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Informational Barriers to Energy Efficiency – Theory and European Policies*

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Abstract

This BEER addresses informational barriers to energy efficiency. It is a widely acknowledged result that an energy efficiency gap exists implying that the level of energy efficiency is at an inefficiently low level. Several barriers to energy efficiency create this gap and the presence of asymmetric information is likely to be one such barrier. In this article a theoretical framework is presented addressing the issues of moral hazard and adverse selection related to energy efficiency. Based on the theoretical framework, European policies on energy efficiency are evaluated.

The article is divided into two main parts. The first part presents the theory on information asymmetries and its consequences on energy efficiency focusing on the problems of moral hazard and adverse selection. Having established a theoretical framework to understand the agency barriers to energy efficiency, the second part evaluates the policies of the European Union on energy efficiency.

The BEER finds that problems of moral hazard and adverse selection indeed can help explain the seemingly low levels of energy. In both presented models the cost to the principal from implementing high energy efficiency outcome is increased with the informational asymmetries. The theory reveals two implications to policies on energy efficiency. First, the development of measures to enable contractual parties to base remuneration on energy performance must be enhanced, and second, the information on technologies and the education of consumers and installers on energy efficiency must be increased. This could be complemented with certification of installers and energy efficiency advisors to enable consumers to select good agents. Finally, it is found that the preferred EU policy instrument on energy efficiency, so far, seems to be the use of minimum requirements. Less used in EU legislation is the use of measuring and verification as well as the use of certifications. Therefore, it is concluded that the EU should consider an increased use of these instruments, and in particular focus on a further development of standards on measurability and verification as well as an increased focus on education of consumers as well as installers and advisors on energy efficiency.

Keywords: Energy efficiency, Informational barriers, European policies

JEL-codes: Q48, D82, F42

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1. Introduction

The World is facing complex energy challenges. Countering climate change caused by rising emissions of carbon dioxide, ensuring affordable access to energy for an increasing population and securing the supply of energy. These challenges has become more severe with the recent economic downturn, since affordable energy plays a key role in economic growth and measures taken to curb the rising carbon emissions are likely to come at a cost. Additionally, geopolitical events and increasing volatility of energy prices have increased the insecurity of energy-supply. In order to address these challenges, in December 2008, the European Union (EU) adopted an integrated energy- and climate change policy embracing the well known 20 20 20 - 2020 goals of a 20% cut in greenhouse gases, 20% reduction in energy consumption and a 20% share of energy from renewable sources by the year 2020 (European Union, 2009). Moreover, it is estimated that in order to limit the average global temperature increase to less than 2°C compared to pre-industrial levels, global greenhouse gas emissions must be reduced to less than 50% of 1990 levels by 2050 (European Commission, 2009). The EU has announced a clear willingness to take lead on this with far-reaching reductions.

In March 2009 the congress "Climate Change: Global Risks, Challenges and Decisions" was held at the University of Copenhagen. At the congress, scientists, representing broad research areas, clearly stated that the global carbon dioxide emissions are rising faster than previously expected and that the worst case scenarios outlined by the International Panel on Climate Change (IPCC) are being realized. Also, the conference presented harder evidence than ever that these emissions are causing an increased surface temperature creating sea-level rise, distortions of ocean and ice sheet dynamics and extreme climatic events (University of Copenhagen, 2009). With the irreversible nature of these consequences the imperative to address climate change is now stronger than ever for global policy makers at the world conferences in Copenhagen in December 2009 and Mexico City in 2010.

Because of these multifaceted challenges, strategies to counter climate change are likely to pose trade-offs. Increased energy efficiency is a key strategy with low trade-offs and huge win-win opportunities. Several studies have attempted to quantify the potential improvements to energy efficiency. In 2001 the IPCC found that cost-effective energy efficiency improvements could contribute to half of the needed carbon emissions reduction by 2020 (International Panel on Climate Change, 2001), which was confirmed e.g. by Lechtenböhmer et. al. (2005) and by the McKinsey Global Institute (2007). Additionally, investments in energy efficiency improvements often yield high return rates. The well-known McKinsey studies on the abatement cost curve for carbon emissions have illustrated how a more efficient use of several technologies actually can abate carbon emissions and result in an economic gain (Enkvist, Naucler, & Rosander, 2007) (McKinsey & Company, 2009). However, studies suggest as well that this large energy efficiency potential is not realized (International Panel on Climate Change, 2001) (Ecofys, 2001) (Business Europe, 2007). This difference between the most energy efficient available processes and technologies and those actually in use is called "the energy efficiency gap" (The Allen Consulting Group, 2004).

The existence of this gap is often explained by the presence of market failures such as negative externalities, the public good attribute of information, the positive externalities of technology adoption and the asymmetric information in energy service markets leading to problems of adverse selection, moral hazard and split incentives. Additionally, the following barriers, which are not considered as market failures, might also contribute to an explanation of the energy efficiency gap: Hidden costs, reduced product performance and increased option values of delaying investments (Sorrel, 2004) (Bleischwitz, Bahn-Walkowiak, Bringezu, Lucas, & Steger, 2009).

This paper focuses on the market failure posed by informational asymmetries. In doing so it draws upon recent findings of economics of information and new institutional economics. The latter approach offers potentially a broad scope for an analysis that captures all kinds of transaction costs and behaviors (Sorrel, 2004) (Stern, 2008)[3]. While acknowledging the need to advance such a broad scope (Bleischwitz R. , 2003), this BEER takes its point of departure in the necessity to understand the barriers to energy efficiency caused by asymmetric information.

So far, the focus in the literature on agency and informational barriers has largely been on the problem of splitted incentives between principals and agents (IEA, 2007). This problem deviates from traditional principal agent problems since the problem is caused by a split between the investor and the user of technologies, and not by asymmetries of information. As such, a change in the contractual arrangement could in theory help alleviate the problem, for instance by implementing measures that ensures that *users* of energy can also invest in energy efficiency. However, there seem to be a lack of theoretical descriptions on how informational asymmetries impact the outcome of energy efficiency.

That is exactly where this BEER starts; it seeks to contribute to the understanding of market barriers arising through informational asymmetries. This is done by proposing a simple theoretical framework analyzing the cause and potential alleviations of inefficiencies caused by the problems of moral hazard and adverse selection. In a setting adopted from literature on economics of information it is illustrated how moral hazard and adverse selection impact on the outcome of energy efficiency. It is argued that these informational barriers are at least as important as splitted incentives. Afterwards, European legislation is briefly evaluated to assess the extent to which informational asymmetries are accommodated.

This article is divided into two main parts. The first part presents the theory on information asymmetries and its consequences on energy efficiency with a focus on the problems of moral hazard and adverse selection. For each problem the cause of the problem is illustrated and the optimal contracts in case of symmetric as well as asymmetric information are identified. The consequences of these contracts on the level of energy efficiency are then analyzed. Having established a theoretical framework to understand the agency barriers to energy efficiency, the second part shortly evaluates the policies of the European Union on energy efficiency.

[3] See also (Fri, 2003), (Grubb & Ulph, 2002), (Jacobsson & Bergek, 2004), (Jaffe, Newell, & Stavins, 2002), (Mennel & Sturm, 2008) and (Ostertag, 2002)

2. Theory

Following Arrow (1962), an implicit assumption in welfare-economics is that the information is symmetric among the participants in the markets. Free-market Walrasian equilibriums will then, according to the First Welfare Theorem, lead to Pareto efficient outcomes, where no welfare improvements can be made. In reality, however, the information is often asymmetric, which causes the implicit assumption for the welfare theorem to break down, whereby the outcome is likely to end up being inefficient (Mas-Colell, Whinston, & Green, 1995). The observed energy efficiency gap might be the result of such an inefficient outcome and potentially caused by informational asymmetries between the participants in the market for energy efficiency.

As Nobel laureate Oliver E. Williamson (1975) (1985) has emphasized, contracts play a major role in organizing economic relationships and poorly designed contracts can lead to inefficient outcomes like the energy efficiency gap. For this reason, the understanding of the design of contracts, given the informational environment, is important in order to understand why inefficient outcomes occur and what can be cone to alleviate these inefficiencies (Macho-Stadler & Pérez-Castrillo, 1997). This part attempts to provide such an understanding of contractual settings related to energy efficiency.

The presented framework builds on literature on economics of information and microeconomics as presented by Macho-Stadler and Pérez-Castrillo (1997) and Mas-Colell, Whinston and Green (1995). This means that the formal way of presenting and solving the problems follows the lines of the literature in the sense that the models contain a principal maximizing an objective function subject to an agent's participation constraint. The maximization is done using the Lagrange method. However, in this setting the framework has been adapted to accommodate an energy efficiency context. The first section illustrates the basic setup. This means that the contract where a principal contracts an agent under symmetric information is found. Then the model is extended to illustrate the optimal contracts under moral hazard and adverse selection. In both extensions the ideal situation – the first best - is identified. Then, the problem in hand is illustrated and the optimal contract – the second best - given the information asymmetry is identified. For each problem the consequences of the problem and the contracting in case of asymmetric information is analyzed. Finally, the findings are summarized in a conclusion.

2.1 The Base Model

Both models presented in this part are developed from a common framework. A principal contracts an agent in order to maximize an objective function. Since both models originate from this framework it is reasonable first to develop the basic framework where information is symmetric and then later extend it to the issues of asymmetric information. Also, since the contract under symmetric information will be used as a benchmark case for later comparison it is reasonable first to develop it. Therefore, the following paragraphs first state the assumptions underlying the model, then present and solve the maximization problem in order to find the optimal contract under symmetric information.

Assumptions

In the base model the information is symmetric. This means that the principal knows what effort the agent exerts as well as the agent's type, whereby the principal can write a contract dependent on effort and direct this contract to a specific agent. The principal wants to hire the agent to search for and install a given amount of energy efficiency, EE, and therefore offers the agent a contract. This contractual relationship goes on for one period. It is assumed that the level of energy efficiency can be translated into a monetary gain for the principal, for instance through a lower energy bill. The contract specifies the effort the agent must exert denoted by e and the wage as a function of the outcome, denoted by w. The contract can be considered as a document specifying the agent's obligations and the transfers that must be made in different outcomes. The contract proposed by the principal is either accepted or rejected by the agent. However, it is assumed that the contract is designed such that it will always be accepted in equilibrium. After the agent has exerted his effort the outcome is realized.

There are N possible outcomes denoted by X, where $X = \{EE_1, EE_2, \dots, EE_N\}$ and $EE_1 < EE_1 < \dots < EE_N$, meaning that the higher the subscript the higher is the energy efficiency. This final outcome is the result of both on the effort exerted by the agent but also of some random component. One can imagine that the degree of measured energy efficiency depends both on the agent's effort but also on some random component relating to the behavior of the users, the complexity of the technologies installed and of the environment the technologies are installed in, the climate and maybe pure luck. The probability of a given outcome, EE_i, depends on the effort exerted by the agent and $p_i(e) > 0$ for all i, where $\sum_{i=1}^{N} p_i(e) = 1$. The probability for a given outcome must be positive for all effort-levels since, if this was not the case, a given result could signify what effort level was not exerted. When the outcome is realized the wage is paid to the agent.

Since both the principal and the agent are exposed to uncertainty through the random component, their risk preferences must be examined. The concept employed here is that of expected utility, meaning that the preferences are of a von Neumann-Morgenstern type. The principal's payoff function, which must be increasing in the obtained level of energy efficiency and decreasing in the wage payment to the agent, is given by:

$$B(EE - w)$$

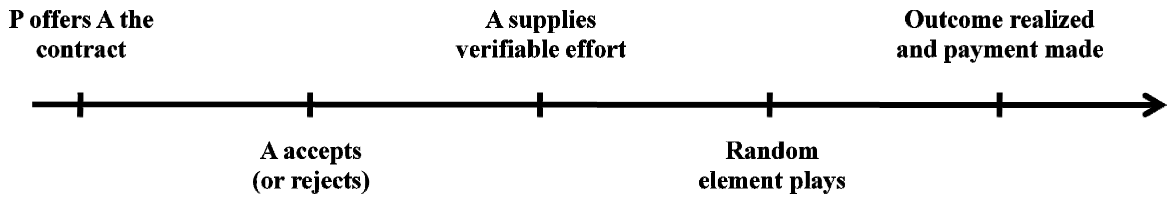
where it is assumed that $B' > 0$ and that $B'' = 0$ reflecting that the payoff of higher energy efficiency and lower wage payment is increasing at a constant pace and that the principal is risk-neutral. Note that the principal, as such, does not care about the effort exerted by the agent, only because it affects the final outcome. The agent's utility, which is assumed to be increasing in the wage but decreasing in the effort exerted, is given by:

$$U(w, e) = u(w) - v(e)$$

where it is assumed that $u' > 0$ and $u'' < 0$ reflecting the standard assumptions that the agent has a decreasing marginal utility to wage and that the agent is risk-averse when it comes to the remuneration. It is also assumed that $v' > 0$ and $v'' > 0$ reflecting the assumptions that the agent suffers from an increasing marginal disutility to effort. It is also assumed that the agent has a reservation utility of $\underline{U}$, which is the level of utility that the contract offered must at least be equal to. One can imagine that the agent has another option than the contract proposed where this other option gives the agent a utility equal the reservation utility. Because of this the contract offered by the principal must at least give the agent a utility equal to the reservation utility.

Briefly to summarize the timing of the relationship; first, the principal offers the agent the contract which the agent accepts (or rejects). Then the agent supplies a verifiable effort, which together with the random component determines the final outcome and the payoff are paid. The timing is illustrated in the timeline below.

Figure 1 – Timeline in the base model



Solving the model

Since the relationship is of a sequential nature the solution concept applied is that of a sub-game perfect Nash equilibrium. This implies that the solution is found from backwards, meaning that the principal offers the agent a contract, which specifies the transfer the agent will get in all potential outcomes and the effort the agent must exert, $C = \{e, w(EE_1), \ldots, w(EE_N)\}$. Furthermore, the contract is made such that the agent will obtain his reservation utility since otherwise he could get a higher utility from not engaging in the relationship. From backwards, the agent then accepts or rejects the contract after calculating what his expected utility will be and taking the optimal level of effort into account. The principal then offers the agent the contract that ensures him the highest expected payoff taking account of what the agent's decision will be. Formally, the principal solves the following maximization problem:

$$Max_{e,w(EE_1),\ldots,w(EE_N)} \sum_{i=1}^{N} p_i(e)B\big(EE_i - w(EE_i)\big)$$

$$s.t. \quad \sum_{i=1}^{N} p_i(e)u\big(w(EE_i)\big) - v(e) \geq \underline{U}$$

where the constraint ensures that the agent will participate in the contract since the expected utility he obtains is at least equal to his reservation utility, for which reason the constraint is called the *participation constraint* (PC). The problem is solved using the Lagrangian:

$$\mathcal{L} = \sum_{i=1}^{N} p_i(e)B\big(EE_i - w(EE_i)\big) + \lambda\left(\sum_{i=1}^{N} p_i(e)u\big(w(EE_i)\big) - v(e) - \underline{U}\right)$$

where the solution can be identified from the first order condition (FOC) in case the second order condition (SOC) is negative. Furthermore, since we are maximizing over several variables the cross-derivative must be zero. These conditions are:

FOC: $$\partial\mathcal{L}/_{\partial w(EE_i)} = p_i(e)B'\big(EE_i - w(EE_i)\big)(-1) + \lambda p_i(e)u'(w(EE_i)) = 0$$

SOC: $$\partial^2\mathcal{L}/_{\partial w(EE_i)^2} = p_i(e)B''\big(EE_i - w(EE_i)\big) + \lambda p_i(e)u''(w(EE_i)) < 0$$

Cross derivative: $$\partial^2\mathcal{L}/_{\partial w(EE_i)\partial w(EE_j)} = 0$$

Regarding the SOC it is seen that this condition must be negative since both probabilities are positive, λ is bigger than or equal to zero (can by definition not be negative) and since both B'' and u'' are negative (see assumptions above). Regarding the cross derivative this must be zero since $w(EE_j)$ does not occur in the FOC. As the conditions needed to identify the solution from the FOC are present the solution is found from the FOC to be:

$$\lambda = {B'\left(EE_i - w^O(EE_i)\right)} \Big/ {u'(w^O(EE_i))}$$

This condition is called the optimality condition denoted with the superscript (O) in the wages. Notice that since both B' and u' are positive, λ must be positive as well, meaning that the participation constraint binds in equilibrium. This is clearly no surprise since the only effect of a combination of wage and effort that ensures a utility higher than the reservation utility is that the principal's payoff is lowered. Therefore, the principal has no incentive to offer a contract that gives the agent a utility higher than needed to contract him. Knowing that the principal is risk neutral, $B'' = 0$, it must be the case that B' equals a constant, whereby the optimality condition requires that $u'(w^O(EE_i))$ equals a constant for all outcomes, i.

Knowing that the agent is risk averse (his utility function is concave), the only possible way to ensure that his marginal utility is the same for all outcomes is to give him the same wage in all outcomes. In other words $u'(w^O(EE_i)) = u'\left(w^O(EE_j)\right)$ requires that $w^O(EE_i) = w^O(EE_j)$, meaning that the optimal contract is independent of the result. Why is this the case? The reason is that the effort is verifiable, which enables the parties to contract directly on the effort, and that the principal is risk-neutral and the agent risk averse. With this risk-pattern it is optimal for the principal to demand the effort level from the principal that maximizes his payoff and insure the agent completely from the risk in the outcome by offering him a constant wage. The agent receives w^O in all outcomes and this wage only depends on the effort level demanded by the principal. Finally, since the participation constraint binds the exact wage payment can be found:

$$u(w^O) - v(e) = \underline{U} \Leftrightarrow w^O = u^{-1}\left(\underline{U} + v(e^O)\right)$$

This wage will be used as a reference wage in comparisons later.

Consequences

To conclude, in the base model where information is symmetric, the principal and the agent can write contracts directly on the effort level. Knowing this fact the principal will design a contract such that the agent will accept it and exert the effort which gives the principal the highest payoff. When designing the contract the principal looks at the combinations of wage and effort which makes the agent participate. The principal then chooses to offer the agent the contract which gives the principal the highest payoff. No other outcome can be better than this, and since the principal's profit is maximized the outcome must be Pareto optimal. The agent could be made better off, but this would come at a cost to the principal. The consequence of contracting in the case of symmetric information is that the most efficient outcome is reached, and assuming that the outcome with the highest energy efficiency pays the principal the highest payoff, the highest possible level of energy efficiency will be installed and the energy efficiency gap closed. However, this is not likely to be the case and the two models explained below offer some explanation.

2.2 Moral hazard

The previous section illustrated the optimal contract in the situation where a principal contracts an agent to install some energy efficiency in a setting where the effort exerted by the agent is verifiable. However, in many relationships this assumption might be unrealistic. Take for instance the case of an architect or an engineer hired by a principal to exert some effort to install energy efficiency. If the level of effort exerted by the agent, i.e. how much time and resources are spent by the agent in looking for the most efficient and best performing technologies, cannot be verified the relationship suffers from potential moral hazard. If a contract in this situation just pays the agent a fixed wage, which was optimal in the base model, the agent has no incentive to work hard and find the best performing technologies given the environment. Even though a contract might have specified that the agent must work hard, due to the non-verifiability of effort there is room for opportunistic behavior by the agent, whereby the exerted effort-level will be the lowest possible. Fortunately, the non-verifiability does not completely exclude the possibility to write contracts. In theory, it might still be possible for the principal to contract the agent in a rational way, which is done by designing a compensation scheme that rewards the agent when the outcome signals that he exerted high effort and punish the agent when the outcome signals a low effort.

This section analyzes the situation where a principal hires an agent to install some energy efficiency and where the effort exerted by the agent to look for the best performing techniques is no longer verifiable. To specify, a non-verifiable effort means that it might be observed but it cannot be verified in a court-room, whereby it becomes impossible to contract on it. The method used in the analysis is the following. First the optimal contract, the first best, in the case of verifiable effort is specified. This is followed by an illustration of the problem of moral hazard. As mentioned, even though effort might be non-verifiable, it might still be possible for the principal to contract the agent. Therefore, the following section analyses the optimal contract in the presence of moral hazard. The final section illustrates the likely consequences of both the moral hazard in itself, and the implications of the optimal compensation scheme when moral hazard is present.

First best

The first best outcome is the ideal situation where the effort exerted by the agent is at its optimal level. This implies that both the agent will engage in the contract since it offers him a utility equal to his reservation utility and maximizes the principal's payoff. This is simply the contract found in the base model, being:

$$w^O = u^{-1}\left(\underline{U} + v(e^O)\right)$$

In this model the principal has chosen the effort level that maximizes his profits given that the agent will participate. One can for instance imagine that there are two effort levels; high and low. The contract above can then be written such that a high effort results in a high wage (w^H, e^H) or that a low effort results in a low wage (w^L, e^L). In the case of verifiable effort a contract satisfying this condition, following the maximization problem in the base model, cannot be improved. It is at its optimal level.

Problem

As mentioned in the introduction to moral hazard, in many settings it is impossible to contract directly on effort. However, in practice contracts might still be designed as if the effort was verifiable (but it is not!) or it might be the case that it is impossible to write other contracts than contracts with a flat wage. This implies that the exerted effort is at its lowest possible level, meaning that:

$$w^{min} = u^{-1}\left(\underline{U} + v(e^{min})\right)$$

This result holds both in cases where effort is non-verifiable but the contract is still written on a specific effort level (i.e. the principal believes it is possible to contract on the effort), and in the situation where the principal knows it is impossible to contract directly on effort, but it is impossible to incorporate other measures in the contract.

Second best

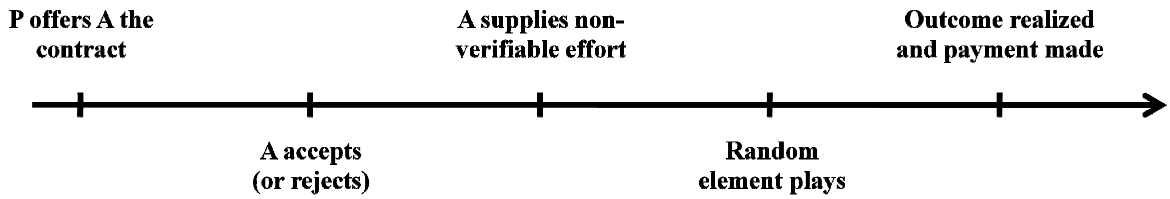
Even though effort is non-verifiable, as mentioned above, it might still be possible to contract in a way that ensures an effort level above the minimal one. For the setting of the model some additional assumptions must be made. First, in the following it is assumed that there are only two effort levels; high (H) where the agent works hard and low (L) where the agent is lazy and only perform at the minimum effort-level. Formally it is given by $e \in \{e^L, e^H\}$. Following from the specification of the disutility these effort levels implies that $v(e^H) > v(e^L)$. Additionally, with only two effort levels the notation can be simplified such that, $p_i^H = p_i(e^H)$ and $p_i^L = p_i(e^L)$. In order to ensure that high outcomes are more likely under high than low effort it must be the case that:

$$\sum_{i=1}^{k} p_i^H < \sum_{i=1}^{k} p_i^L \text{ for all } k = 1, \ldots, n-1$$

The outcomes of the relationship are unchanged from above, meaning that there are N potential outcomes denoted by X, where $X = \{EE_1, EE_2, \ldots, EE_N\}$ and $EE_1 < EE_1 < \ldots < EE_N$.

Briefly to summarize the timing of the relationship; first, the principal offers the agent the contract which the agent accepts (or rejects). Then the agent supplies a non-verifiable effort, which together with the random component determines the final outcome from which the payoffs are paid. The timing is illustrated in the timeline below.

Figure 2 – Timeline in the moral hazard model



The principal can as such, through the contract he offers, demand two effort levels from the agent and the principal makes this decision based on which effort level that maximizes his profit. In the case where it is the low effort level that it optimal for the principal, no real moral hazard problem exists, since the principal can just offer the agent a fixed wage ensuring that the agent's reservation utility is reached, implying that $w^L = u^{-1}\left(\underline{U} + v(e^L)\right)$. This situation is not really interesting, since the contract is similar to the ones above.

The situation becomes more interesting when it is optimal for the principal to demand a high effort from the agent. This will be the case when good outcomes are sufficiently attractive, meaning that the level of energy efficiency, EE_i, is high for large i's. If this is the case it is necessary to incentivize the agent, meaning that an incentive constraint must be incorporated in the maximization problem. This incentive constraint is the following:

$$\sum_{i=1}^{N} p_i^H u\big(w(EE_i)\big) - v(e^H) \geq \sum_{i=1}^{N} p_i^L u\big(w(EE_i)\big) - v(e^L)$$

The constraint above has the intuitive implication that the agent will chose to exert high effort if the expected utility from this is higher than or equal to the expected utility from exerting low effort.

In order to find the optimal contract, when it is not possible to contract on effort and which induces the agent to exert high effort the principal must solve the following maximization problem:

$$Max_{w(EE_1),\ldots,w(EE_N)} \sum_{i=1}^{N} p_i^H B\big(EE_i - w(EE_i)\big)$$

$$s.t. \quad \textstyle\sum_{i=1}^{N} p_i^H u\big(w(EE_i)\big) - v(e^H) \geq \underline{U} \qquad \text{(PC)}$$

$$\textstyle\sum_{i=1}^{N} p_i^H u\big(w(EE_i)\big) - v(e^H) \geq \sum_{i=1}^{N} p_i^L u\big(w(EE_i)\big) - v(e^L) \qquad \text{(IC)}$$

where (PC) indicates the participation constraint and (IC) indicates the incentive constraint. Note that since it is no longer possible to contract on effort this variable is excluded from the maximization problem. The problem can be solved using the Lagrangian:

$$\mathcal{L} = \sum_{i=1}^{N} p_i^H B\big(EE_i - w(EE_i)\big) + \lambda\left(\sum_{i=1}^{N} p_i^H u\big(w(EE_i)\big) - v(e^H) - \underline{U}\right) + \mu\left(\sum_{i=1}^{N} p_i^H u\big(w(EE_i)\big) - v(e^H) - \sum_{i=1}^{N} p_i^L u\big(w(EE_i)\big) + v(e^L)\right)$$

where, since the SOC is negative and the cross-derivative is equal to zero, the solution can again be found from the FOCs. The FOC for outcome i is:

$$\partial\mathcal{L}/\partial w(EE_i) = -p_i^H B'\big(EE_i - w(EE_i)\big) + \lambda p_i^H u'\big(w(EE_i)\big) + \mu(p_i^H - p_i^L)u'(w(EE_i)) = 0 \Leftrightarrow$$

$$\lambda + \mu\left(1 - p_i^L/p_i^H\right) = B'\big(EE_i - w(EE_i)\big)/u'(w(EE_i))$$

Since it is assumed that $B''\big(EE_i - w(EE_i)\big) = 0$ it must be the case that $B'\big(EE_i - w(EE_i)\big)$ equals a constant, which in the following is denoted k. This gives the optimality condition:

$$\lambda + \mu\left(1 - p_i^L/p_i^H\right) = k/u'(w(EE_i)) \quad \text{(MH.1)}$$

which characterizes the optimal contract in case of moral hazard. Before analyzing on the result it should be noted that both constraints are binding, meaning that both multipliers are positive. This is proved in annex I.

With the result that both multipliers are positive, the design of the optimal contract in case of non-verifiable effort can be analyzed. First note the ratio of probabilities which is called the likelihood ratio. It indicates the precision with which the outcome of energy efficiency EE_i signals that the effort exerted by the agent was e^H. The smaller this ratio, the larger is p_i^H relative to p_i^L and so the indication that the effort exerted was e^H is stronger. The two cases where the ratio decreases and increases are worth analyzing:

1) ${p_i^L}/{p_i^H}$ decreases => left hand side of (MH.1) increases => right hand side must increase as well => $u'(w(EE_i))$ must decrease => $w(EE_i)$ must increase given the assumptions on $u(w,e)$.
2) ${p_i^L}/{p_i^H}$ increases => left hand side of (MH.1) decreases => right hand side must decrease as well => $u'(w(EE_i))$ must increase => $w(EE_i)$ must decrease given the assumptions on $u(w,e)$.

The two cases illustrate how the optimal compensation mechanism in the case of non-verifiable effort works. If the outcome of energy efficiency EE_i (for example high energy efficiency) is relative more likely to occur under high effort compared to low effort it signals that the agent exerted high effort, whereby the agent must be rewarded through a higher wage. Contrary, if the outcome of energy efficiency EE_i (for example low energy efficiency) is relatively more likely to occur under low effort compared to high effort it signals that the agent exerted low effort, whereby the agent must be punished through a lower wage.

Consequences
Having presented the design of the optimal contract the consequences of this contract must be assessed. With the non-verifiability introduced in the contract, variation in the agent's compensation is introduced as well. Knowing that the agent is risk averse and thereby dislikes uncertainty it must be the case that his expected compensation when exerting high effort is strictly greater than the fixed wage in the observable case: $w^{H*} = u^{-1}\big(\underline{U} + v(e^{H*})\big)$

To see this point formally note that since the agent's expectation to his utility is $E[U(w(EE_i), e^H)] = \underline{U} + v(e^H)$, which basically follows from the binding participation constraint, and since $u''(w) < 0$, Jensen's inequality tells us that the agent's utility of the expected wage is:

$$U(E[w(EE_i), e^H]) > \underline{U} + v(e^H)$$

This implies that since $w^{H*} = \underline{U} + v(e^{H*})$ it must be the case that:

$$E[w(EE_i), e^H] > w^{H*}$$

As a result, the non-verifiability of effort increases the principal's expected compensation costs when implementing the high effort level.

This result can have major implications for the implementation of the high effort level and thereby on the level of energy efficiency. The fact that the cost of implementing the high effort level is higher, everything else equal, it becomes more likely that the principal will not demand the high effort level since it is too expensive. Instead the principal will demand the low effort level, where the non-verifiability does not change the implementation cost. The reason for this somehow striking result is that because of the agent's risk aversion he must be paid some premium to take on the risk associated with the incentive; in other words the expected transfer from the principal to the agent is higher than in the base model. In the case where this extra compensation needed to induce the agent to exert high effort outweighs the extra benefit to the principal from having a high effort-outcome compared to a low effort outcome, the principal will simply choose the low effort level. Note that to detect if this is the case it is necessary to assume functional forms on the payoff and utility function and not general forms like the ones used here. The fact that with non-verifiability it might be too expensive for the principal to demand high effort has a direct link to the level of energy efficiency which is necessarily lower under low effort than under high effort. This lower level of installed energy efficiency can then contribute to the explanation of the energy efficiency gap.

2.3 Adverse Selection

In the base model above it was assumed that the principal knew the agent's type. However, in many contractual relationships this assumption is not realistic and the relationship considered here, a principal contracting an agent to exert an effort to increase the energy efficiency is no exception. Take for instance the case where two different agents differ in their productivity. In case the principal does not have knowledge on each agent's type he does not know his ability, skills and maybe even education, and as such he does not know which contract to offer the agent. This setting is known as adverse selection. The economic description of adverse selection was pioneered by Akerlof (1970) in the Lemons model. In this model, Akerlof showed how asymmetric information in the market for used cars, where the seller has more information on the quality of the car than the buyer, causes the market for used cars to disappear. However, the disappearance of the market might not always be the case of asymmetric information on the agent's type. Sometimes it is possible to discriminate between the agents. However, this discrimination implies a cost.

This section analyses the relationship where a principal hires an agent to install an amount of energy efficiency, but there is asymmetric information regarding the agent's type i.e. how the hired agent's utility function looks like. Contrary to the situation under moral hazard, the effort exerted is assumed to be verifiable and it is still assumed that the principal is risk neutral and the agent risk averse. Furthermore, since uncertainty in the outcome does not play a key role for the relationship's inefficiencies, it is left out of the setting. This implies that the outcome of energy efficiency is no longer a function of both effort exerted and the random component, but now only a function of the effort. Since the effort exerted is now verifiable, the principal is risk neutral, and that the uncertainty is left out of the model the outcome is simplified to $\sum_{i=1}^{n} p_i x_i = EE(e)$. On the function on the outcome it is assumed that $EE'(e) > 0$ and that $EE''(e) < 0$, illustrating that the energy efficiency is assumed to exhibit a decreasing marginal returns to effort. The fact that the principal's payoff is now no longer dependent on the random component implies that it is possible to simplify the notation such that the function $B(EE - w)$ now equals

$$EE(e) - w$$

Regarding the agents, it is assumed that there are two types of agents that the principal cannot distinguish between. The agents have the same reservation utility and utility from wage and only differ in their disutility to effort. This means that the first type has a disutility of $v(e)$ and the second type a disutility of $kv(e)$, where $k > 1$, such that for a given effort level the second type's disutility is higher, whereby it becomes more expensive to contract the second type. For this reason the first type is the good type (denoted by G) and the second type is the bad type (denoted by B). The rest of the agents' preferences are similar to the base model meaning that the preferences are described by the equations:

$$U^G(w,e) = u(w) - v(e) \text{ and } U^B(w,e) = u(w) - kv(e)$$

Finally it should be noted that, even though the principal does not know the exact type of a given agent, it is assumed that he knows the proportion of the two types of agents in the population, where type-G share is denoted q and type-B share is $1 - q$. It is assumed that both types are always present, meaning that $1 > q > 0$.

First best

With the new setting specified, the first best contract, i.e. the contract under symmetric information, can be found. When the principal knows every agent's type he does not have to maximize over uncertainty of the types, meaning that he can construct a maximization problem for each type and not pool the types into one maximization problem. Furthermore, since the principal can contract on both effort and wage the contract is the same as the one in the base model. With the additional simplifying assumptions the principal's maximization problem when hiring a type-G agent is:

$$Max_{e,w}\ EE(e) - w$$

$$s.t.\ \ u(w) - v(e) \geq \underline{U}$$

From the base model it is known that the optimal contract in case of symmetric information is: $w = u^{-1}\left(\underline{U} + v(e)\right)$ which can be inserted in the maximization problem to give:

$$Max_e\ EE(e) - u^{-1}\left(\underline{U} + v(e^O)\right)$$

Solving this problem gives the following first order condition:

$$\text{FOC: } EE'(e) - (u^{-1})'\left(\underline{U} + v(e^O)\right)\ v'(e^O) = 0\ \Leftrightarrow EE'(e) - {v'(e)}/{u'(w)} = 0$$

The first order condition and the participation constraint then characterize the optimal contract, which in the following is denoted by (e^*, w^*). For a type-G agent the optimal contract satisfies the two equations:

1) $EE'(e^{G*}) = {v'(e^{G*})}/{u'(w^{G*})}$ (AS.1)

2) $u(w^{G*}) - v(e^{G*}) = \underline{U}$ (AS.2)

For a type-B agent the maximization problem is only changed when it comes to the disutility, whereby the conditions describing the optimal contract are:

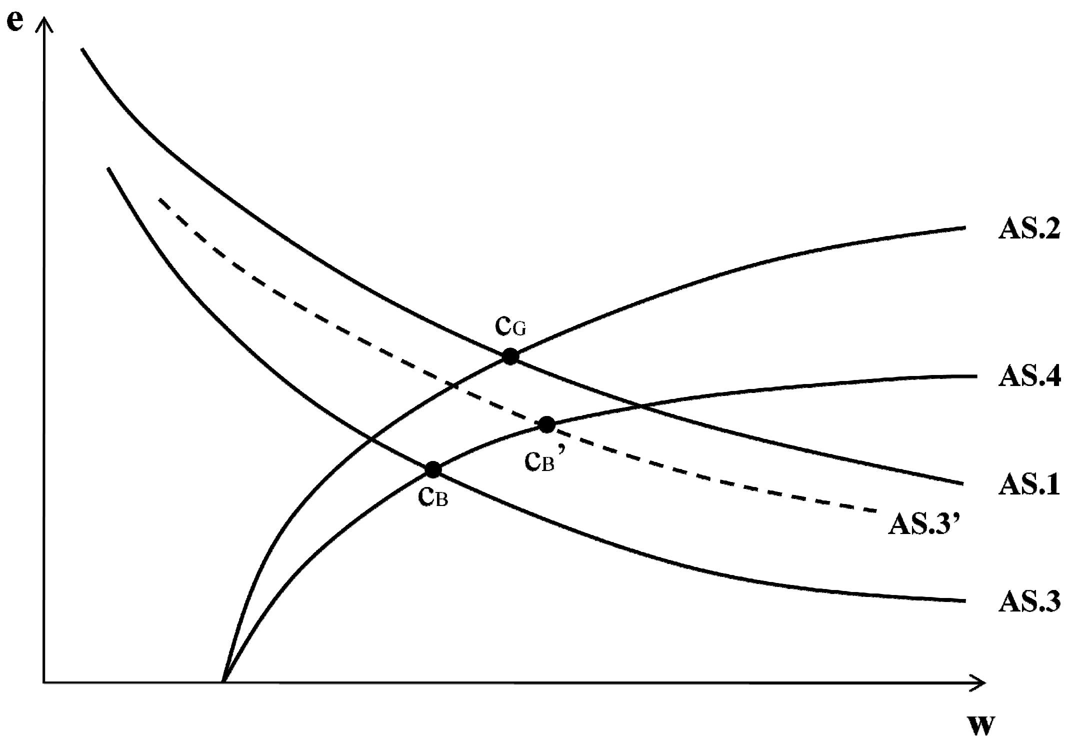
3) $EE'(e^{B*}) = {kv'(e^{B*})}/{u'(w^{B*})}$ (AS.3)

4) $u(w^{B*}) - kv(e^{B*}) = \underline{U}$ (AS.4)

Before continuing to the analysis of the problem it is worth analyzing the optimal contracts in case of symmetric information. The four conditions above, (AS.1) to (AS.4), can be drawn in a (w,e)-diagram as the one below. The slopes of the curves are derived in the annex II.

In the diagram, note that the curve (AS.4) is below (AS.2) since the constant $k > 1$. Furthermore, note that for a given effort-level the left hand side of (AS.1) and (AS.3) are the same which, since $k > 1$, implies that (AS.3) must be below (AS.1). The diagram reveals two important properties from the optimal contract. The first is that it is optimal for the principal to demand more effort from the agent with the lowest disutility of effort. That is to say that $e^{G*} > e^{B*}$. The second is that the relationship between the wages might be ambiguous, meaning that $w^{G*} > w^{B*}$ or $w^{G*} < w^{B*}$. This somehow counterintuitive result follows from the fact that it is not clear how far the curve (AS.3) lies from (AS.1). (AS.3) might just as well lie in the curve (AS.3').

Diagram 1 – optimal contracts with two different agents
The diagram shows potential locations of the optimal contracts

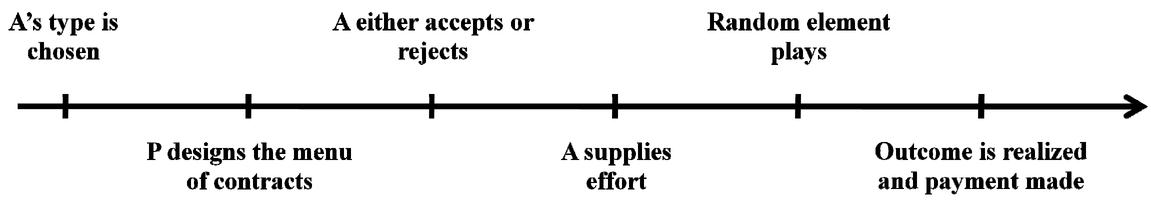


Problem
When information on the agents' types becomes asymmetric major problems arise in the setting above. One is the fact that it might be the case that in the optimal contract it can be the case that $w^{G*} < w^{B*}$ while $e^{G*} > e^{B*}$. This situation is illustrated in the diagram above with the curve (AS.3') where the equilibrium contracts are C_G and $C_B{}'$. In case the principal does not know the agents' types and the contract cannot be optimal for the principal. The reason is that a type-G agent will obtain a higher utility from the contract intended for type-B agents than from the one intended for type-G agents, since the wage is higher and the effort is lower. The outcome is that the principal will end up offering type-B contracts to all agents – even type-G agents. As with the case of moral hazard, a symmetric information contract is no longer optimal in the presence of asymmetric information.

Second best
Like in moral hazard it is still possible for the principal to contract facing an adverse selection problem. In this case the proportion of each agent, q, becomes relevant. Briefly to summarize the

timing of the relationship; first, some external factor determines the agents' types, which is then only observed by the agents. Then the principal designs the contracts which the agents accepts (or rejects). Then the agents supply the effort, which, together with the random element, determines the final outcome from which the payoffs are paid. The timing is illustrated in the timeline below.

Figure 3 – Timeline in the adverse selection model



The aim is now for the principal to design a menu of contracts ensuring that each agent chose the contract intended for its specific type and to design these contracts such that the principal's payoff is still maximized. When the agents chose the exact contract intended for their type the principle employed is called the revelation principle. The method used is to add one constraint for each potential type to the principal's maximization problem which ensures that each agent chose the contract intended for their type. These constraints are the problem's incentive constraints.

The principal's maximization problem which maximizes the principal's utility and ensuring that the agents pick the contracts intended for their types is then the following:

$$Max_{e^G,e^B,w^G,w^B}\ q(EE(e^G)-w^G)+(1-q)(EE(e^B)-w^B)$$

$$s.t.\ \ u(w^G)-v(e^G)\geq \underline{U}, \qquad \text{(PC-G)}$$

$$u(w^B)-kv(e^B)\geq \underline{U}, \qquad \text{(PC-B)}$$

$$u(w^G)-v(e^G)\geq u(w^B)-v(e^B) \qquad \text{(IC-G)}$$

$$u(w^B)-kv(e^B)\geq u(w^G)-kv(e^G) \qquad \text{(IC-B)}$$

where (PC-G) is the participation constraint for the good type and (PC-B) the participation constraint for the bad type. Similarly, (IC-G) is the incentive constraint for the good type, which ensures that a type-G agent picks the contract intended for him, and (IC-B) is the incentive constraint for type-B agents ensuring that a type-B agent picks a type-B intended contract. Before solving the problem it can be argued that only the (IC-G) and the (PC-B) are the binding constraints. This argumentation is in the annex III. Knowing this, the problem can be solved using the Lagrangian:

$$\mathcal{L}=q(EE(e^G)-w^G)+(1-q)(EE(e^B)-w^B)+\mu\big(u(w^B)-kv(e^B)-\underline{U}\big)$$
$$+\lambda\big(u(w^G)-v(e^G)-u(w^B)+v(e^B)\big)$$

which has the following FOCs:

$$\partial\mathcal{L}/_{\partial w^B}=-(1-q)+\mu u'(w^B)-\lambda u'(w^B)=0$$

$$\partial\mathcal{L}/_{\partial w^G}=-q+\lambda u'(w^G)=0$$

$$\partial \mathcal{L} / \partial e^B = (1-q)EE'(e^B) - \mu k v'(e^B) + \lambda v'(e^B) = 0$$

$$\partial \mathcal{L} / \partial e^G = qEE'(e^G) - \lambda v'(e^G) = 0$$

Before identifying the optimal contract the expressions for the two multipliers must be identified. Note the following:

$\partial \mathcal{L} / \partial w^G = -q + \lambda u'(w^G) = 0 \Leftrightarrow \lambda = q / u'(w^G) > 0$ since (IC-G) binds. This is confirmed by the fact that $q > 0$ and that $u'(w^G) > 0$, implying that the fraction must be positive.

$\partial \mathcal{L} / \partial e^B = (1-q)EE'(e^B) - \mu k v'(e^B) + \lambda v'(e^B) = 0 \Longrightarrow \mu > 0$, since (PC-B) binds. This is confirmed by the fact that since both the first and the last term are positive it must be the case that $\mu > 0$, since otherwise the expression could not equal zero.

And finally, to find the expression for μ, λ is substituted into $\partial \mathcal{L} / \partial w^B$ to get:

$$\partial \mathcal{L} / \partial w^B = -(1-q) + \mu u'(w^B) - q / u'(w^G) \, u'(w^B) = 0 \Leftrightarrow \mu = (1-q) / u'(w^B) + q / u'(w^G)$$

With expressions for the two multipliers the conditions characterizing the optimal menu of contracts in case of asymmetric information can be found.

First, substituting λ into $\partial \mathcal{L} / \partial e^G$ to get:

$$\partial \mathcal{L} / \partial e^G = qEE'(e^G) - q / u'(w^G) \, v'(e^G) = 0 \Leftrightarrow EE'(e^G) = v'(e^G) / u'(w^G) \qquad \text{(AS.G)}$$

Then substitute λ and μ into $\partial \mathcal{L} / \partial e^B$ to get:

$$\partial \mathcal{L} / \partial e^B = (1-q)EE'(e^B) - \left((1-q) / u'(w^B) + q / u'(w^G) \right) k v'(e^B) + q / u'(w^G) \, v'(e^B) = 0 \Leftrightarrow$$

$$EE'(e^B) = k v'(e^B) / u'(w^B) + q / 1-q \; (k-1) v'(e^B) / u'(w^G) \qquad \text{(AS.B)}$$

The two conditions (AS.G) and (AS.B), along with the binding constraints (PC-B) and (IC-G) characterize the optimal menu of contracts. Before continuing to the final step of the analysis, the consequences of asymmetric information, four results can be derived from the optimal menu of contracts.

1. The good type earns informational rent. This means that in order to make the good agent reveal his type and accept the contract intended for him he must be paid some extra rent – an informational rent. The informational rent is characterized by the additional rent from the contract on top of the reservation utility the good agent obtains and is given by:

$$IR = u(w^G) - v(e^G) - \underline{U}$$

Since (PC-B) binds it follows that $u(w^B) - kv(e^B) = \underline{U}$, and since (IC-G) binds it follows that $u(w^B) = u(w^G) - v(e^G) + v(e^B)$. Inserting these findings in the expression above the information rent becomes:

$$IR = u(w^G) - v(e^G) - u(w^G) + v(e^G) - v(e^B) + kv(e^B) \Leftrightarrow$$

$$IR = (k-1)v(e^B) > 0$$

2. The demanded effort level of the good type is at the efficient level. This follows from the condition that

$$EE'(e^G) = {v'(e^G)}\Big/{u'(w^G)}$$

which is equal to the demanded effort level from the good type under symmetric information. The fact that the demanded effort level is not distorted away from its optimal level in the case of asymmetric information is the standard result within economics of information of "no distortion at the top".

3. The effort level of the bad type is distorted downwards. This follows from:

$$EE'(e^B) = {kv'(e^B)}\Big/{u'(w^B)} + {q}\big/{1-q}\;{(k-1)v'(e^B)}\Big/{u'(w^G)}$$

where the first term equals the optimal level from the symmetric case. Since the second term is positive it is the case that the total expression is larger than the expression under symmetric information and since $EE' > 0$ and $EE'' < 0$ it must be the case that e^B has to fall below the optimal level.

4. The bad type earns no informational rent like the good type does. This result follows directly from the (PC-B), which binds:

$$u(w^B) - kv(e^B) = \underline{U}$$

Consequences

With the design of the optimal contract presented the consequences of this contract must be assessed as well. With the asymmetric information on the agents' types introduced in the contracts, it becomes necessary for the principal to pay the good and highly productive agents an informational rent in order to make them reveal their type by accepting the contract intended for them. This is necessary to make them accept a contract where the effort is higher than the contract intended for the bad types. The formal cost of the informational rent was derived above. The implication is, like with the consequences of moral hazard derived above that the principal's expected compensation costs when implementing the high productivity type agents is increased.

More generally, a likely consequence of this result is then that the demand for high type agents will decrease since the cost of engaging them has increased. With fewer good type agents engaged in type-G contracts the outcome cannot be efficient, and the final result will necessarily be a low and inefficient level of installed energy efficiency. Note that this gloomy outlook changes only if the principal receives a return on his investments in the form of a lower energy bill such that that the total life-cycle costs of energy efficiency measures become negative.

2.4 Conclusion

This part has illustrated how informational asymmetries can impact on the level of energy efficiency. The more severe the informational asymmetries are, the more inefficient the outcome and thereby a more inefficient use of energy. The results of the moral hazard and adverse selection models are summarized in the table below.

Table 1 – Summary of the theory's implications

The table summarizes the results and consequences from asymmetric information

	Moral hazard	Adverse selection
First best	• Possible to contract on effort • No additional cost to the principal • Most efficient outcome => most efficient level of energy efficiency	• Possible to contract on type • No additional cost to the principal • Most efficient outcome => most efficient level of energy efficiency
Problem	• Not possible to contract on effort • If not possible to contract on outcome => lowest possible effort exerted • Inefficient outcome => inefficient level of energy efficiency	• Not possible to contract on type • If not possible to reveal type => only low effort contracts in equilibrium • Inefficient outcome => inefficient level of energy efficiency
Second best	• Possible to contract on outcome • Agent is exposed to risk and must be compensated => additional cost to the principal • Efficiency improved but not optimal	• Possible to reveal type • Additional cost to the principal from informational rent to the good type • Efficiency improved but not optimal
Consequences	• Additional cost to the principal => more likely that principal will not offer high effort contract => lower level of energy efficiency installed	• Additional cost to the principal from engaging good types => more likely that principal will not contract good types => lower level of energy efficiency installed

In both models the principal's cost of implementing a high energy efficiency increases with the informational asymmetry, be it as an insurance payment to the agent for taking on risk as in the moral hazard model, or be it as an additional informational rent to the good type agents as in the adverse selection model. Though not illustrated formally, since functional forms are needed to do this, the likely implication is that the installed level of energy efficiency is not at its optimal level, which adds to the energy efficiency gap.

3. Evaluation of European policies

The first part of this BEER illustrated how information asymmetries can help to explain prevailing low levels of energy efficiency. Based on the presented theory, this second part aims at evaluating the most important aspects of legislation enacted by the European Union within energy efficiency. The evaluation will assess to what extent the existing legislation accommodates the described two types of agency problems, and thereby to what extent the legislation accommodates agency barriers to energy efficiency. The evaluation is kept on an overall level. By this is meant a level which addresses the overall elements and implications of the legislation, without diving too much into specific details and without conducting any additional research such as interviews with officials.

Since all EU legislation is subject to the principle of subsidiarity according to art. 5 of the Treaty establishing the European Community (TEC), the first section conducts a subsidiarity test of energy efficiency as an EU policy area. The test concludes that energy efficiency is an area where the EU can legislate. However, the extent to which EU can legislate is more blurred. The second section then provides a brief overview of the main elements of existing EU legislation on energy efficiency. The third section evaluates to what extent existing legislation accommodates agency barriers, whereas the fourth section makes a similar evaluation but based on flanking policies. The fifth section concludes.

3.1 Subsidiarity test of energy efficiency

Regulation and public policies are, from an economist's point of view, usually justified in policy areas where market failures prevent the market to reach the most efficient outcome on its own. For reasons raised in the introduction and the barriers which are the topic of this BEER, energy efficiency is usually considered to be such a policy area. For the remainder of this part it is therefore assumed that public policies to spur energy efficiency are in general legitimate. From a European point of view, what is more interesting is whether and to what extent the EU should legislate. To assess the subsidiarity issue this section conducts a five step subsidiarity test on energy efficiency as an EU policy area (Pelkmans, 2006).

1. Is energy efficiency an area of shared competences? Yes, very likely so. Since the rational use of natural resources is determined as an aim of the EU in art. 174 of the TEC, sustainable development is acknowledged in art. 6 of the TEC and since energy efficiency potentially characterizes essential aspects of products placed on the Internal Market, energy efficiency can be considered as an area of shared competences.
2. Can the TEC art. 5 – criteria on the "need-to-act-in-common" be applied? Yes. First, energy efficiency relates directly to the environment within areas like carbon emissions and pollution, since higher energy efficiency, for a given consumption of energy, implies a lower pollution. Carbon emissions and pollution have cross-border effects which imply a need to act on common. Second, since energy efficiency can be addressed at the level of each product placed on the market within the Internal Market there might be a need to act together to avoid disturbances of the Internal Market.
3. Is reliable inter member state cooperation credible? Probably not always. As what is seen in other areas of legislation related to the environment there are different preferences between the member states dependent on; income level, climate zone and production composition etc. As such, there are cases where voluntary cooperation probably will not work. Also, for the reason of different preferences there might be limitations to the extent of EU legislation, meaning that different preferences imply high centralization costs.
4. Since step 1 and 2 were accepted and step 3 denied, the test concludes that policies on energy efficiency can be enacted at the EU level.
5. The fifth step then addresses to what extent (proportionality) the implementation, monitoring and enforcement of the policies should be assigned to the EU level. Since it does not appear to be strictly necessary to have neither the implementation nor the monitoring or the enforcement based at the EU level, the scope for EU policy making on energy efficiency is probably limited to a focus on overall issues and mostly in the form of directives, which are then transposed into national law by the member states.

To conclude, the subsidiarity test confirms that EU policies based on energy efficiency can be justified. The extent and level of detail of these policies are however limited to be in the form of overall directives, which implies that the implementation is left to the member states.

3.2 Overview of existing legislation

Following the mandate confirmed by the subsidiarity test above, the EU has enacted legislation on energy efficiency with increasing stringency since 2000. The EU lists the following eight directives as directives dealing with energy efficiency (European Commission, 2009):

- **Energy end-use efficiency and energy services Directive** (2006/32/EC); sets general targets for national energy savings, promotes energy efficiency in public procurement, advocates energy performance contracting and third-party financing of energy efficiency investments, and addresses activities such as energy audits and energy efficiency funds as well as the measurement and verification of energy savings.
- **Energy performance of buildings Directive** (2002/91/EC); promotes the energy performance of buildings by introducing a framework for an integrated methodology for measuring energy performance, applying minimum energy performance requirements to new and certain existing buildings with a regular updating of these requirements, implementing energy certification and advise for house owners[4].
- **Ecodesign for energy-using appliances Directive** (2005/32/EC); promotes energy efficiency by establishing a framework where manufacturers or importers of energy using products are obliged to lower the energy consumption of the product throughout the product's lifecycle. The manufacturers are obliged to take these measures already at the design stage. The measures used are minimum performance requirements.
- **Household appliances labeling Directive** (1992/75/EEC); seeks to promote energy efficiency through the labeling of the energy performance of products within seven types of household appliances (mainly energy intensive white goods).
- **Ballasts for fluorescent lighting Directive** (2000/55/EC); promotes energy efficiency in fluorescent lighting by gradually moving towards the use of more efficient ballasts. This is done through minimum power consumption requirements.
- **Energy efficiency of domestic refrigeration appliances Directive** (1996/57/EC); applies minimum energy efficiency standards to domestic refrigeration appliances in order to promote energy efficiency. Additionally, the CE conformity marking guarantees that the appliance meets these standards.
- **Energy efficiency of hot-water boilers** (1992/42/EEC); applies minimum energy efficiency standards to liquid or gaseous fuel fired hot-water boilers. Additionally, the CE conformity marking guarantees that the appliance meets these standards.
- **Cogeneration Directive** (2004/8/EC); promotes the use of cogeneration techniques in the production of heat and electricity. Since cogeneration is considered as a more efficient technique than traditional techniques the directive is considered an energy efficiency directive.

In addition to these directives, the European Commission has adopted the Energy Star program jointly with the United States to promote the manufacturing of energy efficient office equipment. Furthermore, the Commission has adopted an action plan on energy efficiency covering the period 2007 – 2013 (European Commission, 2009). The EU also promotes energy efficiency through several flanking policies such as market-based instruments. As with many other EU policies, standards promoted by international organizations are used, and through the Intelligent Energy – Europe program the EU has supported action on energy efficiency, co-financed several studies on

[4] For a further treatment of this directive see (Bleischwitz, Giljum, Kuhndt, & Schmidt-Bleek, 2009)

the promotion of energy efficiency and raised public awareness on energy efficiency through information campaigns (European Commission, 2009).

3.3 Accommodation of agency barriers in the legislation

The revised theory focuses basically on two methods to alleviate the inefficiencies caused by the asymmetric information. The first is the measurability and verification of energy efficiency, the variable EE, and later of effort, e, required to install energy efficiency, which might alleviate the moral hazard problems. The second is the increased information on the agents' characteristics; labeling of products, certification of advisors and installers and in general more education (raise knowledge on energy efficiency), which might alleviate the adverse selection problems. The intent with this analysis is to evaluate the extent to which the overall legislation accommodates the agency barriers proposed by the theory.

To conduct an encompassing analysis of the directives, a survey of the policy instruments contained in each directive was conducted. The three most relevant policy instruments were identified as:

1. Minimum requirements
2. Measuring and verification
3. Certification

Note again that the results presented below are based on an analysis of the overall ideas and lines in the legislation and not on specific details. Note also, that the findings are based on our subjective and short evaluations and can therefore possibly be discussed. The results of the analysis are summarized in the table below.

Table 2 – Identifying agency barrier accommodating policies
The table identifies the main policy instruments contained in each directive

Directive	Minimum requirements	Measuring and verification*	Certification
Energy end-use	No	Partly	Partly
Buildings	Yes	Partly	Yes
Ecodesign	Yes	No	No
Labeling	No	Yes	Yes
Lighting	Yes	No	No
Refrigeration	Yes	No	Yes**
Water boilers	Yes	No	Yes**
Cogeneration	No	No	No

*The instrument relates to the measuring and verification of energy efficiency and not specific characteristics of the service or product
** Refrigerators and water boilers are required to meet minimum requirements to obtain the CE certification

Source: Own research based on overall evaluation of the instruments contained in the directives

A few comments on the findings seem appropriate. On the energy end-use directive, which basically aims at establishing a market for energy efficiency, the notion on the measuring and verification instrument is assessed to be only partly, since the directive (art. 15) establishes a committee to assist the Commission in developing a harmonized top-down and bottom-up measuring system (European Community, 2006). A specific method is, as such, not established by the directive. However, studies have been commenced to assist in the development of these methods, for instance the EMEEES project[5] and the AID-EE project[6]. Additionally, the same directive (art. 8) only stipulates that the member states, when they believe it is necessary, must set up systems to evaluate and certify energy savings (European Community, 2006). Since this provision is not mandatory, it is left to the member states and it only counts in case the member states believe it is necessary, the assessment is only to be partly. On the buildings directive the measuring and verification is again only assessed to be partly, since the directive (art. 3) only calls for a regional or national methodology to calculate savings and since the directive (in its annex) only state certain minimum requirements to this methodology. Again, as such, the directive does not specify any specific method and leaves it to the member states to decide on the issue.

The first instrument evaluated is the use of minimum requirements in the legislation which is contained in five of the eight directives. Minimum requirements can be seen as a way to partly accommodate the problem of adverse selection, since minimum requirements, everything else equal, will lower the share of poorly performing products in the market. In the model on adverse selection this corresponds to an increase in the variable, q, which in turn lowers the variable on the share of bad agents, $1-q$. In EU legislation these minimum requirements are both in the form of requirements to the performance of products and projects, but also requirements to the materials and composition. Related to moral hazard the minimum requirements can also be seen as a way to increase the minimum exerted effort-level, e^{min}, since the minimum requirement makes it mandatory for products and projects to comply with certain thresholds, which in turn requires a certain level of effort to be exerted. However, though the final outcome as such is moved closer to its optimum, the use of minimum requirements cannot be perfect to accommodate the barriers, since the instrument does not really attempt to remove the full range of barriers.

The second instrument is the measuring and verification of energy savings. In the theory on moral hazard above these instruments will establish a reliable measure on the variable, EE, which is necessary in order to make the principal and the agent contract on energy efficiency. In case it is not possible to contract on the energy efficiency, the exerted effort, at least theoretically, will be e^{min} resulting in a low energy efficiency level. Contrary to the minimum requirements above this instrument does not only address the minimum characteristic or effort, but it also opens up for an exploitation of the potential upside of contracting on energy efficiency. The outcome is likely to be a higher level of energy efficiency.

The third instrument is the use of certification of businesses, products and projects. The link to the theory is the following. The use of certification might serve as a way to increase the principals' knowledge about the agent, his or her performance and the agent's characteristics in the adverse selection model. In the extreme case where the certification reveals all relevant characteristics about the agent to the principal the result will be the outcome of the base model where information is symmetric. Thus, certification enables the principal to contract the agent with the most preferably characteristics, and thereby potentially, assuming that energy efficiency is worth exploiting, increase the use of high efficient agents, which in turn will increase the energy efficiency.

To summarize on the use of policy instruments to alleviate agency barriers to energy efficiency the overall assessment must be that the European legislation to some extent accommodates these

[5] EMEEES - Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services. A project coordinated by the Wuppertal Institute and conducted with 21 partners to establish integrated methods for evaluation of the performance of 20 types of energy efficiency technologies. See: http://www.evaluate-energy-savings.eu/emeees/en/home/index.php.

[6] AID-EE – Active Implementation of the European Directive on Energy Efficiency. An EU Intelligent Energy for Europe project that has, inter alia, developed guidelines for monitoring and evaluation. See: http://www.aid-ee.org/index.htm and (Khan, Harmelink, Harmsen, Irrek, & Labanka, 2006)

barriers. This is mostly done through the use of minimum requirements, but also through measuring, verification and certification. Minimum requirements seem to be the preferred instrument, which possible is due to its specific nature and thereby easy understanding and implementation. Also, certification is used where possible, though there seem to be scope to increase its use. However, measuring and verification seem to halt as a policy instrument. A potential reason is the complex nature of such measurement methods. Additionally, the principle of subsidiarity can explain why these issues in general have been placed on the member state level. However, in order to establish a market for energy efficiency, as clearly intended with the energy end-use directive, the adoption of a harmonized method will be preferential.

3.4 Accommodation of agency barriers through flanking policies

The EU makes also use of flanking policies to promote and support its existing legislation. Indeed one should stress the power of market-based instruments such as the EU ETS to unleash markets for eco-innovation. On energy efficiency a good example of such a flanking policy is also the financing of studies within the Intelligent Energy – Europe program. This program serves as the EU's tool to fund studies and projects to improve, not only energy savings, but also the use of renewables (European Commission, 2009). Additionally, like in other policy areas the European Commission can request the European Committee for Standardization (CEN) to develop standards in support of policies on energy efficiency. However, so far only one CEN-standard – reference CWA 15693:2007 named "Saving lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations" - has been developed directly related to energy efficiency. Though this standard is important, it seems that there is scope for a further development of European standards on energy efficiency. Such an intention is also expressed by the Commission, which considers standards on energy efficiency to be a powerful tool to raise energy efficiency. In the Action Plan for Energy Efficiency 2007 – 2013 it is stated that the use of energy efficiency standards will be promoted in the future (European Commission, 2006). Here it should be mentioned that in documents from the European Commission the word "standard" is often used interchangeably with the word "requirement", which complicates the understanding of the intended meaning. However, at least in the Action Plan it seems that the mentioned promotion of standards covers actual CEN-standards.

3.5 Conclusion on EU policies

The short assessment of the legislation found that the preferred policy instrument seems to be the use of minimum requirements. This might be because of the easy understanding of minimum requirements as well as due to the principle of subsidiarity. However, though the policy improves the outcome, as argued, the policy is not perfect since it does attempt to remove the full range of agency barriers. Less used in EU legislation is the use of measuring and verification as well as the use of certifications. The principle of subsidiarity might be a part of the explanation complemented by the inherent complexity of these policies. However, an increased use of these instruments should be considered by the EU, since the instruments have the potential to move the final outcome further to the efficient level. The increased use should in particular focus on a further development of standards on measurability and verification, in cooperation with the International Organization for Standardization (ISO) and the Efficiency Valuation Organization (EVO)[7]. Finally, there should be an increased focus on education of consumers as well as training of installers and advisors on energy efficiency, which potentially could be done through an enlarged Intelligent Energy – Europe program. These assessments are supported by experts (Ferreira & de Wachter, 2008) (ECEEE,

[7] EVO is a non-profit organization devoted to creating measurement and verification tools to assess the efficiency of products and processes. The EVO has developed the International Performance Measurement and Verification Protocol (IPMVP) which provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities.

2006) (ECEEE, 2008) (Khan, Harmelink, Harmsen, Irrek, & Labanka, 2006) (Bleischwitz, Giljum, Kuhndt, & Schmidt-Bleek, 2009).

4. Conclusion

With the complex set of energy challenges facing the world today and the urgency required to deal with climate change, the call for innovative solutions is high. Energy efficiency is generally perceived to be underexploited whereby such innovative solutions must focus on how to use energy more efficiently. Market failures and other deficits pose barriers to such increase of energy efficiency and the understanding of these barriers is required to target the policy response and promote energy efficiency.

So far, the focus of prevailing research on agency and informational barriers has largely been on the problem of splitted incentives between principals and agents. Not neglecting this problem, this BEER deviates from that approach and underlines the need to look at pure asymmetries of information in contractual relationships. This was done on two levels:

- A theoretical framework that originates within economics of information and incorporates elements such as objective functions, participation and incentive constraints, and maximization under uncertainty was presented. The theory was then applied to encompass the problems of moral hazard and adverse selection. In both presented models the cost to the principal from implementing high energy efficiency outcome increased with the informational asymmetries, with the likely implication that the installed level of energy efficiency is not at its optimal level.

- A short assessment of European policies was conducted. EU policies acknowledge information asymmetries and seemingly focus on the use of minimum requirements. This might be because of the easy understanding of the instrument as well as the principle of subsidiarity. Less used in EU legislation is the use of measuring and verification as well as the use of certifications. Therefore, it can be concluded that the EU should pay more attention to information asymmetries and consider the latter options with a higher priority. In particular, a focus on a further development of standards for measurability and verification as well as an increased focus on education of consumers as well as training of installers and advisors on energy efficiency is recommendable.

A last word on our profession: Economists strive for the most efficient use of resources. Ever since they are taught the economics of the welfare theorems in their introductory microeconomics courses, they often assume that markets are well-functioning and reach the most efficient outcome. And when economists are confronted with obvious inefficiencies, resulting in inefficient outcomes, they are attracted to understand the causes and consequences as well as the potential solutions. We - the authors of this BEER - are no exceptions. Inspired by the need to understand the implications of information asymmetries on energy efficiency, a theoretical framework on informational asymmetries and energy efficiency was presented. And with the great need to act on the energy challenges facing the world and the urgency to deal with climate change and other sustainability issues this modest contribution to the literature is relevant but far from sufficient to fully understand the nature of energy efficiency including its institutional and behavioral dimension – much more research on how incentives can spur the transformation of information into action, as well as, the generation of new knowledge in areas of key concern is needed. In that regard, we find it quite encouraging that the 2009 Nobel-price in economics was awarded to Elinor Ostrom for enhancing the understanding of sustainable institutional management of natural resources. But research is only one pillar. Better policy responses can be done now and are indeed needed to address “the energy efficiency gap”.

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ANNEX

Annex I

Why both constraints bind in the moral hazard problem -
In the moral hazard problem both constraints must bind meaning that both Lagrange-multipliers, λ and μ, are positive. Here this result is proven. The proof is made by excluding possibilities where the constraints do not bind.

Assume first that none of the constraints bind, meaning that $\lambda = 0$ and $\mu = 0$. Then the FOC becomes:

$$k \big/ u'(w(EE_i)) = 0$$

However, this cannot be a solution since $u' > 0$ implies that $k \big/ u'(w(EE_i)) \neq 0$

Assume then that only the participation constraint binds, meaning that $\lambda > 0$ and $\mu = 0$. Then the FOC becomes:

$$k \big/ u'(w(EE_i)) = \lambda$$

However, this can neither be a solution since it implies that the wage is constant like in the base model, i.e. that $w(EE_i) = w(EE_j)$, whereby the agent will chose to exert low effort. This is not possible since the incentive constraint is violated.

Next, assume that only the incentive constraint binds, meaning that $\lambda = 0$ and $\mu > 0$. Then the FOC becomes:

$$\mu\left(1 - p_i^L \big/ p_i^H\right) = k \big/ u'(w(EE_i)) \Leftrightarrow p_i^H - p_i^L = p_i^H k \big/ \mu u'(w(EE_i))$$

Summing over the outcomes,

$$\sum_{i=1}^{N} p_i^H - \sum_{i=1}^{N} p_i^L = \sum_{i=1}^{N} p_i^H k \big/ \mu u'(w(EE_i))$$

reveal that this cannot be a solution since the left hand side is equal to zero (the sums of the probabilities are by definition each equal to one) and the right hand side is larger than zero. This last result is not surprising since the implication of a non-binding participation constraint would be that the principal paid the agent more than necessary to engage in the contract.

The final result is that whenever there is a solution both constraints bind.

QED

Annex II

Derivation of the slopes of the curves in the first best outcome in the adverse selection -
In the adverse selection problem's first best outcome, the conditions characterizing the optimal contracts are:

For the good type:

1) $EE'(e^{G*}) = {v'(e^{G*})}/{u'(w^{G*})}$ (AS.1)

2) $u(w^{G*}) - v(e^{G*}) = \underline{U}$ (AS.2)

and for the bad type

3) $EE'(e^{B*}) = {kv'(e^{B*})}/{u'(w^{B*})}$ (AS.3)

4) $u(w^{B*}) - kv(e^{B*}) = \underline{U}$ (AS.4)

Here the slopes of the conditions in a (w,e)-diagram are identified.

Total differentiating equation (AS.1) gives:

$$EE''(e^{G*})\partial e^{G*} = \frac{v''(e^{G*})u'(w^{G*})\partial e^{G*} - u''(w^{G*})v'(e^{G*})\partial w^{G*}}{(u'(w^{G*}))^2} \Leftrightarrow$$

$$\frac{\partial e^{G*}}{\partial w^{G*}} = \frac{-u''(w^{G*})v'(e^{G*})}{EE''(e^{G*})u'(w^{G*}) - v''(e^{G*})u'(w^{G*})} < 0$$

The slope must be negative since the numerator is positive and the denominator is negative. The numerator is positive since $u''(w^{G*})$ is negative, implying that $-u''(w^{G*})$ is positive, and $v'(e^{G*})$ is positive. The denominator is negative since $EE''(e^{G*})$ is negative whereas the other derivatives are positive.

Total differentiating (AS.2) gives:

$$u'(w^{G*})\partial w^{G*} - v'(e^{G*})\partial e^{G*} = 0 \Leftrightarrow {\partial e^{G*}}/{\partial w^{G*}} = {u'(w^{G*})}/{v'(e^{G*})} > 0$$

The slope must be positive since both derivatives are positive.

Similar reasoning can be applied to the conditions (AS.3) and (AS.4) since the only difference is the constant k.

Annex III

Why it is the (IC-G) and (PC-B) that binds in the adverse selection model -
In the adverse selection problem it is only the incentive constraint for the good type and the participation constraint for the bad type that binds.

From (IC-G) and (PC-B) the following must hold:

$$u(w^G) - v(e^G) \geq u(w^B) - v(e^B) \geq u(w^G) - kv(e^G) \geq \underline{U}$$

Which implies that (PC-G), $u(w^G) - v(e^G) \geq \underline{U}$, must be more than fulfilled, meaning that the constraint does not bind with equality. The conclusion is that if both (IC-G) and (PC-B) are fulfilled, then (PC-G) is fulfilled for sure and does not have to be taken into account in the maximization problem.

Furthermore, from (IC-B) and (IC-G) then following holds:

$$k(v(e^G) - v(e^B)) \geq u(w^G) - u(w^B) \geq v(e^G) - v(e^B)$$

This equation can only hold if $v(e^G) - v(e^B) > 0$ since $k > 1$. This implies as well that $e^G > e^B$. However, if $v(e^G) - v(e^B) > 0$ it must be the case that $u(w^G) - u(w^B) > 0$, whereby the good type must get a higher wage. The conclusion is that (IC-B) and (IC-G) cannot bind simultaneously. Assume then that (IC-B) binds in the solution. However, this would imply that the bad type's utility would have to be negative caused by a negative wage, which is not possible.

Finally, suppose that (PC-B) and (IC-B) are the binding constraints. Then e^G would be as high as possible whereas w^G would be as low as possible, which would violate (PC-G).

The conclusion is that it is the participation constraint for the bad type and the incentive constraint for the good type that binds in equilibrium.

QED

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