searching for the optimum decision (Simon, 1957; Foss, 2003). According to the organization and management literature, this leads to path dependent behaviour. The notion of path dependencies recognizes that "history matters". Thus a firm's previous investments and its repertoire of routines constrain its future behaviour (Teece et al., 1997). In other words, firms continue to perform business as usual. This can be because of sunk costs or technical interrelatedness, i.e., whole systems are seldom replaced at once which raises the probability of continue doing the same (Lambert and Tikkanen, 2006). Organizations develop patterns of behaviour, often referred to as routines or set of rules, to respond to problems as they arise. Once a set of rules is developed it is reinforced by, for instance, in-house training and incentive structures. Thus, bounded rationality can induce rules following behaviour which can lead to path dependence (Heffernan, 2003). According to this strand of literature a set of rules or problem solving techniques within the firm will persist since they are costly to change but also because the system itself is not questioned. This may motivate the use of policy instruments that raise attention to energy use issues.

Voluntary energy efficiency agreements may involve, as illustrated above, the substitution of energy management systems for conventional taxes on energy use, and for this reason it is important to analyze if such a switch improves the possibility to internalize information asymmetries and raise companies' attention towards energy efficiency measures. As explained below, the choice between these two types of policy instruments is likely to influence the cost-effectiveness of the overall policy.

3.2 The Cost-effectiveness of Voluntary Agreements

Voluntary agreements – in which a company commits to undertaking certain measures to reduce, for instance, energy use in return for tax rebates – are often claimed to constitute cost-effective policy instruments (e.g., European Commission, 1996). One reason is that such agreements, it is argued, permit substantial flexibility in compliance strategies, and often the administrative costs can be kept low (e.g., Segerson and Miceli, 1998). It is difficult to identify previous studies that empirically test these claims, but there exist a number of theoretical studies that discuss the potential cost-effectiveness of voluntary agreements and possible sources of ineffectiveness. A majority of these studies focus on collective (sector-based) agreements, but they still contain arguments that apply equally well to agreements between individual firms and the government.

Golombek and Moen (1999) focus on a situation where an industry organization acts on behalf of all firms in the industry and enters an agreement with the government to achieve certain emission reductions. In return, the government promises not to implement any new environmental taxes and/or regulations. The authors assume that the organization decides upon an internal allocation of emission reduction measures across individual firms, but it cannot perfectly monitor the performance of each

firm. The results of their analysis show that there is a clear risk that the emission reduction will not be performed cost-effectively (and that thus a uniform emissions tax had been better). The reason for this is that the larger companies typically stand more to gain from the promised tax rebate, and will therefore have a stronger incentive to reduce emissions compared to the smaller firms. The small firms can free-ride on the measures undertaken by the larger firms, and the marginal cost of emission reduction will be likely to differ across these two groups of firms.

Glachant (1999) concludes that the presence of firm-government asymmetric information tends to reduce the cost-effectiveness of voluntary agreements and instead strengthens the case for using market-based instruments. He claims that:

"[Voluntary agreements] are cost efficient in the following context: very large shared uncertainty, concentrated industrial sectors in which the heterogeneity in pollution abatement activities is low. In this respect, voluntary approaches which have been used to promote a move of traditional waste management scheme towards recycling (packaging recycling, car recycling) seem well suited. Indeed, this policy area is characterised by important changes in pollution abatement activities and thus gives birth to large uncertainties. Concerning CO₂ reduction agreements in high energy consuming industries, we can be more suspicious about the cost efficiency of voluntary approaches. As a matter of fact, in these sectors, given the weight of energy cost in total production costs, firms have paid much attention to energy saving activities for a long time. It can be assumed that the nature and the cost of energy saving techniques are well known by each firm and that the informational context is asymmetric."

In other words, if firms possess more knowledge about their abatement costs and/or potential for energy efficiency improvements than does the government representatives, market-based instruments are likely to be more cost-effective. Through their optimizing (cost-minimizing) behaviour firms reveal their true abatement costs when exposed to, for instance, a tax on emissions. In this way the problem of asymmetric information can be solved, but in the case of voluntary agreements these information gaps persist and firms lack an incentive to reveal their real costs and opportunities.³

As was noted above, many analysts stress the fact voluntary agreements permit a large degree of flexibility in terms of compliance strategies and in this way they induce cost-effective solutions. Bizer (1999) points out, however, that one ought not to exaggerate the importance of this argument, and he notes that even traditional command-and-control regulations often involve a considerable amount of negotiations about the technical and economic potential for, say, emissions reductions at the firm level. Bizer (1999) also questions – in part on empirical grounds – the ability of voluntary agreements to stimulate technological progress and long-term cost reductions.

An important aspect of voluntary agreements between individual firms and the government concerns the voluntary features of the instrument. Only those firms that consider it worthwhile to participate will choose to do so. This self-selection may have important impacts on the cost-effectiveness of the agreements, and Figure 1 provides an attempt to illustrate possible outcomes. In this example we assume that initially each firm pays a unit tax on its electricity consumption, but the government commits to abandoning the tax if the firm voluntarily chooses to implement an energy management system and strive to identify and pursue reasonably profitable energy efficiency improvements. The upper part of Figure 1 illustrates for an entire industry sector the (net) costs of different measures to improve energy efficiency, and the horizontal distance indicates the energy saving potential of each measure. According to Figure 1 some measures would be profitable even in the absence of the electricity tax (i.e., their net cost is negative). With the imposition of the electricity tax all firms are provided an incentive to undertake otherwise unprofitable investments in energy efficiency, and if all firms face the same unit tax and possess perfect information about all possible measures and their costs, the most cheapest options will be pursued first and the tax will tend to promote a cost-effective increase in energy efficiency.

³ This may also have unfavourable long-term consequences for the implementation of energy policy measures. In the presence of information asymmetries the firm will have an incentive to signal high compliance costs to avoid the likelihood of stringent future regulations. In the economics literature this is sometimes referred to as the ratchet effect (e.g., Kolstad, 2000).

Figure 1: The Self-selection Problem in Voluntary Energy Efficiency Programs

However, as discussed above due to information inefficiencies and bounded rationality reasons not all these measures will necessarily be pursued (or even identified). In Figure 1 these latter (hidden) projects are highlighted using shaded areas. The lower part of Figure 1 shows two companies, A and B, which differ in terms of energy intensity and thus also in terms of prior experience of paying attention to energy efficiency improvements. Firm A has a low electricity cost share and thus a limited total potential for reduction in electricity use, but the firm's past incentives to attend to its electricity use have been limited. For these reasons it is plausible to assume that relatively low-cost measures but with a limited overall potential have been neglected by this firm. Firm B, in contrast, has a higher electricity cost share and it has therefore paid more attention to reducing its electricity use in the past. This means that the amount of previously unattended measures may be fewer (the right shaded area in Figure 1) but their overall energy saving potential may also be higher. In the presence of a uniform electricity tax all measures below the electricity tax line – except those with shaded areas – will be pursued.

Let us now consider the case where the two firms are offered a tax rebate if they implement an energy management system. For simplicity we assume that the energy management system will help both firms to identify all possible measures (i.e., even the shaded ones) and that the required hurdle rate for energy efficiency investments would induce the same economic incentive as would the electricity tax. A reasonable outcome is that only firm B will choose to enter the agreement, since it has relatively much to gain from the tax rebate in terms of reduced expenses. In our example this has the advantage that this firm will be “forced” to pay more attention to its electricity use and adapt its

corporate organizational structure accordingly, and it will thus be able to identify and ultimately pursue all profitable investments. Firm A, the one with a low electricity cost share and thus the least prior experience of attending to electricity use, will however have fewer incentives to join the system, and this implies that there is a risk that the previously unattended – and comparatively cheap – energy efficiency improvements remain unattended. This reduces the cost-effectiveness of the voluntary agreement scheme.

In sum, our simplified example illustrates a number of important factors determining the cost-effectiveness of voluntary agreements on energy efficiency improvements between the industry and the government:

- Compared to a uniform unit electricity tax, a necessary (but not a sufficient) condition for a voluntary agreement scheme performing better from a cost-effectiveness point-of-view is that there is evidence of information efficiencies in the tax case leading the relevant firms to forego otherwise profitable investments. The larger the degree of shared uncertainty (among firms and the government), the stronger is the case to substitute voluntary programs for taxes.
- The voluntary component of the programs implies that only those with high energy cost shares and thus plenty of prior experience of energy efficiency improvements will join, and as a consequence cheap measures in less energy-intensive firms risk remaining unattended.
- A uniform hurdle rate across all *participating* firms will promote a cost-effective allocation of investments but only across these firms, not the least since it provides flexibility on the part of firms to undertake only those investments that are “profitable”.
- However, if the hurdle rate provides very different economic conditions compared to the electricity tax still paid by the non-participating firms it will lead to a situation where the marginal cost of energy savings differ across different groups of firms.

In the next section we make use of the above theoretical arguments to briefly comment on the potential cost-effectiveness of the still ongoing Swedish PFE program.

4. The Cost-effectiveness of the Swedish Program for Energy Efficiency (PFE)

Since the Swedish PFE system is still ongoing we focus our attention in this section on the design of this system, and how this can affect the adoption of cost-effective energy efficiency investment. We need first to comment on the relevant objectives and potential market failures associated with PFE. As was noted in section 2, PFE originates from the desire to compensate the companies that were subjected to the new process-related electricity tax. This explains the program’s focus on energy intensive companies only, and its main objective is to promote the implementation of investments in more efficient use of electricity.

The experiences from other countries (section 2) show that often carbon dioxide reduction remains an important objective for these types of programs. However, since a large share of the companies that participate in PFE (see below) also are part of the European emissions trading system for carbon dioxide (EU ETS) no such additional net reductions will be achieved by PFE. Specifically, any sector-specific carbon reductions achieved due to PFE will simply imply that the relevant sectors either bank or sell surplus emission allowances or use them to increase their use of fossil fuels. In other words, the total emissions of carbon dioxide will remain the same, and are given by the caps under the National Allocation Plans. Any attempt to use PFE in the allowance trading sector to achieve global carbon dioxide reductions will therefore be futile.

According to the Swedish Energy Agency, the investments planned by the participating firms are estimated to reduce overall electricity consumption by at least 1 TWh per year. In section 3 we discussed a number of potential market failures explaining why profitable energy efficiency investments in industrial firms are not pursued. It should be noted however that the more energy-intensive companies that we consider the less likely we are to identify substantial information asymmetries and evidence of bounded rationality. High electricity cost shares provide a strong incentive to pay attention to different ways of reducing these costs. Nevertheless, even energy intensive companies may not pursue all cost-effective options. Due to the public good character of new knowledge the private rate

of return on energy efficiency investments may be lower than the corresponding rate of return, thus motivating the use of lower hurdle rates than the ones typically applied by the private companies.

Moreover, an additional reason lies in the fact that these companies often are large and then problems of asymmetric information (principal-agent problems) arise at the firm level. The engineers that have the best knowledge about the production process may not face enough incentives to search for efficiency improvements although the board of directors and the CEO prioritizes such behaviour. On the other hand, asymmetric information between the firms and the government may also be present, not the least in energy-intensive industries such as those participating in PFE, and this reduces the likelihood that a large number of profitable energy efficiency projects will result following this type of government intervention. In sum, the substitution of an energy management system for a regular tax may raise the firm-internal awareness of energy saving opportunities but at the same time it reduces the incentive to reveal more costly measures to increase energy efficiency as would a tax. Thus, the voluntary agreement and tax instruments tend to address different types of information failures and it is therefore important to assess the relative importance of each of these inefficiencies.

Early experiences from the Swedish case confirm that PFE has led to increased knowledge about energy use even in the energy-intensive companies. The energy management systems that form part of PFE should include the company's energy policy, quantifiable targets as well as an action plan outlining how the targets are to be met. Accordingly, these systems may be perceived as one way of closing information gaps and raising firm-level attention towards energy use issues. Interviews with the companies participating in PFE show that the program has induced these to allocate a large share of their investment funds on energy efficiency improvements, and the companies confirm that the program has raised overall competence levels with respect to energy use and savings (Hammes, 2006). This has led companies to in part question its existing repertoire of routines and "rules of thumb". Thus, this indicates the presence of firm-specific information asymmetries, although it does not tell us whether addressing these is overall economically efficient.⁴ The degree of shared uncertainty about investment possibilities and costs between the regulator and the firm is likely to be limited among the energy-intensive companies and the regulatory authorities, thus generally speaking in favour of a tax solution. Still, it should be clear that additional in-depth empirical studies are needed before more elaborate conclusions can be drawn.

Since the PFE program applies a uniform hurdle rate for energy efficiency investments a cost-effective allocation of energy savings measures across the participating companies will be promoted, but this is only true if the problem of firm-government information asymmetries is limited. Moreover, there is a clear risk this hurdle rate will induce measures with marginal costs substantially different from those undertaken in the non-participating group of companies. Moreover, the problem of self-selection may have a negative impact on the cost-effectiveness. In Figure 2 we show the number of companies eligible for participation in PFE grouped by total electricity costs (upper half) as well as the number of participating companies categorized in the same manner. Figure 2 shows that from the total group of 1277 companies as much as 83 percent had a total annual electricity cost of less than SEK 50 000. From this low energy-intensive group only about 1 percent ultimately chose to join PFE, but 31 out of a total 38 companies (83 percent) with an annual electricity cost exceeding SEK 1 million did join PFE. This provides evidence of a self-selection process that may influence the cost-effectiveness of the program; companies with high electricity costs are strongly overrepresented among the PFE participants.

This conclusion is reinforced by Figure 3, which shows the electricity consumption levels of the participating companies by sector. The participating companies, approximately 10 percent of the eligible ones, consume about 30 TWh of the taxed electricity, i.e., 86 percent of the total electricity consumption of all eligible companies. Most participants are found in the pulp and paper industry, which represents as much as 72 percent of total electricity consumption in the participating group.

⁴ One reason for this is that the re-allocation of investments towards increased energy efficiency may crowd out other productive investments.

Figure 2: Eligible and Participating Companies in PFE Categorized by Total Electricity Costs

Source: Söderholm and Hammar (2005).

As has been indicated above, this process of self-selection leads to a number of problems. *First*, the presence of firm-government information asymmetries imply that electricity taxes would do a better job in energy-intensive companies while an energy management system could be more effective in companies with a low energy-intensive production process due to the lack of prior experience of energy efficiency measures. The current set-up of PFE induces the reverse situation. *Second*, although

firm-internal information asymmetries may well exist in the participating energy-intensive companies – implying that energy management systems could do a good job in detecting cost-effective measures – this is likely to be even more true for the non-participating companies (again due to their comparatively low accumulated knowledge stock in the energy efficiency field).

Figure 3: Participating Industry Sector and their PFE-relevant Electricity Consumption

Source: Söderholm and Hammar (2005).

Finally, any discussion on the cost-effectiveness of different policy instruments must include comments on the costs of administering these instruments. It is too early to provide an overall assessment of these costs in the case of PFE, but it should be clear that its administration costs are likely to be higher than those related to the electricity tax. In the former case costs arise both at the Swedish Energy Agency but also at the Swedish National Tax Board, which administers the tax reduction. The administrative costs include, not the least, efforts to assess baseline assessments of the energy efficiency measures that would have occurred in the absence of PFE.

5. Concluding Remarks and Implications

The paper has discussed a broad theoretical framework within which one can critically assess the impacts and the cost-effectiveness of voluntary energy efficiency programs, and it illustrates in part how this framework could be employed in practice. The results presented are therefore of particular use in policy evaluation studies. The results show that the presence of information inefficiencies and asymmetries represent one of the major motives for policy intervention in the industrial energy efficiency field, but the substitution of energy management systems for electricity taxes do not appear to address these asymmetries cost-effectively. In part this conclusion arises from the fact that the set-up of many voluntary programs offering tax rebates only induces energy-intensive companies to participate in the programs, and these companies generally have paid relatively lot of attention to energy efficiency measures in the past. In addition, for these companies the presence of firm-government asymmetries is likely to be significant.

While the above provides, we argue, a critical analysis of the static cost-effectiveness of many voluntary energy efficiency programs, one should however be careful in using this as a general critique of these types of programs. There are several reasons for this, and we choose to stress three here. *First*, cost-effectiveness represents only one out of many policy criteria affecting the choice of instrument, including, for instance, goal fulfilment, distributional impacts and legitimacy. *Second*, the Swedish PFE system represents a way of securing the industry's international competitiveness while maintaining the goal of increased energy efficiency. With this dual objective, PFE may well constitute a second-best option. Related to this is also the fact that environmental taxation (including carbon pricing) is often lax in energy-intensive industries for competitiveness and carbon leakage reasons, and this means that these companies may face artificially low energy prices and thus too low incentives to undertake investments in energy efficiency. Again, since taxation is difficult voluntary agreements may represent second-best solutions (e.g., Ankarhem and Brännlund, 2006). *Finally*, the analysis in this paper has primarily focused on the static cost-effectiveness of voluntary programs, but in the end the *long-term* impacts of these types of systems must also be acknowledged. The Swedish PFE system introduces a systematic way of organizing energy use in the company and thus raises the attention towards efforts that may generate future cost savings in the energy field. In the long-run this may lead to significant learning impacts and – given the public good characteristics of this new knowledge – to substantial spillover effects. This shows the need for elaborate *ex post* evaluations of these types of programs, as well as future research efforts on the presence of market failures, policy, and technological development in the process industries.

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