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Offering Energy Efficiency under Imperfect Competition and Consumer Inattention

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Abstract

Energy efficiency is considered to be a win-win situation for both the economy and the environment. Producing products and services at lower energy input and related input costs can contribute to climate change abatement and economic competitiveness. Actual implementation of energy efficiency falls short to expectations, though. For one thing, research suggests that consumer inattention is an underlying force for underinvestments. For another thing, energy supply markets are often characterized by imperfect competition. Do firms in the energy retail market have incentives to voluntarily introduce energy efficiency? Or should informational regulation inform inattentive consumers? In this article I show that consumer inattention and imperfect competition are the crucial drivers for firms' decisions to introduce or conceil energy efficiency to customers. I find two symmetric equilibria: One in which both firms introduce energy efficiency and one in which both firms conceil energy efficiency. Equilibrium coordination depends on the distribution of consumers that are attentive to energy efficiency and consumers that are not. Further, mandatory disclosure laws are found to be weakly welfare increasing.

Keywords: Imperfect Competition, Consumer Inattention, Product Differentiation, Disclosure, Energy Efficiency

JEL classification: D83, L13, L41

1. Introduction

In some markets there are products that allow consumers to partly substitute away from other products they receive positive utility from. However, the availability and substitutional characteristics of these prod-

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ucts are often unknown to consumers, thus leading to underconsumption of the partial substitute compared with the welfare optimum. This is particular true for the provision of energy efficiency. In general, the purpose of energy efficiency is to reduce the consumption of energy used to create a certain product or deliver a certain service. Apart from obvious economic gains by reducing input costs, energy efficiency is also beneficial with respect to abating climate change.

Although a large body of articles and studies (e.g., Granade et al., 2009) asserts a huge potential for investments in energy efficiency, actual implementation rates fall short of expectations. This difference between actual and optimal implementation of energy efficiency is often termed the *energy efficiency gap*. On the one hand, research on this issue, for example by Allcott and Greenstone (2012), suggests that consumers are simply unaware of energy efficiency as a substitute for energy consumption, resulting in potential inefficiencies in market outcomes. To address these, numerous energy efficiency support schemes aim to incentivize such investments. For instance, within the US Climate Action Plan USD 250 million is assigned to the Energy Efficiency and Conservation Loan Program (White House, 2013) and in Germany, renovation work on buildings to improve energy efficiency is supported with approximately EUR 700 million each year (BMWi, 2015). On the other hand, energy for domestic heating is usually supplied by a utility competing in a market with an oligopolistic market structure. This leaves the question of whether firms could strategically coordinate on an equilibrium in which none introduces energy efficiency?

This article is motivated by the observation of such gaps between optimal and actual consumption of energy efficiency. If the underconsumption of partial substitutes originates from consumer inattention[1], it is of interest whether *informational regulation* by means of mandatory disclosure should be used to inform consumers about the existence and characteristics of energy efficiency. Given the popularity of such interventions ever since the 1980s (Sunstein, 1999), it is to be expected that such markets would potentially face mandatory disclosure laws. But are these interventions really necessary? From an industrial organization perspective, it is not clear whether firms would refrain from offering and disclosing energy efficiency that interacts with their energy retail business in equilibrium. The arguments for and against the voluntary introduction of energy efficiency by the firms are as follows: Energy efficiency reduces demand for energy offered by the firms. Intuitively, firms offering energy would not want to bite the hand that feeds them. However, assuming energy efficiency is efficient for consumers, firms could offer and disclose energy

[1] As Loewenstein et al. (2014) have recently discussed, there are quite a few types of consumer inattention that influence firms' disclosure efficiency and price setting. Therefore, consumer naivety, limited attention to given information, and inattention to missing information are important aspects of consumer bounded rationality when discussing firm strategies in the framework introduced above. The different types of inattention originate in differing internal search costs for the subordinate good. Internal search costs are cognitive costs associated with the investigative search for the subordinate good and sorting and evaluating search results (Stigler, 1961; Smith et al., 1999).

efficiency. Even though this would reduce demand for energy, it would allow the firm to win over consumers from the competing firms that do not offer energy efficiency, thus resulting in a strategic interaction similar to the prisoner's dilemma. This suggests that in equilibrium firms could voluntarily introduce energy efficiency.

From the interactions of the above-mentioned arguments with respect to imperfect competition and consumer inattention it is unclear whether firms would voluntarily introduce energy efficiency and if not, whether there is a case for mandatory disclosure laws.

In this article, I investigate why and under what conditions firms that supply energy choose to introduce energy efficiency. Correspondingly, I show that consumer inattention and imperfect competition play substantial roles in firm strategies and how they determine voluntary introduction. These results are mainly driven by the distribution of informed and uninformed consumers as well as the inability of firms to price discriminate between consumer types.

Furthermore, it is shown that mandatory disclosure could in general reduce consumer surplus and that optimal mandatory disclosure under a consumer surplus standard would not inform all consumers. However, in equilibrium, mandatory disclosure leads to a weak increase in the consumer and total surplus.

The remainder of the article is structured as follows: Section 2 introduces the model setup, and the subsections in Section 3 describes the analysis and results. Welfare implications and the efficacy of mandatory disclosure are discussed in Section 5. In Section 6, the results are reconsidered for if consumers fail to recognize the competition on the market for energy efficiency. Section 7 discusses the results and Section 8 concludes. Additional figures and tables, proofs and example visualizations are given in the Appendix.

2. Model Setup

Consider a duopoly with spatial competition in the energy retail market and non-spatial duopoly competition with a competitive fringe without capacity restriction in the market for energy efficiency. As for energy retail, consumers are uniformly distributed along a linear city with normalized length of 1 (as in Hotelling, 1929). Firms A and B are positioned at $x_A = 0$ and $x_B = 1$ along the linear city, respectively. Each consumer receives a surplus of v from consuming energy and has a taste parameter for energy represented by her location on the linear city x. I assume v to be sufficiently large, such that the entire market is covered in all instances. For each location $0 \leq x \leq 1$, consumers at that location have a disutility of tx if buying from firm A and $t(1-x)$ if buying from firm B. The demand elasticity in the market for energy retail is assumed to be perfectly inelastic. Hence, demand for energy can be normalized to one.

Turning to energy efficiency, this can in general take numerous different forms. For instance, energy efficiency could be provided by installing efficient windows, a new heating system or insulating the outer walls, among others. For this article, I will use home energy counseling as a running example for the provision of energy efficiency (subsequently, the product will be termed efficiency service). Home energy counseling is suitable for two reasons. First, it is often stated that information provision on inefficient energy consumption behavior (e.g., by illustrating energy consumption patterns for old and new domestic appliances) has large saving potential at low costs. Second, there is a large potential supply for home energy counseling, as professionals from a wide range of backgrounds can become accredited home energy counselors after some advanced training. This therefore justifies the assumption of a competitive fringe in efficiency service supply.

Consumers receive no direct utility from consumption of the efficiency service, but reduce their consumption of energy. After consumption of the efficiency service, consumers purchase only $\rho \in (0, 1)$ of the energy, keeping the utility from consumption v fixed. That means the efficiency service reduces demand for energy by shifting the utility function outwards, such that the same utility level is reached with less quantity consumed. I assume positive marginal costs of production for energy to be greater than zero ($c > 0$). This reflects the fact that firms have to cover the costs for extraction, transportation, importing and refining the energy supplied to the consumers. However, I normalize the marginal costs for the efficiency service to zero. Hence, marginal costs for energy c reflect the cost savings from the efficiency service.

However, whether or not the efficiency service is consumed depends on the types of consumers with regards to inattention. One fraction of the population $\alpha \in (0, 1)$ is naive. They are well informed about the characteristics and prices of energy (e.g., from repeated interactions on the market). Nonetheless, naive consumers are unaware of the efficiency service. That is, they completely ignore its existence and therewith its potential to increase welfare for the consumer. The complementary fraction of the population $1 - \alpha$ is sophisticated. Sophisticated consumers are fully aware of the existence, characteristics and prices of both products. The existence of a competitive fringe for the efficiency service allows a sophisticated consumer to partly substitute away from consumption of energy, by purchasing the service at marginal costs from the competitive fringe or the firms (if they decide to offer the efficiency service). Similar to Klemperer (1987) and Karle and Peitz (2014), I assume the consumer types α and $1 - \alpha$ to be evenly distributed along the linear city.

A visualization of the linear city and distribution of consumer types is given in Figure 1.

Prior to discussing firms' actions and the timing of the game, it is worth analyzing the modelling approach. First, an oligopolistic market structure describes the energy retail market best, as in most countries regional monopolies were the norm prior to the liberalization of energy markets. After liberalization, firm entry was

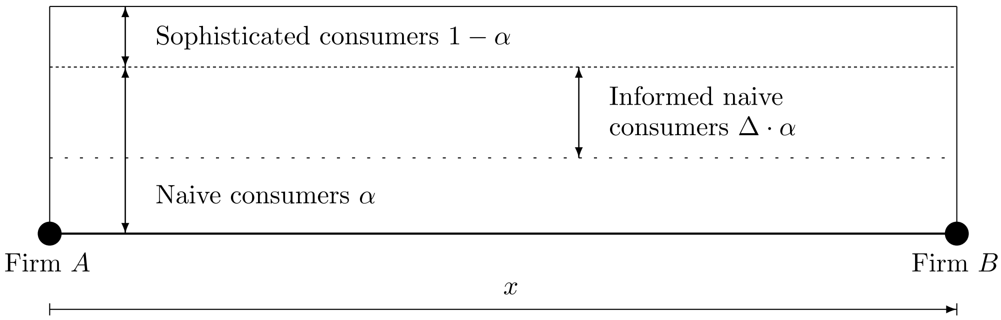

Figure 1: Illustration of the mass of consumers and consumer types α, $1-\alpha$ and Δ.

scarce and hence previously monopolized incumbent firms compete mainly with one another. Second, even though energy supply is technically a homogeneous good, it is unlikely that the assumptions for a strict capacity-unrestricted Bertrand equilibrium hold. Similar to Laffont et al. (1998), I assume the firms to offer different product characteristics that attract different consumers. In my example, firms could admix certain percentages of bio methane to their supply of natural gas in order to appeal to environmentally cautious consumers. Another source of differentiation could be branding and marketing by the firms. By branding the products, firms persuade consumers that these products are less homogeneous than they actually are. In particular, the latter can be illustrated by sponsorship energy companies provide for sport events and teams. In addition, branding aims at horizontal rather than vertical differentiation, as in grid-bound markets the quality (i.e., the security of supply) is determined by the infrastructure and is unaffected by the firm supplying energy. Third, the demand elasticity of energy demand is highly inelastic, leading to the assumption of short-term inelastic demand in the energy retail market. In summary, the above-mentioned characteristics of the problem are well captured by the spatial competition approach applied in this article.

The strategy profiles of the firms as well as the consumer responses are subsequently discussed in an overview of the timing of the game.

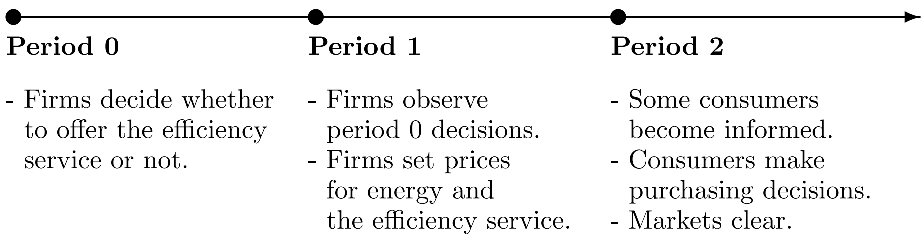

Figure 2: Illustration of the time line of the game.

Period 0: Firms A and B decide whether to introduce the efficiency service or not. If firms choose to offer the efficiency service, they have to initiate an information campaign to disclose the existence of the efficiency service and the firms offer to the consumers. Hence, I assume the decision to offer and to inform about the efficiency service to be linked. Offering and disclosing do not incur costs. Furthermore, it is assumed that firms must not bundle energy and efficiency services and that the competitive fringe is unable to disclose the existence of the efficiency service to the consumers[2]. Hence, Firms A and B can choose one of the following strategies in period 0:

Not offering the efficiency service (*NO*) The firm refrains from offering the efficiency service and does not provide information on the existence of the energy service.

Offering the efficiency service (*O*) The firm offers the efficiency service and advertises the existence of the efficiency service as well as their offer to all consumers. For example, firms could set up billboard ads or distribute leaflets to all consumers.

Period 1: Firms A and B observe the decisions made in period 0 and set prices for energy $(p_{A,e}, p_{B,e})$ and the efficiency service $(p_{A,s}, p_{B,s})$, if they chose to offer it. Firms set uniform prices for all consumer types.

Period 2: Consumers choose which products to buy from which firm. Sophisticated consumers $1 - \alpha$ observe the existence, characteristics and prices of the energy and efficiency service and purchase the efficiency service at marginal costs from either the firms or the competitive fringe, thereby consuming only $\rho \in (0, 1)$ of energy. The actions of the naive consumers α depend on the period 0 decisions of the firms. If neither firm chooses to offer and disclose the efficiency service, naive consumers observe the characteristics and prices on the energy retail market only and purchase energy either from firm A or B. If, however, at least one firm offers and discloses the efficiency service, a share $\Delta \in (0, 1)$ of all naive consumers becomes informed naive consumers and behaves like sophisticated consumers. This is because the information provision reduces their search costs for the efficiency service, such that they become aware of it. The mass of consumers becoming informed from disclosure and offering being strictly smaller than the entire mass of naive consumers represents the insight that consumers have *limited attention and awareness to given information* and therefore differing internal search costs. As Loewenstein et al. (2014) summarize, disclosure effects are counteracted by limited capacity to digest the information. As a result, a share of naive consumers are left uninformed.

[2]In line with the running example of home energy counseling as the efficiency service, it is reasonable to assume that home energy counselors, often self-employed, initiate a supra-regional information campaign.

An illustration of the consumer mass with the different consumer types is also given in Figure 1[3]. After the different consumer types make their purchasing decisions, the market clears and firms make profits π_i, with $i \in \{A, B\}$.

3. Analysis and Equilibrium Results

In order to identify the subgame-perfect Nash equilibria (SPNE), every potential interaction of firm period 0 decisions has to be evaluated. In period 0 both firms decide to either offer and disclose the efficiency service (O) or refrain from doing so (NO). This requires a total of three subgames to be considered: both firms refrain from offering and disclosing the efficiency service *(NO, NO)*, both firms offer and disclose the efficiency service *(O, O)*, and one firm discloses and offers the efficiency service, while the other firm does not *(NO, O)* or *(O, NO)*.

3.0.1. Both Firms Refrain from Offering and Disclosing the Efficiency Service (NO, NO) - (Subgame 1)

If both firms refrain from offering and disclosing the efficiency service, the mass of naive consumers α purchases energy only and has unit-demand for it. Sophisticated consumers $1 - \alpha$ purchase the efficiency service from the competitive fringe at zero marginal costs and consume only ρ of energy. That means, they reduce their demand for energy by $1 - \rho$. As neither firm offers and discloses the efficiency service to the naive consumers, not a single naive consumer becomes informed and hence Δ equals 0.

Therefore, there are two consumer groups with different utility functions.

A naive consumer at location x in the linear city has utility $U_{\alpha,A,x}$ buying energy from firm A and utility $U_{\alpha,B,x}$ buying from firm B.

$$U_{\alpha,A,x} = v - p_{A,e,1} - tx \tag{1}$$

$$U_{\alpha,B,x} = v - p_{B,e,1} - t(1 - x) \tag{2}$$

A sophisticated consumer at location x has utility $U_{1-\alpha,A,x}$ buying energy from firm A and utility $U_{1-\alpha,B,x}$ buying from firm B.

$$U_{1-\alpha,A,x} = v - p_{A,e,1}\,\rho - tx \tag{3}$$

$$U_{1-\alpha,B,x} = v - p_{B,e,1}\,\rho - t(1 - x) \tag{4}$$

Comparing Equations (1) and (2) with Equations (3) and (4) shows that the efficiency service alters the

[3]A table summarizing the notation is given in the Appendix in Table A.1.

utility function of sophisticated consumers by means of the energy costs. Compared to naive consumers, sophisticated consumers purchase less energy, yet receive the same level of utility from energy consumption.

The firms demands for energy follow from the consumers $\hat{x}_\alpha$ and $\hat{x}_{1-\alpha}$ that are indifferent between purchasing from firm A or firm B.

$$q_{A,e,1}(p_{A,e,1}, p_{B,e,1}) = \alpha\,\hat{x}_\alpha + (1-\alpha)\,\rho\,\hat{x}_{1-\alpha} \tag{5}$$

$$q_{B,e,1}(p_{A,e,1}, p_{B,e,1}) = \alpha\,(1-\hat{x}_\alpha) + (1-\alpha)\,\rho\,(1-\hat{x}_{1-\alpha}) \tag{6}$$

Resulting in the following profits of the firms, with $i \in \{A, B\}$:

$$\pi_{i,1} = q_{i,e,1}\,(p_{i,e,1} - c) \tag{7}$$

Solving this subgame for equilibrium prices and profits results in the following Lemma.

Lemma 1. *If neither firm offers and discloses the efficiency service, equilibrium firm profits are given by, with $i \in \{A, B\}$:*

$$\pi^*_{i,1} = \frac{t}{2}\frac{(\alpha + \rho - \rho\alpha)^2}{\alpha + (1-\alpha)\rho^2}. \tag{8}$$

Proof. Given in the Appendix.

The formula for the equilibrium profits of this subgame $\pi^*_{i,1}$ has the expected characteristic that with an increasing degree of product differentiation, as modeled via t, profits increase likewise. That also means that if firms were to offer identical products, i.e., $t = 0$, they would receive zero profits. Also, equilibrium profits are independent of marginal costs, as firms reimburse these costs via the prices they charge for energy. Another characteristic of the equilibrium profits is best shown using graphical illustrations.

Figure 3 shows the (symmetric) equilibrium profits of both firms for $t = 1$ and four different values for ρ. It can clearly be seen that profits are at a maximum, and independent of ρ, if either all consumers are naive or sophisticated. The result is intuitive for all consumers being naive (i.e., $\alpha \to 1$). In equilibrium prices are set at $c+t$ and profits equate to $t/2$. This result is well known from Hotellings spatial competition models. As for all consumers being sophisticated (i.e., $\alpha \to 0$), these results are also intuitive. If firms face a reduction of demand by ρ, they compensate this demand-reducing effect by increasing the price by a factor of $1/\rho$. This also results in profits of the firms of $t/2$. Prohibiting price discrimination between both consumer types requires the firms to set prices that are in between these extremes, for all $0 < \alpha < 1$. Hence, resulting in Lemma 2.

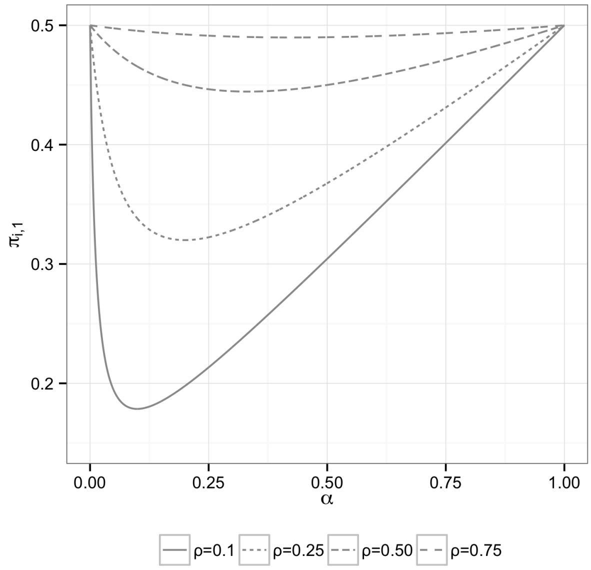

Figure 3: Exemple visualization of $\pi^*_{i,1}$, with $i \in \{A, B\}$, at $t = 1$.

Lemma 2. *If neither firm offers and discloses the efficiency service, the firms' profits are U-shaped in the share of naive consumers α. Equilibrium profits are at a minimum if*

$$\bar{\alpha} = \frac{\rho}{1+\rho}. \tag{9}$$

Proof. Given in the Appendix.

If firms offer and disclose the efficiency service, they shift a share Δ from the naive consumers α towards the sophisticated consumers. Thus, the result of Lemma 2 allows a first step to be taken towards the identification of the consumer type distribution that is most beneficial for the firms. As Lemma 2 states, profits of both firms $\pi^*_{i,1}$, with $i \in \{A, B\}$, are U-shaped in α. Adhering to Figure 3, it is clear that firms will only want to offer and disclose if disclosing results in a mass of uninformed naive consumers $\alpha(1-\Delta)$ that is smaller than $\bar{\alpha}$ and results in a higher profit level than it was at α. This result will be further elaborated upon in the subsequent evaluations.

3.0.2. Both Firms Offer and Disclose the Efficiency Service (O, O) - (Subgame 2)

If both firms offer and disclose the efficiency service, the mass of naive consumers α is reduced by informed naive consumers $\Delta\,\alpha$. Hence, the uninformed naive consumers $\alpha(1-\Delta)$ purchase energy only and have unit-demand for it. The sophisticated share of consumers $1-\alpha$ purchases the efficiency good from either the competitive fringe or firms A or B. Thus, they consume only ρ of energy. The informed naive consumers $\Delta\,\alpha$ behave like sophisticated consumers.

Even though the firms face three consumer groups in this subgame, the informed naive consumers behave just like sophisticated consumers. Hence, the existence of informed naive consumers simply changes the distribution of consumers for the firms. This has a direct impact on the quantities demanded on the energy retail market:

$$q_{A,e,2}(p_{A,e,2}, p_{B,e,2}) = \alpha(1-\Delta)\,\hat{x}_{\alpha(1-\Delta)} + (1-\alpha(1-\Delta))\,\rho\,\hat{x}_{1-\alpha(1-\Delta)} \tag{10}$$

$$q_{B,e,2}(p_{A,e,2}, p_{B,e,2}) = \alpha(1-\Delta)\,(1-\hat{x}_{\alpha(1-\Delta)}) + (1-\alpha(1-\Delta))\,\rho\,(1-\hat{x}_{1-\alpha(1-\Delta)}) \tag{11}$$

Although the firms offer the efficiency service, price pressure from the competitive fringe, as well as the inability to bundle sales of energy and the efficiency service, drive the price for the efficiency service down to marginal cost. This means that $p_{i,s,2}$ $(i \in \{A, B\})$ equals zero. Equilibrium profits are as expressed in Lemma 3.

Lemma 3. *If both firms offer and disclose the efficiency service, firms' equilibrium profits are given by* $(i \in \{A, B\})$*:*

$$\pi^*_{i,2} = \frac{t}{2}\frac{(\alpha(\Delta-1)(\rho-1)+\rho)^2}{\alpha(\Delta-1)\,(\rho^2-1)+\rho^2}. \tag{12}$$

Proof. Given in the Appendix.

At first sight, it is difficult to evaluate the differences between $\pi^*_{i,1}$ and $\pi^*_{i,2}$. The effect of informing a share of the naive consumers is best highlighted using a graphical illustration.

Figure 4 shows $\pi^*_{i,2}$ as a function of the share of naive consumers α and four values for Δ, keeping ρ and t fixed. As $\pi^*_{i,2}$ with $\Delta = 0$ is equivalent to $\pi^*_{i,1}$, the figure shows that for small values of α firms are better off offering and disclosing the efficiency service, as this results in higher pay-offs (for any value of Δ). Conversely, for higher values of α (and $\Delta \ll 1$) firms are worse off offering and disclosing the efficiency service. These findings are in line with the presumption expressed in Subgame 1.

3.0.3. One Firm Offers and Discloses the Efficiency Service, while the Other Firm Does Not (NO, O) or (O, NO) - (Subgame 3)

Without loss of generality I assume Firm A to offer and disclose the efficiency service, while Firm B does not offer nor disclose it. If Firm A offers and discloses it, the mass of naive consumers α is reduced by a share Δ. Hence, leading to informed naive consumers $\Delta\,\alpha$ as if both firms offered and disclosed the efficiency service. As the firms observe the period 0 decisions of both firms prior to their pricing decision, the resulting equilibrium prices and profits are equivalent to the profits in subgame 2.

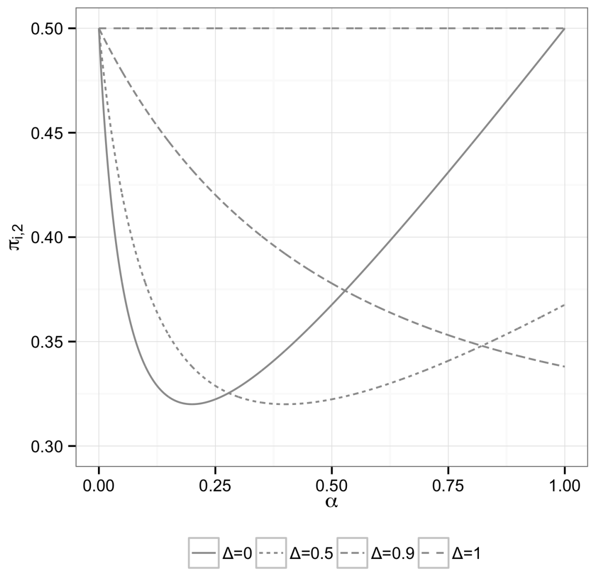

Figure 4: Example visualization of $\pi^*_{i,2}$, with $i \in \{A, B\}$, at $t = 1$ and $\rho = 0.25$.

Lemma 4. *If one firm offers and discloses the efficiency service and the other firm does not, the firms' equilibrium profits are given by (with $i \in \{A, B\}$):*

$$\pi^*_{i,3} = \pi^*_{i,2}. \tag{13}$$

Proof. The proof is straightforward and thus omitted.

4. Subgame Perfect Nash Equilibrium Strategies

The subgame results allow us to identify the subgame perfect Nash equilibria (SPNE). With the previously defined model and the related profits of the firms the normal form of the strategic game and the firm total payoffs are given by the illustration in Figure 5.

	NO	*O*
NO	$\pi^*_{i,1}$, $\pi^*_{i,1}$	$\pi^*_{i,2}$, $\pi^*_{i,2}$
O	$\pi^*_{i,2}$, $\pi^*_{i,2}$	$\pi^*_{i,2}$, $\pi^*_{i,2}$

Figure 5: Normal form of the strategic game with the firms' payoffs (with $i \in \{A, B\}$).

Prior to the identification of the steady state, i.e. the SPNE of the game, it is necessary to understand the preference relation of the firms. I assume firms to act rationally and to prefer higher to lower profits. With the findings of Lemma 4 that $\pi^*_{i,3} = \pi^*_{i,2}$ ($i \in \{A, B\}$) and the fact that if at least one firm chooses to offer and disclose the efficiency service, both firms earn $\pi^*_{i,2}$, it is necessary to understand whether $\pi^*_{i,1}$ dominates $\pi^*_{i,2}$ or vice versa.

Lemma 2 already led to the conclusion that the optimality of disclosure depends on the location of a critical value for α, i.e., $\bar{\alpha}$, that gives the minimal value for profits with respect to the share of naive consumers (that remain uninformed even though the firms disclosed the information). Evaluating the firms profits in Subgame 1 (see Lemma 1) and in Subgame 2 (see Lemma 3) gives the preference relation described in the subsequent proposition.

Proposition 1. *If at least one firm offers and discloses the efficiency service (i.e., (O, O), (NO, O) or (O, NO), i.e., firms earn $\pi^*_{i,2}$) it dominates the profit compared to if both firms refrain from offering and disclosing the efficiency service (i.e., (NO, NO) and firms earn $\pi^*_{i,1}$), if*

$$\alpha(\Delta - 2) > -1 \tag{14}$$

as well as

$$\rho \geq \Gamma(\alpha, \Delta) = \sqrt{\frac{\alpha^2(1-\Delta)}{(1-\alpha)(1-\alpha+\Delta\alpha)}} \tag{15}$$

holds. This implies that for any fixed Δ the marginal returns of offering and disclosing the efficiency service decrease for increasing values of α. Thus making the optimality of introducing the efficiency service less likely the higher the share of naive consumers.[4]

Proof. Given in the Appendix.

Proposition 1 states algebraically the conditions for the payoff dominance of $\pi^*_{i,2}$ over $\pi^*_{i,1}$. Both conditions spell out the presumptions made in the discussion of Subgames 1 and 2. Equation (14) gives the necessary condition between the fraction of consumers that is naive α and the share of naive consumers that becomes informed Δ. As $\Delta \in (0,1)$, $(\Delta - 2)$ takes values between -1 and -2. Hence, it becomes apparent that even if only a very small fraction of the naive consumers becomes informed from introducing the efficiency service, firms receive higher payoffs if both firms offer and disclose it, if the fraction of naive consumers α is smaller than 0.5. However, if a large share of naive consumers becomes informed, the firms receive higher payoffs if at least one firm introduced the efficiency service, for almost any value of α. Equation (15) gives the second necessary condition. In general, it states that the demand for energy after consuming the efficiency service should not be below a threshold value $\Gamma(\alpha, \Delta)$. As $\partial\Gamma(\alpha, \Delta)/\partial\alpha > 0$ and $\partial\Gamma(\alpha, \Delta)/\partial\Delta < 0$, higher threshold values for ρ follow for higher shares of naive consumers, while lower values follow for higher shares of naive consumers that become informed.

[4]Exemplary visualizations of $\alpha(\Delta - 2)$ and $\Gamma(\alpha, \Delta)$ are given in Figures C.1 and C.2 in the Appendix.

The logic behind this result is as follows. Both firms face two consumer groups in period 1: uninformed naive $\alpha(1-\Delta)$ and sophisticated consumers as well as informed naive consumers $1-\alpha(1-\Delta)$. If only the prior are supplied with energy, the reaction functions of the firms are independent of ρ. However, if only the latter would have been supplied, the reaction functions are shifted outwards with decreasing values for ρ, i.e., larger energy demand reduction effects from the efficiency service. The demand reduction effect changes the relation of taste mismatch costs and the price paid for energy. This is therefore equivalent to an elevated degree of product differentiation and more captivity of consumers to the nearest firm (e.g., Tirole, 1988). As the market is covered, both groups purchase, and price discrimination is not feasible, the mass of uninformed naive consumers restricts the firms' possibility of compensating the demand reduction caused by the sophisticated and informed naive consumers with elevated prices. Hence, as the demand reduction effect induced by ρ cannot be entirely compensated, the firms are worse off for all of $\alpha \in (0,1)$, compared to when α is at its limits (i.e., $\alpha \to 0$ or $\alpha \to 1$). With stronger demand reduction effects, i.e., smaller values of ρ, the firms require higher prices to compensate for the reduction in energy demand. However, as the mass of uninformed naive consumers $\alpha(1-\Delta)$ places limits on such an endeavor, a smaller share (i.e., $\alpha < \bar{\alpha}$) of uninformed naive consumers is required to get marginal increases in profits from decreasing the mass of naive consumers by means of introducing the efficiency service, i.e., $\partial\pi_{i,2}/\partial\Delta \geq 0$ with $i \in \{A, B\}$.

The preference relation evaluated above allows for identification of the SPNE strategies in period 0.

Proposition 2. *If $\alpha(\Delta-2) > -1$ and $\rho \geq \Gamma(\alpha,\Delta)$ hold, there are three period 0 SPNE strategies in pure strategies: (NO, O), (O, NO) and (O, O). All of which are payoff equivalent. However, only (O, O) is a Trembling Hand Perfect Equilibrium (THPE). If either one of these conditions is violated there is one period 0 SPNE strategy in pure strategies (which is also a THPE): (NO, NO).*

Proof. The proof is straighforward and based on the findings of Proposition 1 and omitted for the most part. Trembling Hand Perfection, as in Selten (1975), of *(NO, NO)* and *(O, O)* follows from the fact that neither *(O, NO)* nor *(NO, O)* are robust to small mistakes that lead the other firm to play an off-equilibrium strategy. Consider for example *(NO, O)*, if $\alpha(\Delta-2) > -1$ and $\rho \geq \Gamma(\alpha,\Delta)$. It follows from Proposition 1 that this is a period 0 SPNE pure strategy. However, if firm B assigns a small probability to playing NO instead, firm A would have been better off playing O alternatively. □

Subsequently, I will focus on the THPE *(NO, NO)* and *(O, O)*, as even though *(NO, O)*, *(O, NO)* and *(O, O)* are payoff equivalent SPNE pure strategies, in an actual business setting, both firms would prefer to play *0* to mitigate risks. This would change, if costs ϵ for introducing the efficiency service were to arise. Assuming $\epsilon \gtrapprox 0$ such that period 1 decisions are independent of ϵ, firms would only coordinate on asymmetric equilibria, i.e., *(NO, O)*, *(O, NO)*, if $\alpha(\Delta-2) > -1$ and $\rho \geq \Gamma(\alpha,\Delta)$. This is because both firms would want the other firm to bear the costs of informing consumers and free ride on the information provision. This leaves the firms with a situation similar to the Battle-Of-The-Sexes (Osborne and Rubinstein, 1994) and a related equilibrium selection problem. As this complicates the problem rather than giving new insights, I do not consider introduction costs in my analysis.

In summary, Propositions 1 and 2 showed that there are conditions under which the firms coordinate on an equilibrium in which they introduce and therefore voluntarily disclose efficiency services. At first, this is counterintuitive, as introducing the efficiency service will inevitably reduce the demand on the energy retail market, where firms A and B generate their profits. However, due to imperfect competition on this market, firms A and B can compensate for demand reductions by increasing prices. The potential to do so is restricted by the distribution of consumers that purchase the efficiency service and those that do not. Introducing the efficiency service does not occur in equilibrium if either $\alpha(\Delta - 2) \leq -1$ or $\rho < \Gamma(\alpha, \Delta)$. This means that if a major share of consumers is naive (i.e., $\alpha \gg 0$) and of these only a minor share of naive consumers becomes informed (i.e., $\Delta \ll 1$), firms will refrain from introducing the efficiency service. Likewise, if the demand reduction effect from consuming the efficiency service is large, firms are unable to recover losses by increasing prices and refrain from introduction. Therefore:

- The returns from introducing the efficiency service are decreasing with increasing shares of naive consumers α. This makes introduction less profitable if there are just a few sophisticated consumers.
- High shares of naive consumers that become informed Δ cause increasing returns from introduction. This means that if a very high share of naive consumers processes the information provided by the firms and becomes informed naive consumers, the firms will introduce the efficiency service in equilibrium.

Hence, the failure of introducing and subsequently voluntarily disclosing efficiency services in markets with imperfect competition may therefore originate from high shares of naive consumers, low shares of additional adopters or severe demand reduction effects caused by the efficiency service. How this translates into welfare effects is discussed below.

5. Welfare Effects and Mandatory Disclosure

Proposition 2 showed that there are SPNE strategies in which both firms offer and disclose the efficiency service as well as those with both firms refrain from doing so. To evaluate these equilibria, it is necessary to examine their welfare implications. I will present the welfare implications, discuss them from a competition policy point of view and analyze the merits of mandatory disclosure policies below.

Using a model of spatial product differentiation with symmetric firms, inefficiencies arise from taste mismatch as well as the marginal energy costs c. Lemma 5 immediately follows.

Lemma 5. *Total surplus is at its highest value if all consumers purchase the efficiency service and with an increasing share of sophisticated and informed naive consumers.*

Proof. Proof is straight forward and omitted.

Consequently, from a total surplus point of view, it is always preferable for the firms to introduce the efficiency service. This is because introduction reduces the quantity of energy consumed and hence the surplus lost from marginal costs c. If the competition jurisdiction were based solely on a total welfare standard, public policies would always want to inform consumers about the efficiency service. Nonetheless, it is worth taking a look at competition policy that is based on a consumer welfare standard. I identify which outcome is preferable from consumers' perspective and describe mandatory disclosure policies that maximize consumer surplus.

Focussing on consumer surplus and the implied question of whether courts, authorities and competition policy in general abide by a consumer rather than a total welfare standard is highly controversial. Motta (2004) discusses this issue in detail. Given all the arguments for and against a strict consumer surplus standard (Motta, 2004), I apply this standard mainly based on arguments regarding an unbalanced set of powers on the side of the firms, e.g., informational advantages or lobbying (Lyons, 2002).

Lemma 5 illustrated that under a total welfare standard, mandatory disclosure policies would always increase total surplus. However, under a consumer surplus standard, this is not the case, as the following Lemma 6 points out.

Lemma 6. *In general, under a consumer surplus standard, mandatory disclosure laws can lead to a decrease in welfare.*

Proof. The alteration of consumer surplus is given by the difference of changes in total surplus, i.e., Λ_{TS}, and the changes of the firms' total profit, i.e., $2\,(\pi^*_{i,2} - \pi^*_{i,1})$. Changes in total surplus are given by

$$\Lambda_{TS} = \alpha\Delta\, c\,(1-\rho). \tag{16}$$

In other words, total surplus changes solely based on the fact that as a result of forcing firms to introduce the service, a consumer mass of $\alpha\,\Delta$ reduces consumption of energy by $(1-\rho)$ and hence payments to cover marginal costs. Hence,

$$\begin{aligned}\Lambda_{CS} &= \alpha\Delta\, c\,(1-\rho) - 2\,(\pi^*_{i,2} - \pi^*_{i,1}) &(17)\\ &= \alpha\Delta(1-\rho)\left(c - \frac{(1-\rho)t\left((1-\alpha)\rho^2(\alpha(1-\Delta)-1) + \alpha^2(1-\Delta)\right)}{((1-\alpha)\rho^2+\alpha)\,(\alpha(1-\Delta)\,(1-\rho^2)+\rho^2)}\right). &(18)\end{aligned}$$

Evaluating if Λ_{CS} is below zero using `Mathematica` computational software[5], it follows that $\Lambda_{CS} < 0$ if the

[5]The code is available by the author on request.

following conditions hold:

$$\frac{(1-\rho)t\left((1-\alpha)\rho^2(\alpha(1-\Delta)-1)+\alpha^2(1-\Delta)\right)}{((1-\alpha)\rho^2+\alpha)\left(\alpha(1-\Delta)\left(1-\rho^2\right)+\rho^2\right)} > c, \tag{19}$$

$$\alpha(\Delta-2) > -1, \tag{20}$$

$$\rho > \Gamma(\alpha,\Delta). \tag{21}$$

□

Given the result of Lemma 6, it immediately follows that competition authorities under a consumer surplus standard would refrain from informing consumers under certain conditions. Given the results so far, this is intuitive, as informing consumers such that only a small share of uninformed naive consumers remains allows the firms to charge higher prices for energy. However, the conditions under which informing consumers would have adverse consumer surplus effects give rise to the following proposition.

Proposition 3. *In equilibrium, mandatory disclosure is never welfare-reducing.*

Proof. Lemma 6 highlighted that if certain conditions hold mandatory disclosure can reduce consumer surplus. However, it is clear that two of these conditions are equivalent to the conditions under which firms voluntarily coordinate on an equilibrium in which both firms offer and disclose the efficiency service. This means that if the conditions for mandatory disclosure to be consumer surplus-decreasing hold, firms nevertheless voluntarily introduce the efficiency service. Hence, welfare is not lost from mandatory disclosure but instead from firms' period 0 decisions. If the conditions do not hold, mandatory disclosure is at least weakly consumer surplus-increasing. Total surplus will always increase from mandatory disclosure, as was shown in Lemma 5. □

With the findings of Proposition 3 it became apparent that *informational regulation* by means of mandatory disclosure laws is weakly consumer surplus-increasing. This means that if firms refrain from introducing the efficiency service, mandatory disclosure increases the competition between firms and leads to elevated levels of consumer surplus. Furthermore, it is worth mentioning that the mere existence of the efficiency service weakly increases consumer surplus regardless of the firms' period 0 decisions or mandatory disclosure policies. The inability to price discriminate and the related existence of naive as well sophisticated consumers make the firms worse off compared to a situation without the efficiency service. Even though consumer surplus increases in total, sophisticated and informed naive consumers are better off in terms of surplus than uninformed naive consumers.

The findings of Lemma 2 suggest that the optimal action for the authorities could be to mandate disclosure such that some uninformed naive consumers $\alpha(1-\Delta)$ remain. As it is known that if uninformed naive consumers $\alpha(1-\Delta)$ are at $\bar{\alpha}$ the firms' profits are minimized, a share of uninformed naive consumers that maximizes consumer surplus exists.

Corollary 1. *Under a consumer surplus standard, mandatory disclosure would optimally refrain from debiasing all consumers. Optimally, it would leave a share of*

$$\breve{\alpha} = \frac{(\rho-1)^2\rho^2(c\rho+c+t) - \sqrt{(\rho-1)^4\rho^2 t(c\rho+c+t)}}{(\rho-1)^3(\rho+1)(c\rho+c+t)} \tag{22}$$

uninformed. Furthermore, the consumer surplus-maximizing share of uninformed naives is strictly smaller then the profit-minimizing share, i.e., $\breve{\alpha} < \bar{\alpha}$.

Proof. Given in the Appendix.

With the results of Corollary 1, the optimal action of the competition authorities would be to inform consumers such that a share of $\breve{\alpha}$ of uninformed naives remain. This illustrates that in markets with product interactions that have substitution effects, it might be optimal from a consumer welfare perspective to refrain from debiasing all consumers in order to cap the price-setting behavior of the firms. Given the functional form of the firms' profits with respect to the share of the uninformed naive consumers $\alpha(1-\Delta)$, it is clear that firms would want to further inform consumers from that point onwards, as profits are strictly decreasing in the share of uninformed naive consumers below $\bar{\alpha}$.

6. Extension: Positive Profits from the Efficiency Service

So far it has been assumed that fierce competition on the efficiency service market drives prices of all firms down to marginal costs, which are normalized to zero. Nonetheless, I assumed consumer inattention with respect to the existence of the efficiency service. One could argue that in addition to this dimension of inattention, consumers fail to recognize the entire supply side on the market for efficiency services, once they have learned about the efficiency service.

Assume that if the firms introduce the efficiency service a fraction of the naive consumers $\varphi \in (0,1)$ will fail to assess the existence of a competitive fringe offering the efficiency service at marginal costs. With respect to search costs, informed naive consumers that fail to recognize the existence of the competitive fringe have reduced their internal search costs for the existence of the product. However, the internal search costs for competing offers for the efficiency service remain such that other offers remain unknown. Hence, the fraction φ of informed naive consumers $\alpha\,\Delta$ buys the efficiency service from firm A or B depending on their preferences and the offering and pricing decisions of the firms. The complementary fraction $1-\varphi$ behaves like sophisticated consumers.

It follows immediately that this second dimension of consumer inattention allows the firms to partly price discriminate between a share φ of informed naive consumers and the rest of the consumers. Hence, in the introducing equilibrium *(O, O)*, firms will capture additional surplus from some of the informed naives by charging a positive price for the efficiency service (which is only purchased by $\varphi \, \Delta \, \alpha$ from firms A and B) and a strictly lower price for energy compared to Subgame 2.

Additionally, this second dimension of inattention will partly destabilize the neither offering nor disclosing equilibrium *(NO, NO)*. If one firm were to refrain from introducing the efficiency service, the other firm would want to offer and disclose the efficiency service, thereby receiving monopoly power over the share φ of the informed naives. This means that it can set higher prices for the efficiency and lower prices for energy. In general, this will make the introducing firm better and the other firm worse off, making the situation similar to a prisoner's dilemma game. However, the monopoly power over φ consumers is restricted. The introducing firm has to trade off attracting consumers farther away in the linear city by lowering its prices off against reducing profits from consumers in the vicinity of the firm's location. Given that the other firm offers energy at a certain price at the other end of the city, to attract the consumers farthest away from the introducing firm, the firm would have to charge such a low price for both goods that these prices and the mismatch costs would still be below the offer for energy from the other firm. It is therefore obvious that the introducing firm will sacrifice demand for higher profits and let a share of informed naive consumers make decisions similar to uninformed naive consumers. Therefore, firms make a part of informed naive consumers behave like uninformed naive consumers. Under certain values for α, Δ, φ and ρ this restricted monopoly power destabilizes the *(NO, NO)* equilibrium. However it does not apply to all values[6]. The general conditions for a failure of the voluntarily introducing equilibrium still hold: i.e., a high share of naive consumers α and a low share of naive consumers that become informed Δ result in an equilibrium in which neither firm offers or discloses the efficiency service. Furthermore, a low share of informed naives that are inattentive to the competition on the efficiency service bolsters the *(NO, NO)* equilibrium. Hence, the different dimensions of consumer inattention have different effects on the incentives of firms to introduce the efficiency service.

Overall, consumer inattention with respect to the supply side of the market for the efficiency service will reduce the degree of competition. Making informational regulation, by means of making the degree of competition on the efficiency service market transparent, essential to increase consumer surplus.

[6] The calculations are straightforward, but come with rather unsightly, lengthy and complex expressions. Presentation of the algebraic results has been omitted for improved readability. Related `Mathematica` expressions are available from the author on request.

7. Discussion

I will now summarize the results so far and outline some general conditions for the voluntary introduction of energy efficiency. First, the returns of voluntary introduction are decreasing with increasing shares of naive consumers α. This, making voluntarily offering and disclosing the efficiency service less profitable if there are just a few sophisticated consumers. Second, high shares of naive consumers that become informed Δ have increasing returns to introduction. This means that if a very high share of naive consumers processes the information provided by the firms, firms want to introduce the efficiency service. And third, the existence of consumers inattentive to the competition on the efficiency service market allows the firms to price discriminate by charging prices above marginal costs for the efficiency service.

Informing consumers about the efficiency service is always total welfare-increasing. However, the existence of an equilibrium in which both firms choose to refrain from introducing also leaves a case for mandatory disclosure laws under a consumer welfare standard. Notably, under this standard, authorities would want to refrain from debiasing all consumers in order to maximize consumer surplus and limit the firms' price-setting. Hence, the existence of consumer inattention promotes competition between the firms. However, it was shown that the share of consumers that remains inattentive (i.e., the uninformed naive consumers) is worse off than its informed counterparts. This brings about distributional effects that might influence interventions by the competition or political authority. Also, it raises the question of what other forms of intervention could be applicable to the described economic problem. This further suggests that partial information provision might actually be optimal under a consumer welfare standard.

Furthermore, the results have shown that the opportunity to (at least partly) compensate for energy demand reductions by increasing the price of energy might encourage firms to introduce the efficiency service. Do results change with an oligopoly rather than a duopoly in the market for energy? Quickly reconsidering the equilibrium profits proves this presumption wrong: increasing the number of firms is equivalent to reducing the mismatch costs t. Firm profits after the technology of the efficiency service becomes available are lower than when it was unavailable. This is because the different consumer types only emerge once this technology becomes available. Therefore, it is unreasonable that new firms enter the energy retail market after the efficiency service becomes available[7]. Hence, entry should not occur. Nonetheless, with more firms in the market, which is equivalent to decreasing values for t, price mark-ups are proportionately decreasing. However, this does not alter the firms' introduction decisions.

[7] I assume that the general conditions for market entry remain unaltered (e.g., fixed costs of entry etc.).

So what does this mean for the example given in the introduction? Consider the case of weatherization. Estimates for the range of ρ suggest values somewhere between 0.95 up to 1.05 (see Meier and Tode (2015))[8]. Unfortunately, reliable estimates for parameters α and Δ are difficult to find[9]. Borrowing from research on the efficacy of warning labels provides a broad idea of parameter values for Δ. In this respect, McCarthy et al. (1984) summarize that a mere $2 - 11\%$ adopt to information provision[10]. Making the plausible assumption that there are more naive than sophisticated consumers, e.g., $\tilde{\alpha} = 0.7$ and $\tilde{\Delta} = 0.1$, gives for Equation (14): $-1.33 \not> -1$. Hence, the condition in Equation (14) is violated. Further, $\tilde{\rho} = 0.95 \ldots 1.05 \not\geq \tilde{\Gamma}(\tilde{\alpha}, \tilde{\Delta}) \approx 1.99$. So, also the second condition, i.e., Equation (15) is also violated. Firms would coordinate on refraining from introducing the efficiency service.

Within my model, I assume that all consumers are generally interested in purchasing energy efficiency. This means that I assume that all consumers benefit directly from energy efficiency. Statistics on tenure status, e.g., in Europe, illustrate that this is not the case. Eurostat (2015) shows that in 2014 approx. 30% of the EU-28 population were tenants. It is a well-known landlord-tenant problem that landlords have hardly any incentives to invest in energy efficiency as the energy costs are born by the tenants. Hence, the share of tenants within a population is equivalent to uninformed naive consumers within my model. This leads to the conclusion that within a population with a relatively large share of tenants, firms will refrain from introducing energy efficiency.

Assuming perfectly inelastic demand for energy makes the calculations and the underlying mechanism more tractable. But this makes it impossible to discuss quantity effects in more detail. However, there are numerous real world problems that could be better understood by relaxing the model in this direction. For example, why did car rental companies start offering car sharing services (often under another brand) or why do some public transportation companies operate a bicycle-rental system and others do not. There are undoubtedly driving factors that are not considered in my model (e.g., increasing population density and related congestion in urban areas). However, it is also very likely that consumer attention and inattention are relevant drivers of firms' decisions.

[8] The counterintuitive result from even more consumption originates in the so-called *rebound effect*. See e.g. Gillingham et al. (2013) or Meier and Tode (2015).

[9] This is because, the respective values depend on a large number of different influencing factors. For instance, on the way the information on the introduction of the efficiency service is provided, i.e., how was the information provided, how readable was the information, was the information targeted, to name just a few examples.

[10] While the purpose and presentation of warning labels contrast strongly with advertisement and information provision from firms, one could argue that the relevance of the information on warning labels for the consumer is very much higher. This therefore suggests that the values of $2 - 11\%$ represent upper bounds for the share of naive consumers that become informed from the information, i.e., Δ.

8. Conclusion

In this article I showed that consumer inattention and imperfect competition are the crucial drivers for firms' decisions to introduce energy efficiency to consumers or to conceal it. I find two symmetric equilibria: one in which both firms introduce energy efficiency and one in which both firms conceal energy efficiency. Whether or not firms coordinate on an equilibrium in which both firms introduce energy efficiency depends mainly on the distribution of consumers that are attentive to energy efficiency and consumers that are not. Firms will only want to offer energy efficiency that partly substitutes for their energy offer, i.e., bite the hand that feeds them, if introducing and informing consumers about energy efficiency leaves only a comparably small share of consumers uninformed. In that case, competition on the energy retail market is relaxed and firms can charge higher prices. The consumer type distribution is essential as the mass of uninformed naive consumers restricts the firms' price-setting.

Furthermore, it was shown that it is always total welfare-increasing to inform consumers about energy efficiency. Also, mandatory disclosure laws are always weakly welfare-increasing, i.e., even under a consumer surplus standard.

This article examines a rather specific market, with rather specific assumptions (e.g., duopoly etc.). Nonetheless, the results suggest that it is worth paying additional attention to the interaction of consumer inattention and imperfect competition in other markets too. I found that consumer naivety causes different consumer groups to emerge, thereby limiting firms' price-setting. Interestingly, consumer inattention under imperfect competition both increase and reduce competition.

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Appendix A. Notation

Abbr.	Explanation	Range
α	Naive fraction of the population	$0 < \alpha < 1$
$1-\alpha$	Sophisticated fraction of the population	$0 < 1-\alpha < 1$
ρ	Demand for energy after consumption of the efficiency service	$0 < \rho < 1$
Δ	Share of naive consumers that becomes informed (informed naive consumers)	$0 < \Delta < 1$
φ	Fraction of α that purchase the eff. service from firm A or B	$0 < \varphi < 1$
ϵ	Costs of offering and disclosing the efficiency service	$\epsilon \gtreqless 0$
c	Marginal cost on the energy retail market	$c > 0$
t	Taste mismatch on the energy retail market	$t \geq 0$
x	Location in the linear city	$0 \leq x \leq 1$
U	Consumer utility	–
v	Utility from energy consumption	–
$p_{i,e,j}$	Price for energy of firm i in subgame j	–
$p_{i,s,j}$	Price for the efficiency service of firm i in subgame j	–
$\pi_{i,j}$	Period 2 profit of firm i in subgame j	–
Γ	Functions representing limiting values for ρ	–
CS_k	Consumer surplus	–
Λ_{CS} ,Λ_{TS}	Consumer and total surplus benefits from mandatory disclosure	–

Table A.1: Notation

Appendix B. Proofs

Proof of Lemma 1

From the firms' profits given in Equation (7), the first order conditions follow.

$$\begin{aligned}
\frac{\partial \pi_{A,1}}{\partial p_{A,e,1}} =& \frac{\left((\alpha-1)\rho^2-\alpha\right)(2p_{A,e,1}-p_{B,e,1})+c\left(\alpha+\rho^2-\alpha\rho^2\right)}{2t} \\
&+\frac{t(+\alpha+\rho-\rho\alpha)}{2t}, \qquad \text{(B.1)}\\
\frac{\partial \pi_{B,1}}{\partial p_{B,e,1}} =& \frac{\left((\alpha-1)\rho^2-\alpha\right)(2p_{B,e,1}-p_{A,e,1})+c\left(\alpha+\rho^2-\alpha\rho^2\right)}{2t} \\
&+\frac{t(\alpha+\rho-\rho\alpha)}{2t}. \qquad \text{(B.2)}
\end{aligned}$$

Solving the first order conditions for each firm's price, the reaction functions are:

$$p_{A,e,1} = \frac{\left((\alpha-1)\rho^2-\alpha\right)p_{B,e,1}+(\alpha-1)c\rho^2-\alpha(c+t)+(\alpha-1)\rho t}{2(\alpha-1)\rho^2-2\alpha}, \qquad \text{(B.3)}$$

$$p_{B,e,1} = \frac{\left((\alpha-1)\rho^2-\alpha\right)p_{A,e,1}+(\alpha-1)c\rho^2-\alpha(c+t)+(\alpha-1)\rho t}{2(\alpha-1)\rho^2-2\alpha}. \qquad \text{(B.4)}$$

Solving the reaction functions in Equation (B.3) and (B.4) for the equilibrium prices, results in (with $i \in \{A, B\}$)

$$p^*_{i,e,1} = c + \frac{t(\alpha + \rho - \rho\alpha)}{\alpha + \rho^2 - \alpha\rho^2}. \tag{B.5}$$

Plugging these equilibrium prices into Equation (7) gives the second period equilibrium profits of Lemma 1. □

Proof of Lemma 2

The first derivative of the equilibrium period 2 profits with respect to α is:

$$\frac{\partial \pi^*_{i,1}}{\partial \alpha} = \frac{(\rho - 1)^2 t(\alpha(\rho - 1) - \rho)((\alpha - 1)\rho + \alpha)}{2\left(\alpha + \rho^2 - \alpha\rho^2\right)^2}. \tag{B.6}$$

It immediately follows that period 2 profits are at a minimum at $\partial\pi_{i,1}/\partial\alpha = 0$, i.e., $\bar{\alpha} = \rho/(1 + \rho)$, as $\partial^2\pi_{i,1}/\partial\alpha^2|_{\bar{\alpha}=\rho/(1+\rho)} < 0$. With a maximum that is outside of the domain for α and ρ at $\acute{\alpha} = \rho/(\rho - 1)$, it immediately follows that $\partial\pi_{u,1}/\partial\alpha$ is positive for $\alpha < \bar{\alpha}$ and negative for $\alpha > \bar{\alpha}$. □

Proof of Lemma 3

A naive consumer at location x in the linear city has utility $U_{\alpha(1-\Delta),A,x}$ buying the main good from firm A and utility $U_{\alpha(1-\Delta),B,x}$ buying from firm B.

$$U_{\alpha(1-\Delta),A,x} = v - p_{A,e,2} - tx \tag{B.7}$$

$$U_{\alpha(1-\Delta),B,x} = v - p_{B,e,2} - t(1 - x) \tag{B.8}$$

A sophisticated or informed naive consumer at location x has utility $U_{1-\alpha(1-\Delta),A,x}$ buying energy from firm A and utility $U_{1-\alpha(1-\Delta),B,x}$ buying from firm B.

$$U_{1-\alpha(1-\Delta),A,x} = v - p_{A,e,2}\,\rho - tx \tag{B.9}$$

$$U_{1-\alpha(1-\Delta),B,x} = v - p_{B,e,2}\,\rho - t(1 - x) \tag{B.10}$$

The firms' profits are given by Equation (B.11). From the existence of the competitive fringe it follows that $p_{i,s,2} = 0$. With $i \in \{A, B\}$:

$$\pi^*_{i,2} = q_{i,e,2}\left(p_{i,e,2} - c\right). \tag{B.11}$$

From the firm profits given in Equation (B.11), the following first order conditions result:

$$\frac{\partial \pi_{A,2}}{\partial p_{A,e,2}} = \frac{\left(\rho^2 - \alpha(\Delta-1)\left(\rho^2-1\right)\right)\left(2p_{A,e,2} - p_{B,e,2}\right)}{2t} \tag{B.12}$$

$$+ \frac{c\rho^2(\alpha(\Delta-1)+1) - \alpha(\Delta-1)(c+t) + \rho t(\alpha(\Delta-1)+1)}{2t}, \tag{B.13}$$

$$\frac{\partial \pi_{B,2}}{\partial p_{B,e,2}} = \frac{\left(\rho^2 - \alpha(\Delta-1)\left(\rho^2-1\right)\right)\left(2p_{B,e,2} - p_{A,e,2}\right)}{2t} \tag{B.14}$$

$$+ \frac{c\rho^2(\alpha(\Delta-1)+1) - \alpha(\Delta-1)(c+t) + \rho t(\alpha(\Delta-1)+1)}{2t}. \tag{B.15}$$

Thus, the reaction functions for the energy retail prices are

$$\begin{aligned} p_{A,e,2} =& \frac{\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)p_{B,e,2} + c\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)}{2\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)} \\ &+ \frac{t(\alpha(\Delta-1)(\rho-1)+\rho)}{2\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)}, \end{aligned} \tag{B.16}$$

$$\begin{aligned} p_{B,e,2} =& \frac{\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)p_{A,e,2} + c\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)}{2\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)} \\ &+ \frac{t(\alpha(\Delta-1)(\rho-1)+\rho)}{2\left(\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2\right)}. \end{aligned} \tag{B.17}$$

Solving the reaction functions in Equation (B.16) and (B.17) for the equilibrium prices, gives (with $i \in \{A, B\}$)

$$p^*_{i,e,2} = c + \frac{t(\alpha(\Delta-1)(\rho-1)+\rho)}{\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2}, \tag{B.18}$$

$$p^*_{i,s,2} = 0. \tag{B.19}$$

Plugging these equilibrium prices into Equation (B.11) gives the second period equilibrium profits of Lemma 3. □

Proof of Proposition 1

Using the period 2 firms' profits in both settings as given in Equation (8) and (12), the conditions for the superiority introducing the efficiency service are given by the inequality ($i \in \{A, B\}$)

$$\pi^*_{i,2} = \frac{t}{2}\frac{(\alpha(\Delta-1)(\rho-1)+\rho)^2}{\alpha(\Delta-1)\left(\rho^2-1\right)+\rho^2} \geq \pi^*_{i,1} = \frac{t}{2}\frac{(\alpha+\rho-\rho\alpha)^2}{\alpha+(1-\alpha)\rho^2}. \tag{B.20}$$

This inequality is reduced using `Mathematica` computational software. The code is available from the author on request. The results in Proposition 1 follow. □

Proof of Corollary 1

Similar to Lemma 2, consider the simpler case of subgame 1. It was shown that at $\hat{\alpha}$ the firms' profits are minimized. To calculate the welfare maximum under a consumer surplus standard, consumer surplus needs to be calculated.

$$\begin{aligned}
CS_1 =& \alpha \Bigg[v\hat{x}_\alpha - {p^*}_{A,e,1}\hat{x} - \int_0^{\hat{x}_\alpha} tx\,dx && \text{(B.21)}\\
&+ v\left(1-\hat{x}_\alpha\right) - {p^*}_{B,e,1}\left(1-\hat{x}_\alpha\right) - \int_{\hat{x}_\alpha}^{1} t(1-x)\,dx \Bigg] && \text{(B.22)}\\
&+ (1-\alpha)\Bigg[v\hat{x}_{1-\alpha} - \rho {p^*}_{A,e,1}\hat{x}_{1-\alpha} - \int_0^{\hat{x}_{1-\alpha}} tx\,dx && \text{(B.23)}\\
&+ v\left(1-\hat{x}_{1-\alpha}\right) - \rho {p^*}_{B,e,1}\left(1-\hat{x}_{1-\alpha}\right) - \int_{\hat{x}_{1-\alpha}}^{1} t(1-x)\,dx \Bigg] && \text{(B.24)}\\
=& v + \left(\alpha - \frac{5}{4}\right) t + \alpha c\rho - c(\alpha+\rho) + \frac{\alpha t(-2\alpha(\rho-1)+2\rho-1)}{(\alpha-1)\rho^2-\alpha} && \text{(B.25)}
\end{aligned}$$

Taking the first derivative with respect to α and solving for α gives two possible solutions.

$$\breve{\alpha}_I = \frac{(\rho-1)^2\rho^2(c\rho+c+t) - \sqrt{(\rho-1)^4\rho^2 t(c\rho+c+t)}}{(\rho-1)^3(\rho+1)(c\rho+c+t)} \tag{B.26}$$

$$\breve{\alpha}_{II} = \frac{(\rho-1)^2\rho^2(c\rho+c+t) + \sqrt{(\rho-1)^4\rho^2 t(c\rho+c+t)}}{(\rho-1)^3(\rho+1)(c\rho+c+t)} \tag{B.27}$$

Evaluating both solutions at the second derivative illustrates that only $\breve{\alpha}_I$ is a maximum. Hence, $\breve{\alpha} = \breve{\alpha}_I$. That $\breve{\alpha} < \hat{\alpha}$ follows directly from Lemma 5. □

Appendix C. Example Visualizations of Functions

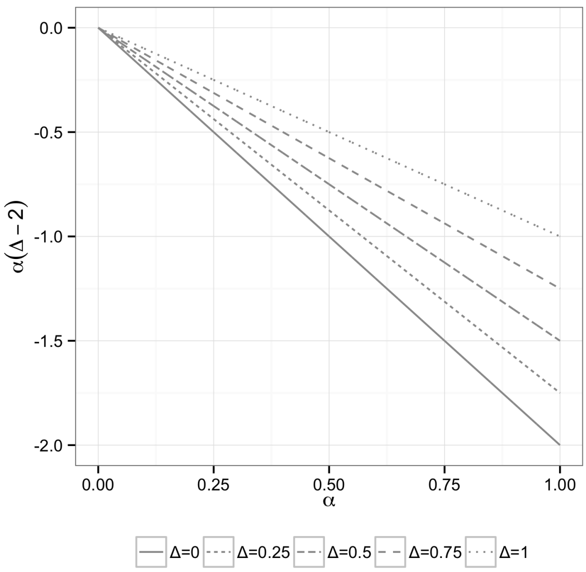

Figure C.1: Example visualization of $\alpha\,(\Delta - 2)$.

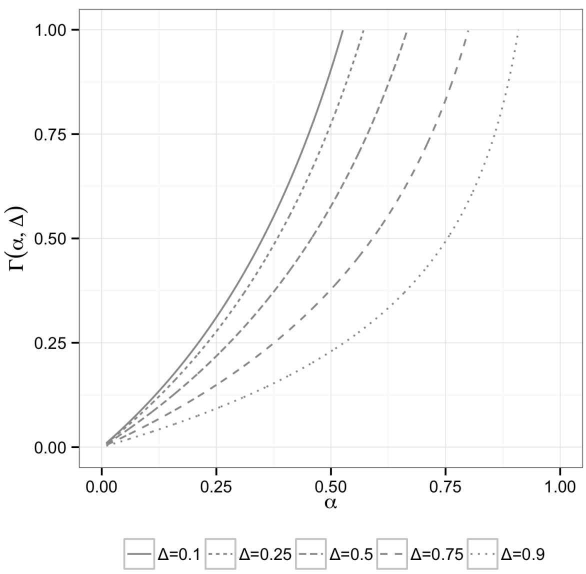

Figure C.2: Example visualization of $\Gamma(\alpha, \Delta)$.

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