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Abstract

"Getting the price right" is a goal of many market-oriented energy policies. However, there are situations where the consumer paying for the energy is separate from the owner of the energy-using device. Economists call this a "principal agent problem". A team organised by the International Energy Agency examined seven end uses and one sector where principal agent problems existed: refrigerators, water heating, space heating, vending machines, commercial HVAC, company cars, lighting, and firms. These investigations took place in Australia, Japan, the Netherlands, Norway, and the United States.

About 2 – 100% of the energy consumed in the end uses examined was affected by principal agent problems. The size (and sometimes even the existence) varied greatly from one country to another but all countries had significant amounts of energy affected by principal agent problems. The presence of a market failure does not mean that energy use would fall substantially if the failure were eliminated; however it does suggest that raising energy prices—such as in the form of carbon taxes—will not necessarily increase efficiency investments.

Introduction

The price of energy is a key factor influencing its efficient use. Governments have long recognized that raising the price of energy (or certain forms of energy) can be an effective tool in discouraging consumption and stimulating more efficient use of energy. "Getting the price right" is therefore the goal of many market-oriented energy policies. Economists argue that, when prices accurately reflect full costs of supplying energy, consumers will make appropriate decisions regarding investments in more efficient equipment, purchases of energy, and use of energy-related services. Several strategies have been proposed to minimize energy and environmental problems by placing additional charges on energy. The charges have many names—carbon taxes, emission charges, green taxes, externalities charges, etc.—but all of them involve directly or indirectly raising the price of energy.

But how effective are higher prices in achieving the desired reductions? And should higher prices be the *primary* policy used to limit energy consumption? This paper examines the extent to which consumers actually "see" energy prices and are therefore likely to respond to them. This study quantifies the amount of energy consumption that is "affected" by a market failure and "insulated" from price signals. This paper presents part of a larger IEA study that will be published later this year (International Energy Agency, 2007).

Many researchers have identified and catalogued market barriers, such as Blumstein et al. (Blumstein et al., 1980) in the process of explaining why consumers ignore seemingly attractive investments in energy efficiency (sometimes referred to as the "efficiency gap"). Others, notably Jaffe and Stavins (Jaffe and Stavins, 1994a, Jaffe and Stavins,

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1994b) and Sorrell (Sorrell, 2004) explored the distinctions between the broader concept of barriers and more precisely defined market failures. Jaffe and Stavins categorised the distinctions and presented them in a matrix similar to that shown in Table 1.

Table 1. Distinctions between market failures and market barriers

	Explains efficiency gap	**Does not explain efficiency gap**
Barriers that are market failures	*Examples:* Public good attributes of information Positive externalities of technology adoption Asymmetric information in energy service markets – leading to problems of adverse selection, moral hazard and ***split incentives***	*Examples:* Distortions in energy pricing (e.g. departures from marginal cost pricing, cross subsidies, VAT differentials etc.) Environmental externalities (e.g. air quality, acid rain, climate change)
Barriers that are <u>not</u> market failures	*Examples*: Hidden costs (e.g. disruptions to production) Reduced product performance (e.g. lower reliability) Option value of delaying investment	

As Table 1 shows, there are many explanations for consumers not investing to the expected levels in efficiency. Market failures are an especially important category, however, because most economists agree that government policies are justified when market failures exist (Australia Productivity Commission, 2005, Hinchy et al., 1991, Sanstad, 2006, Sorrell, 2004, The Stern Review, 2007). Other factors help determine how consumers respond to energy prices. Some of these factors are described in studies of consumer perception of energy use (Kempton, 1981) and behaviour (see, for example, Wilhite et al., 2000). An important first step, regardless, is to confirm that consumers actually see the price signal and are in a position to respond to it.

How Much Energy Consumption is Insulated from the Energy Price? Our Approach

In this paper (and the larger IEA study on which it is based) we focus on a single category of market failure: the principal agent problem (also called "split incentives"). The "principal agent (PA) problem" occurs when one party, the "principal", engages another party, the "agent" to make certain transactions on its behalf. A familiar situation is the relationship between a landlord and a tenant. A simplified description of the obligations is shown in Figure 1.

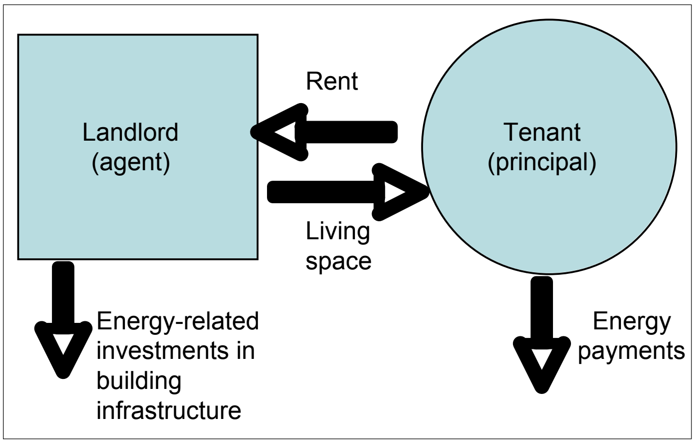

Figure 1. Energy-related transactions for landlord and tenant

The tenant pays rent to the landlord in exchange for use of the building. The tenant pays energy costs that are, to a great extent, determined by the infrastructure present in the building. The landlord makes (or declines to make) investments in the building so as to lower its energy consumption and has little incentive to make efficiency investments because these reduce costs are borne only by the tenant. If energy prices rise (from market fluctuations or as a result of a deliberate policy), the landlord still lacks any short-run incentive to respond with additional investment in efficiency. In these ways, we say that the landlord's decisions regarding energy efficiency and the consumers' energy use are "insulated" from energy prices. The tenant can sometimes conserve but her options are typically constrained to measures that mostly rely on strict conservation rather than efficiency improvements. For certain end uses, such as refrigerators, the tenant has no effective means of adjusting consumption (beyond unplugging the unit) in cases where it is chosen or provided by the landlord.

Other relationships can also exist between the principal and agent regarding responsibility for investments in efficiency and payment of energy costs. Table 2 depicts the four possibilities.

Table 2. Transactions from an end user's perspective

	Can choose technology	**Cannot choose technology**
Pays the energy bill	Case 1: No PA problem	Case 2: Efficiency problem
Does not pay the energy bill	Case 3: Usage and efficiency problem	Case 4: Usage problem

In Case 1, the end user selects the energy-using technology (furnace, car, refrigerator, etc.) and pays for its energy consumption. In this case there is no PA problem because the principal and agent are the same entity. The party will be economically motivated to make a reasonable investment in efficiency (but it does not ensure that it will happen because other barriers may be present).

In Case 2, another entity – the agent—selects the energy-using technology, but the end user—the principal—pays for the energy use. This is the situation depicted in Figure 1. A PA problem exists here and is defined in Table 2 as an "efficiency problem". This is the situation in many rented buildings, where the landlord selects the heating system, level of insulation, and other building characteristics but the tenant must pay the heating or cooling bill. The landlord's decisions regarding investment in efficiency are insulated from the price signal, that is, an increase in energy prices are unlikely to quickly spur new efficiency investments.

In Case 4, the end user neither selects the energy-using technology nor pays the energy bill. We call this a "usage" problem because the end user faces no economic constraint on usage. Here the end users—who are shielded from the price of energy—consume more energy than is reasonable because they do not pay for it. This is the situation where the landlord selects the level of insulation and pays the heating bill determined by the behaviour of the tenants. It leads to the common situations in Eastern Europe (Dempsey, 2006) (and elsewhere) where tenants open windows to regulate the inside temperature, even on the coldest days. This market failure is the reverse of Case 2. Here the landlord is the principal and the tenant is the agent. In this case, the agent is not acting in the landlord's interest.

In Case 3, the end user selects the technology but does not pay the utility bill. In Case 3 both a usage *and* efficiency problem are present. This may seem like a bizarre situation but it does in fact exist. For example, in some companies the employees are permitted to select their cars and the companies pay for fuel consumed on both company and personal trips.

The IEA study focused on Cases 2–4 the "efficiency" and "usage" PA failures. For each PA problem, the study estimated the amount of energy consumed by end users in those cases. In each case, the study sought to identify who is the principal and who is the agent? The defining questions are:

- Who selects, purchases, and owns the energy-using technology?
- Who pays the energy bill?
- Who controls operation of the energy-using technology?

A PA problem *might* exist if these parties are different. For example, many landlords select the water heaters but their tenants must pay the energy bill for the hot water. The landlord has little incentive to invest extra in a high efficiency water heater. Another example is in the provision of cable TV services. Virtually all cable TV service providers require subscribers to use the providers' own decoder boxes to maintain security. (New decoder boxes can consume as much electricity as a refrigerator, so this is a significant home appliance.). The cable TV provider makes the decision regarding the box's energy efficiency—if it is considered at all—while the subscriber pays for the box's electricity consumption. In both of these cases the party making the energy efficiency decision is "insulated" or "shielded" from the energy price signal.

Our principal criteria for selecting case studies were:

- a clear procedure to identify the amount of energy in each of the four cases;
- sufficient data for a credible estimate;
- examples from different sectors; and
- a possibility of duplicating the study in more than one country.

In general, we sought examples that could be examined within a structure of an international collaboration. The "stories" behind each case study needed to be easily understood by a diverse group of researchers.

Results

Eight situations where principal agent problems existed were examined. These are listed in Table 3, along with the countries where analyses were undertaken.

Table 3. Principal agent problems examined in this study

Case Study	Countries
Refrigerators	USA
Water heating	USA, Norway
Space heating	Netherlands, USA, Norway
Vending machines	Japan, Australia
Commercial HVAC	Japan, Netherlands, Norway
Company cars	Netherlands
Lighting	USA
Firms	Australia, Norway

Below, we briefly describe the principal agent problems identified in Table 3.

Refrigerators. Refrigerators are sometimes purchased by landlords for their tenants and by home-builders for homes to be sold. In most cases, these landlords and home-builders will not pay the refrigerators' electricity costs. This creates an efficiency problem—Case 2.

Water heating in buildings. The occupants of a typical single family home select the water heater and pay for the water heating energy use so no PA problem exists—Case 1. However, contractors or other agents make purchasing decisions in a significant fraction of homes, which creates an efficiency problem—Case 2. In rental units, the landlord typically purchases water heaters but the tenant pays for the energy used to heat the water. This creates an efficiency problem – Case 2. In larger buildings the landlord heats water in a central boiler and typically includes energy costs as part of the rent. This creates a usage problem – Case 4.

Space heating in buildings. The occupants of a typical single family home make the decisions regarding heating system investments and pay for the space heating energy use so no PA problem exists—Case 1. However, contractors or other agents make purchasing decisions in a significant fraction of homes, which creates an efficiency problem—Case 2. In rental units, the landlord typically purchases heating equipment and maintains the building's energy-related infrastructure. In some cases the tenant is responsible for paying heating costs; thus the landlord has no incentive to invest in efficiency improvements because the tenant gains all the benefits. This creates an efficiency problem—Case 2—but many variations are possible.

Television set-top boxes. These boxes receive and de-code television signals for televisions connected to cable and satellite networks. The service provider typically requires the customers to use its box so as to maintain security and compatible technology. The customer pays for the box's electricity use and has no discretion about selecting a more efficient model. The service provider is generally a monopoly and therefore has no competitive reason to offer high-efficiency boxes. This creates an efficiency problem – Case 2—for the whole set-top box market.

Residential lighting. Tenants or owners can install efficient lights in homes. In many cases, the occupants—regardless of ownership—can replace incandescent lights with more efficient compact fluorescent (CFL) lamps without changing the fixtures. This situation corresponds to Case 1 where no PA problem exists. On the other hand, electricity costs for some tenants are included in the monthly rent. In these cases tenants have no incentive to buy efficient or switch them off when not required. This creates a usage problem—Case 4—and also applies to all other uses of electricity in the building.

Vending machines and refrigerated display cabinets. The beverage (and food) distributor pays a property owner to locate a vending machine on the property. In return the property owner receives a share of revenues. Food distributors often give grocery stores and other retail outlets free refrigerated display cabinets to store and showcase their products. In both cases, the property owner has little or no information regarding the machine's electricity consumption and no discretion to select a more efficient machine. The property owner must pay for the machine's electricity consumption. In Japan, however, the beverage distributor pays the property owner a second fee—a kind of reimbursement—to cover the vending machine's energy costs. The type of PA problem depends on the specific circumstances of the financial arrangements.

Commercial building HVAC expenses. Heating and cooling costs in commercial buildings are often rolled into the rent or charged according to the floor area rented. Tenants have little incentive to control energy consumption. Similarly, the building owner has little incentive to invest to improve the building's efficiency because all energy expenses are passed to the tenants. This creates a usage problem—Case 4—but may be constrained by certain operating restrictions; for example, the landlord may reduce ventilation rates outside of operating hours.

Company cars. Many countries offer preferential taxes or benefits for cars used for business. As a result, company cars account for nearly half of new car sales in Australia and Belgium. Company cars are typically larger, less efficient, and are driven further than private vehicles. Some firms allow their employees to select their cars and even provide free fuel. This creates a combined usage and efficiency problem—Case 3.

Principal agent problems inside firms. Organisational constraints inside firms and organisations sometimes create internal PA problems. This would appear to defy logic because the principal and the agent are the same entity; however, organization arrangements that are designed to promote growth or other goals can coincidentally create PA problems. Early investigations by DeCanio (DeCanio, 1993, DeCanio, 1994) in the United States, followed by Sorrell in the UK (Sorrell, 2004), Sæle (Sæle et al., 2005) in Norway, and Schleich and Gruber (Schleich and Gruber, 2006) in Germany have described this phenomenon. Many firms maintain separate budgets for capital investment and operations and are administered by two different—and distant—divisions. Managers in charge of operations cannot easily obtain approval for investments that will reduce energy costs because those investments fail to rise to the top of queue. These PA problems create nationally significant amounts of energy use that are effectively insulated from energy price signals (at least in the short term). The IEA study addressed this topic but the analysis is not presented in this paper.

Matrixes with estimates of energy use in each of the four categories of PA problems were developed. An example for residential water heating in the United States adapted from Murtishaw and Sathaye (Murtishaw and Sathaye, 2006) is shown in Table 4. The Table shows the fraction of homes in each of the four cases, which is an intermediate step in the process of estimation. The notes in the Table illustrate some of the assumptions and data requirements needed to make this estimate.

Table 4. Shares of water heaters in different market situations in the United States (adapted from (Murtishaw and Sathaye, 2006))

	Household Can Choose Technology	Household Cannot Choose Technology
Household Pays Energy Bills	**21% of homes** 40% of occupant-owned single-family homes older than 13 years 40% of occupant-owned multifamily homes, older than 13 years, with individual water heaters, utilities not included	**68% of homes** Most rental units Newer occupant-owned units 60% of occupant-owned units, older than 13 years, w/ individual water heaters
Household Does Not Pay Utility Bill	**Negligible** Possibly a small number of condos older than 13 years with individual water heaters	**10% of homes** Significant number of rental units Condos with central boilers Newer condos with utilities included

Only 21% of US homes had water heaters that were selected by the same person that paid the energy bills. In the remaining 78% of US homes, the end user did not select the water heater or did not pay the energy bills (or both). Thus, a PA problem—either an efficiency or usage problem—exists in roughly 3/4 of the homes. This corresponds to approximately 78% of the energy consumed for residential water heating in the US residential sector. A similar approach was used in all of the other cases and the results are summarised in Table 5.

Table 5. Fraction of energy use affected by principal agent problems in various countries examined in this paper

End Use	Countries Examined	Fraction of Energy Use Affected by Principal-Agent Problem
Residential refrigerators	USA	25%
Residential water heating	Norway, USA	38 – 77%
Residential space heating	Netherlands, USA	46 – 48%
Residential lighting	USA	2%
Television set-top boxes	USA	100%
Company cars	NL	32%
HVAC in commercial leased space	Japan, Netherlands, Norway	17 – 44 – 90%
Vending machines	Japan, Australia	44 – 80%

Multiple values are presented when similar analyses were undertaken in more than one country. The Table shows the fraction of energy use within that end use affected by the principal-agent problem ranges from 2% (in residential lighting) to 100% (for set-top boxes). The fraction for residential lighting is low because most users can gain access to the lighting fixtures and change lights to more efficient models (so no PA problem exists). Differences in business practices are reflected in the ranges of energy use affected by the PA problem. For example, nearly all Norwegian commercial leased space includes HVAC expenses in the rent, while in Japan the fraction is much smaller.

Policies towards company cars vary greatly among countries. These policies were sometimes created to support a domestic automobile industry. Nearly a third of vehicle fuel consumption is affected by this market failure in the Netherlands. The problem was once equally prevalent in the United Kingdom; however, tax policies were changed so that many of the PA problems were minimized (Inland Revenue, 2004).

No country or economic system is immune from market failures. This is demonstrated in the cases of HVAC in commercial buildings, water heating, and residential space heating. However, the size of the market failure differed markedly in some countries. Compared to Australia, Japanese vending machine operators have developed a mechanism to minimize PA problems, that is, a reimbursement to the operator to cover energy costs. The same solution could be applied to the PA problem in set-top boxes, that is, to require the service provider to reimburse customers for the boxes' electricity use. In this way, most set-top boxes shift from being in Case 2 to Case 1 where no PA problem exists. The service provider is more likely to consider energy efficiency when establishing specifications for new boxes because it is now responsible for paying energy costs.

The amount of affected energy use caused by each PA problem may appear small but the impact can be significant when the combined PA problems in a whole sector are considered. The combined impact of identified market failures in the US residential sector equals roughly 24% of total primary energy use in that sector (see Table 6).

Table 6. Residential energy use in the United States affected by principal agent problems in this study

	Energy Use Affected by Principal Agent Problems		
Case	**Primary Energy Use (PJ)**	**Fraction of End Use**	**Fraction of All Residential**
Refrigerators	390	25%	2%
Water Heating	1060	42%	6%
Space Heating	2500	48%	15%
Lighting	23	2%	0.1%
Set-Top Boxes	160	100%	1%
Total	*4130*	--	*24%*

Roughly a quarter of the residential energy use is therefore insulated from the price signal. In some cases, the persons paying the energy bills are unable to invest in efficiency improvements while, in other cases, they are unable to effectively manage operations and behaviour.

Conclusions

Market failures often prevent what appear to be cost-effective investments in energy efficiency from taking place. Economists generally agree that governments may intervene in markets where these failures occur. To date, most research has focused on cataloguing these market failures and barriers and not the size of the failures. There will be more urgency to implement policies if the amount of energy affected by market failures is large.

This paper—and the larger, IEA study on which it is based—for the first time sought to estimate the amount of energy consumption that is affected by a single class of market failures, the principal agent problem. The shielding from the price signal varies depending on the relationship between the person responsible for energy investments and the end user who controls energy use. In one case the person paying for the energy is unable to invest in efficiency improvements—an “efficiency” problem—and, in the other case, the person paying for the energy is unable to manage operating behaviour—a “usage” problem.

Principal agent problems appear in many parts of the economy and range widely in the amount of energy use impacted. The examples presented here found affected energy use to be as small as 2% of the end use (in residential lighting) to as large as 100% (for set-top boxes). In one case it was possible to estimate the size of the principal agent problem for a whole sector—24% for the US residential sector. Other principal agent problems exist but we lacked the resources to identify and quantify them.

The same type of principal agent problem appears in many countries although their size varies with the institutional arrangements. Some countries have developed mechanisms to minimise the impact of the market failures, such as novel energy reimbursement schemes (like that used for Japanese vending machines), revised tax arrangements (for UK company cars), and minimum energy efficiency standards for appliances.

The presence of a principal agent problem does not automatically infer that energy is being used in an uneconomic fashion or that removal of the failure will lead to energy savings. Removing PA problem in the U.S. residential sector may not necessarily lead to large energy savings because minimum energy efficiency standards and building codes constrain the range in purchasing decisions. For example, a landlord may buy the cheapest refrigerator or water heater on the market but their efficiencies will not be so much lower than the most efficient on the market. But the four cases depicted in Table 2 suggest that the demand for energy, even within a single end use, is composed of groups facing starkly different market conditions. Each of these groups is likely to respond very differently to higher energy prices. The results also suggest that a unique policy directed towards each group may be more effective than the blunt tool of higher prices.

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