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Abstract: Financial incentives or disincentives in the form of electricity tariffs can be used to encourage energy efficiency. In this paper, two simple tariffs aimed at residential consumers are reviewed: progressive tariffs (PTs), which penalise high consumption of electricity, and electricity saving feed-in tariffs (ESFITs), which provide incentives to reduce consumption of electricity. The effectiveness of these tariffs is quantified and compared using the price elasticity (for PT) and an incentive elasticity (for ESFIT). The results indicate that PTs are more effective in mobilising electricity saving than ESFITs and confirm biases in human decision-making (here loss aversion). While further research is necessary, we propose a tariff which would motivate consumers to reduce their consumption by offering both an incentive for reaching an energy saving goal and a disincentive for failing to reach this goal. The flexibility of such a tariff makes it a promising solution suitable for application in countries with a comparatively high household income and liberalised retail electricity market.

Highlights

- Two types of tariffs for saving electricity are reviewed.
- Their effectiveness is quantified using price elasticity or incentive elasticity.
- We find tariffs with a penalty more effective than those providing an incentive.
- A tariff which includes both incentives and penalties is proposed.

Recent experiences with tariffs for saving electricity in households

Abstract

Financial incentives or disincentives in the form of electricity tariffs can be used to encourage energy efficiency. In this paper, two simple tariffs aimed at residential consumers are reviewed: progressive tariffs (PTs), which penalise high consumption of electricity, and electricity saving feed-in tariffs (ESFITs), which provide incentives to reduce consumption of electricity. The effectiveness of these tariffs is quantified and compared using the price elasticity (for PT) and an incentive elasticity (for ESFIT). The results indicate that PTs are more effective in mobilising electricity saving than ESFITs and confirm biases in human decision-making (here loss aversion). While further research is necessary, we propose a tariff which would motivate consumers to reduce their consumption by offering both an incentive for reaching an energy saving goal and a disincentive for failing to reach this goal. The flexibility of such a tariff makes it a promising solution suitable for application in countries with a comparatively high household income and liberalised retail electricity market.

Keywords:

residential energy efficiency, price elasticity of electricity, electricity saving feed-in tariffs, progressive tariffs, prospect theory, loss aversion, energy efficiency tariffs

Abbreviations

PT	Progressive tariff
ESFIT	Electricity saving feed-in tariff

1. Introduction

Reducing electricity consumption provides multiple benefits, including reduction of carbon emissions, pollution and energy cost. Several countries have committed to reduce their absolute energy consumption and double their rate energy efficiency improvement, which is also one of the UN's Sustainable Development Goals/SDGs (United Nations Department of Economic and Social Affairs, 2017). The EU countries have agreed on an energy saving target of 20% by 2020 and 27% or greater by 2030 (European Commission, 2012). In the US, more than half of the states have adopted long-term mandatory energy saving targets for utilities and efficiency program administrators (Downs and Cui, 2014).

According to an overview of recently proposed policy measures and their contribution to energy saving in the EU, the residential sector is expected to generate almost half of the projected saving by 2020 (Rosenow et al., 2015). The residential sector accounts for approximately 18% of total final energy demand in OECD Americas, around 24% in OECD Europe and nearly 23% world-wide (International Energy Agency, 2016) and thus offers a substantial potential for saving energy.

Between 1990 and 2013, final energy efficiency in households in the EU-28 countries increased at an annual average rate of 1.6 % per year (European Environment Agency, 2015). The saving was mainly due to energy efficiency improvements for space heating and more efficient large electrical appliances. However, various drivers such as an increase in number of households, larger homes, greater comfort and growth in the number of electrical appliances have compensated half of the efficiency gains achieved through technological innovations (European Environment Agency, 2015; Gynther et al., 2015). Energy saving in the US residential sector increased by about 17% per year from 2006 to 2011 (Frankel et al., 2013). However, growth in the number of housing units and the size of homes has resulted in a net increase of electricity consumption in the US residential sector (U.S. Energy Information

Administration, 2015). Thus, even though improvements in the efficiency of equipment results in energy saving, additional measures which include behaviour change are required. Policy measures which address behaviour in addition to technical measures are also likely to be more cost-effective than those which fail to include behaviour (Lutzenhiser, 2014).

Behavioural economics and psychology offer a large variety of approaches to impact consumer decision-making in relation to energy consumption (Frederiks et al., 2015). Measures which address behaviour have only started to be introduced - for example, detailed billing information (e.g. comparison of own consumption with that of neighbours), implementation of incentives (various types of dynamic electricity tariffs), and platforms which provide information and feedback to consumers about their electricity consumption (smart meters, online websites to monitor energy use, etc.).

Recent research shows tariffs which reflect the amount and time of energy consumption (in addition to provision of detailed information) can have an impact on energy use. Dynamic tariffs are one possibility to identify and capture demand response potential of residential consumers. However, it is unclear whether it is realistic to apply dynamic tariffs on large scale, if they are cost-effective, if they can produce absolute reduction in energy consumption (rather than shifts in time of consumption), and if the saving will be persistent. Dynamic tariffs might also require installation of smart meters and implementation of pricing signals which could be costly and too complex for customers to understand and respond to (Layer et al., 2017).

In this paper, we study less commonly known tariffs for saving electricity, which also aim to address behaviour, and which have been previously used to reduce consumption in the residential (and services) sector. The two tariff options analysed are progressive tariffs and electricity saving feed-in tariffs. These do not require smart meters, are fairly simple to implement with pricing signals which are easy to understand, and they can be modified to fit the local situation. Our main research objectives are to: understand whether ESFITs and PTs are effective in saving electricity, identify their respective benefits and drawbacks, understand if punishment (in the form of PT) works better than incentives (in the form of ESFIT) to motivate energy saving. Previous research on these tariffs is detailed in sections 2.1 and 2.2. This paper presents a first attempt to compare the effectiveness of these tariffs. This is carried out by defining indicators to quantify the effectiveness of the tariffs and comparing them based on these indicators. Subsequently, the impact of psychological loss aversion and the potential implications for optimal tariff design is discussed.

The paper is organized as follows: section 2 describes in more detail the energy efficiency tariffs (progressive tariffs and electricity saving feed-in tariffs) which are considered in this paper. In section 3, the methodology used to quantify the effectiveness of these tariffs is presented. Section 4 summarizes the effectiveness of the respective tariffs and a comparison between them across countries and regions. In section 5 we discuss the implication of loss aversion and propose a modified tariff which operates on the basis of a bonus/malus mechanism. Section 6 provides the conclusions of our work.

2. Description of the two types of electricity saving tariffs studied in this paper

2.1. Progressive tariffs (PTs)

Also called rising block tariffs or increasing block tariffs, PTs apply increasing price of electricity with increasing consumption. Usually, the first block or consumption bracket is a low tariff (e.g. US$/kWh), which corresponds to the minimum electricity consumption of a household. The second block or consumption bracket has a slightly higher unit price of electricity and is set to meet the average electricity consumption of a household. Subsequent consumption brackets are charged at an even higher unit cost, thus with more electricity consumed, the cost of electricity rises progressively.

PTs were first implemented in the early 1970s in Italy, California and Japan, with the aim to keep prices for basic electricity consumption low, and to control rising demand for electricity in the context of rising oil prices (Dehmel, 2011). Even though encouragement of electricity saving is an objective of PTs, the focus is often on ensuring secure supply of electricity and to signal to customers a shortage by raising the price. Compared to other policies incentivizing energy saving, there is only little research on these tariffs. Badouard (2012), Faruqui (2008) and Youn and Jin (2016) find that increasing block tariffs encourage significant energy conservation. Some scholars have analysed the response to PTs by using econometric methods to estimate price elasticity in countries or jurisdictions where PTs have been applied, for example in California, Canada and Japan (Bernstein and Griffin, 2005; Borenstein, 2012; Neenan and Eom, 2008; Okajima and Okajima, 2013; Reiss and White, 2005). Recent literature also includes the use of simulated or synthesized price response to understand the application of PTs in developing countries such as China (Sun and Lin, 2013). In some European countries such as France, Germany, and Belgium, the suitability of PTs has been the subject of political debates (Dehmel and Gumbert, 2011; Tews, 2011; Wanko, 2014). Available literature is therefore mostly focused on selected countries, jurisdictions or even specific utilities and is typically authored in the national language.

2.2. Electricity saving feed-in tariffs (ESFIT)

Also known as saving bonus or saving incentive, ESFITs consist of setting a reduction target for a specified time period and providing a monetary reward for consumers who are able to achieve this target. ESFIT has been discussed in a few published articles, but often in qualitative terms (Bertoldi et al., 2009; Bertoldi and Rezessy, 2007; Cowart and Neme, 2013; Eyre, 2013). Utilities in Canada and California have offered ESFIT programs to their customers and the evaluation reports of these programs provide information about their effectiveness

(California Measurement Advisory Council (CALMAC), 2015; Ontario Energy Board, 2015). In Europe some utilities in Switzerland and Germany offer ESFITs. However most of these utilities do not make the program evaluation reports publicly available and only publish the total energy saved due to such programs on their websites.

3. Methodology

Policy instruments such as tariffs are usually evaluated based on their effectiveness (the extent to which they contribute to reaching a specific goal) expressed in quantitative terms. They can also be evaluated based on their cost-effectiveness (financial means required to reach the effect expressed in quantitative terms) and their side effects (multiple benefits, e.g. employment or growth effects) (e.g. Blok, 2006). In addition to these indicators, several others are found in existing literature. For ESFIT programs, the total amount of electricity saved due to a program is often chosen as a measure of effectiveness, and additionally, the total cost of a program divided by the saving achieved from the program (cost effectiveness). Another indicator is the average amount of electricity saved per household. In the case of PTs, since they have historically been implemented at the scale of a country or region, precise data on the total electricity saved attributable solely to the price increase is difficult to find. Based on published literature, the most common method to understand and quantify the response to the price increase due to a PT is through econometric models which estimate the price elasticity of electricity in the country or region of application (using statistical data from the years when the PT is in place).

Due to the absence of consistent indicators across the different types of tariffs, the following indicators were chosen as a measure of effectiveness:

- For the case studies with PT we use the price elasticity of electricity provided in published literature (specifically pertaining to conditions where PT was applied, see section 3.1).

– For ESFIT, we calculate the incentive elasticity (a modification of price elasticity) based on published data (further explained in section 3.2).

In addition, the cost effectiveness of both the tariffs is discussed in the appendix sections A3 and A4.

Consumers can respond to a price increase by reducing consumption in two ways: through curtailment behaviour (switching off lights or lowering indoor temperature in winter), or by replacing inefficient appliances. Estimates of elasticity based on data for a shorter time period (less than one year up to a few years) are referred to as short-run elasticity, which primarily takes into account curtailment behaviour. Studies that determine elasticity over a longer period of time where consumers are assumed to have fully adapted their behaviour and replaced appliances provide long-run price elasticity (Neenan and Eom, 2008). In this paper, the short-run price elasticity under PT is compared with likewise short-term incentive elasticity of ESFIT (calculated over one year or the months in which the program is ongoing).

Despite the limitations on data availability (discussed in sections 2.1 and 2.2); we have reviewed all publicly available data and case studies related to PT and ESFIT. Our main interest is their application in developed countries with comparatively high household income. PT and ESFIT theoretically represent alternative options but it is possible to modify the structure of PT such that it includes both incentives and penalties (see section 6.2). PT and ESFIT may compete with, or complement other policy options for realizing energy saving, such as energy efficiency obligations or energy performance contracting.

3.1. Price elasticity for PT

The effectiveness of PT is measured as ratio of the percentage change (i.e., reduction) in electricity consumption to the percentage change (i.e., increase) in price (Eq. 1). In economic terms, this indicator is referred to as price elasticity of demand for electricity. Price elasticity is negative for household electricity consumption, following the rationale that demand (for electricity) decreases with an increase in price.

$$Elasticity\ (PT) = \frac{(Q2-Q1)/Q1}{(P2-P1)/P1} \quad (1)$$

where:

Q1: Quantity of electricity consumed before application of tariff in (kWh),

Q2: Quantity of electricity consumed after application of tariff (kWh),

P1: Price of electricity before application of tariff (EUR/kWh, USD/kWh, CAD/kWh, Yen/kWh),

P2: Price of electricity after application of tariff (EUR/kWh, USD/kWh, CAD/kWh, Yen/kWh). *P2* is greater than *P1* and *Q2* is smaller than *Q1*.

Published journal articles which provide price elasticity of electricity in different regions (under conditions of PT) were identified. The countries or regions with the respective references are: California (Borenstein, 2009; Reiss and White, 2005), Canada (BC Hydro, 2014; Li et al., 2014), Japan (Okajima and Okajima, 2013), China (Lin and Jiang, 2012, 2011; Zhou and Teng, 2013). While PT has been implemented in California, Canada, Japan and China, this is not the case for Germany and Switzerland (where ESFIT was offered). For these two countries, we use the price elasticity for Germany (Beznoska, 2014; Nikodinoska and Schröder, 2016) and Switzerland (Boogen et al., 2014) to provide a comparison with the incentive elasticity (Section 5.2).

3.2. Calculated incentive elasticity for ESFIT

ESFITs offer a reward (reduction in price) when an energy saving target is met. Thus, if the appropriate decrease in electricity consumption and price are substituted in Eq. 1, the calculated price elasticity of ESFIT programs would result in a positive value. In order to avoid the confusion which arises by comparing a positive price elasticity with a negative price elasticity, a new metric is proposed to study the effectiveness of ESFIT called *incentive elasticity*, which is defined in Eq. 2.

$$Incentive\ Elasticity\ (ESFIT) = \frac{(Q2-Q1)/Q1}{I/P1} \quad (2)$$

where:

Q2: Quantity of electricity consumed after application of tariff (kWh),

Q1: Quantity of electricity consumed before application of tariff in (kWh), *Q2* is smaller than *Q1,*

I: Bonus or incentive amount (EUR/USD/CAD/Yen), I = *P1 – P2 (with I greater than 0)*,

P1: Price of electricity before application of tariff.

The incentive elasticity describes the extent to which consumers reduce their energy use if they are offered a bonus or incentive *I* to do so (this equals *(Q2-Q1)/Q1, with Q2 less than Q1*)[1]. This incentive is expressed in Eq. 2 as a ratio relative to the price (*I/P1)*. Therefore, an incentive elasticity of -0.10 would mean that a bonus of 20% (*I/P1*) results in 2% energy saving ((*Q2-Q1)/Q1)*.

The rationale of the bonus as an incentive for saving electricity may seem counter-intuitive because it implies that consumers reduce their electricity use in spite of the net lower price. However, it must be kept in mind that the implementation of ESFITs should be accompanied by a communication campaign; in the campaign it must be explained to the consumers that an effort to save electricity is rewarded with a bonus or incentive (*I*). Additionally, the incentive is conditional; it is only received when there is an observed decrease in electricity consumption.

Eq. 3 is used to calculate the percentage of electricity saved (the numerator in Eq. 2) based on available data in the ESFIT case study reports.

[1] In the case of the defined incentive elasticity, (relative) price abatement occurs only and only if (relative) saving is indeed achieved. Therefore Q2 is always less than Q1 and incentive elasticity is always a negative value.

$$Percent\ Electricity\ Saved = SP \times ST \quad (3)$$

where:

SP: Percentage of households who achieved the specified electricity saving target,

ST: Electricity saving target expressed as percentage,

Percent Electricity Saved equals *(Q2-Q1)/Q1* in Eq. 2.

Determining the reduction in electricity consumption due to an ESFIT is not trivial since autonomous developments, other policies or external factors (such as economic recession) may have contributed to energy saving apart from the tariff. When determining the percent electricity saved (*(Q2-Q1)/Q*) in the numerator of Eq. 3, lack of more detailed information forces us to consider only those consumers who complied with the requirements for obtaining an incentive. As a consequence, the percentage reduction in electricity calculated in Eq. 3 excludes the saving achieved by participants who did not achieve the specified saving target but still saved electricity, and it also excludes the additional saving (over-compliance) of some participants who exceeded the target. The saved electricity calculated in Eq. 3 is thus a conservative estimate.

A challenge when comparing saving from PTs versus ESFITs is that PT is often a mandatory tariff, while ESFIT is offered as a voluntary tariff (in 4 out of 8 selected cases, customers were required to opt-in for the tariff). The enrolment process requires additional effort, and especially customers who expect to save energy, e.g. due to the recent purchase of an efficient appliance or for other reasons, might tend to sign up for such a tariff (interview/personal communication Frankfurt Spart Strom). The effectiveness of ESFIT might thus be valid only for certain customers who have inherently higher motivation to conserve electricity. Since we aim to identify electricity saving tariffs that are effective for the total population, we base our conclusions primarily on elasticity values for the totality of consumers (Eq. 5) rather than on a particular segment (Eq. 4). We therefore first apply Eq. 3 by calculating the effectiveness for the *households which opted in* for the tariff (Eq. 4) and, second, for *all households* in the relevant region (Eq. 5).

$$SP_{opt\ in} = \frac{Number\ of\ households\ who\ achieved\ specified\ electricity\ saving\ target}{Total\ number\ of\ opt{-}in\ households} \quad (4)$$

$$SP_{all} = \frac{Number\ of\ households\ who\ achieved\ specified\ electricity\ saving\ target}{Total\ number\ of\ households} \quad (5)$$

From around 15 identified case studies with ESFIT, 8 were selected on the basis of the following criteria: Sufficient information provided in online documentation or reports to calculate the incentive elasticity; recently conducted study (year 2000 onwards); and a large sample size. The selected case studies provide an overview of ESFIT applied in Canada (Bishop et al., 2010), US (Reiss and White, 2003; Wirtshafter Associates, 2006), Japan (Mizobuchi and Takeuchi, 2012), Germany (Leuser, 2014; Stadt Frankfurt am Main, 2015), and Switzerland (Bertholet et al., 2014; Energie Wasser Bern, 2010).

4. Results

4.1. Effectiveness of PT

Table 1 provides a brief overview of the PT schemes in the six selected countries. Appendix B provides further details of the PT applied in each of the selected countries with data from the following countries and references: California (Borenstein, 2009; Reiss and White, 2005), Canada (BC Hydro, 2014; Li et al., 2014), Japan (Okajima and Okajima, 2013), China (Lin and Jiang, 2012, 2011; Zhou and Teng, 2013), Germany (Beznoska, 2014; Nikodinoska and Schröder, 2016) and Switzerland (Boogen et al., 2014).

Table 1. Overview of literature and data on PT schemes (BC Hydro, 2014; Beznoska, 2014; Boogen et al., 2014; Borenstein, 2009; Li et al., 2014; Lin and Jiang, 2012, 2011;

Nikodinoska and Schröder, 2016; Okajima and Okajima, 2013; Reiss and White, 2005; Zhou and Teng, 2013).

The price elasticity observed under PT ranges from -0.12 to -0.47 (only includes countries or regions where PT was implemented). Japan and California both show higher elasticity, which might reflect the impact of experiencing successive demand side management programs and progressive tariffs over the last thirty years. The utilities in both regions have several programs targeted towards informing households how to reduce their electricity consumption and provision of rebates to buy efficient equipment.

Conservative estimates of elasticity are reported for China and California (for the second block, typically representing the average population), ranging from -0.250 to -0.350 (Borenstein, 2009; Lin and Jiang, 2012, 2011; Reiss and White, 2005; Zhou and Teng, 2013). Households with lower income in China and Germany show higher elasticity than those with higher household income (Nikodinoska and Schröder, 2016; Zhou and Teng, 2013). Reiss & White (2005) also confirm that households with lower income in California were more sensitive to energy prices than households with medium-to-high income.

In Canada, customers with a higher consumption (over 2400 kWh) had a higher elasticity compared to those with a lower consumption. Li et al. (2014) explain that customers with a relatively high electricity consumption were living in single-family detached houses with electric space heating while customers with relatively low consumption were apartment residents with non-electric space heating. Thus customers with electric heating were found to be more price sensitive than those with gas based heating systems.

The average price elasticity for the studied countries is -0.335 (figure 1). This indicates that for a price increase of 100%, the reduction in electricity consumption would be around 33%, depending on the region, time period and socio-demographics. The actual historical price increase in the different countries ranged from 13% for the lowest block in California to 200%

for the highest block (table 1). While it is difficult to estimate the total saved electricity that can be attributed to PT an indication of its impact is clearly observed when comparing the average household electricity consumption in regions with and without PT. Italy (where PT continues to be applied) has one of the lowest average household electrical consumption in Europe (2485 kWh/household compared to 5830/ household in France and 3362 kWh/household in Germany), while California has the lowest average household electrical consumption in the United States (6900 kWh/household compared to 12196 kWh/household average for US) (World Energy Council, 2016). Based on their empirical analysis of progressive pricing applied in South Korea during summer, Youn and Jin (2016) found progressive pricing policy to be effective in suppressing electricity consumption.

Figure 1. Price elasticity under PT, incentive elasticity with ESFIT (for all households) and (opt-in households only). Data from tables 1 and 3b.

4.2. Effectiveness of ESFIT

Table 2 presents an overview of ESFIT applied in the following countries, with data from the following countries and references: Canada (Bishop et al., 2010), US (Reiss and White, 2003; Wirtshafter Associates, 2006), Japan (Mizobuchi and Takeuchi, 2012), Germany (Leuser, 2014; Stadt Frankfurt am Main, 2015), and Switzerland (Bertholet et al., 2014; Energie Wasser Bern, 2010). Appendix section A2 provides further information on the context of the programs.

Table 2. Overview of ESFIT case studies (Bertholet et al., 2014; Bishop et al., 2010; Energie Wasser Bern, 2010; Leuser, 2014; Mizobuchi and Takeuchi, 2012; Reiss and White, 2003; Wirtshafter Associates, 2006).

The incentive elasticity calculated using Eq. 2 to 5 is presented in tables 3a and 3b. The elasticity values fall in the range of -0.026 to -1.013 for *opt-in households* (table 2a). The incentive elasticities calculated for *all households* are lower with a range of -0.005 to -0.263 (table 2b). In five out of nine cases enrolment was *not* required and the number of households opting in was considered equal to the total number of households (this is also the case for Japan, where a field study of 52 households was evaluated).

The programs in California, Berne, Geneva, Canada, San Diego, Heidelberg and Frankfurt had a large number of (eligible) households and the incentive elasticities (for *all households)* fall within the range of -0.005 to -0.263, which is far lower than when calculated for opt-in households only[2] (Frankfurt with an elasticity -0.506 and Heidelberg with an elasticity of -1.013). This suggests that a certain segment of customers (those who enrolled in the program) had a higher elasticity compared to the rest of the population. Thus, ESFIT programs are by far more effective when only targeting households likely to respond to the tariff (opt-in schemes). Most ESFIT programs do not have high overall saving targets (pers. comms. with Mr. Ralph Kampwirth, Lichtblick, 8/2015; pers. comm. with Mr. Florian Unger, Frankfurt Spart Strom, 9/2015). Typically, a bonus is offered complementary to other saving measures. For example, besides offering a bonus, the city of Frankfurt also runs scrapping programs for household appliances and targets particular neighbourhoods to offer specific advice or information on saving electricity.

Table 3a. Incentive elasticity of ESFIT calculated for enrolled (opt-in) households (Bertholet et al., 2014; Bishop et al., 2010; Energie Wasser Bern, 2010; Leuser, 2014; Mizobuchi and Takeuchi, 2012; Reiss and White, 2003; Stadt Frankfurt am Main, 2015; Wirtshafter Associates, 2006).

Table 3b. Incentive elasticity of ESFIT calculated for all households.

[2] Appendix figure A2 provides a comparison of incentive elasticity for opt-in households with that of all households for each country.

4.3. Comparing the effectiveness of ESFIT and PT

One of the aims of our research is to understand if punishment (in the form of PT) works better than incentives (in the form of ESFIT) to motivate energy saving. To answer this question, we compared the incentive elasticity and price elasticity in various regions, presented in table 4 and figure 1. The maximum range of price elasticity is between -0.100 to -0.885 while for incentive elasticity it is -0.005 to -0.263. Figure 2 provides a comparison of ESFIT (all households) and PT for different regions. Appendix figure A2 includes the same comparison with ESFIT opt-in households included. Incentive elasticity for all regions is clearly lower than price elasticity (figure 2), which could be understood as: customers are more reactive to a penalty (increase in price), than to an incentive (due to the bonus amount). The average price elasticity for the studied countries is -0.335 while the average incentive elasticity is -0.097. In other words, the price elasticity is higher than the incentive elasticity, indicating that PTs is more effective than ESFITs when compared across the total population. One challenge is that, as explained above, the saved electricity calculated in Eq. 3 is a conservative estimate and as a consequence, the incentive elasticity according to Eq. 2 tends to underestimate the real effectiveness of the bonus. However, given the extent of the difference in effectiveness found between PT and ESFIT, we consider the overall conclusion to remain valid. A potential psychological explanation for this difference as well as implications for optimal tariff design will be discussed in the following section 6.

Table 4. Comparison elasticity PT and incentive elasticity ESFIT (all households)(BC Hydro, 2014; Bertholet et al., 2014; Beznoska, 2014; Bishop et al., 2010; Boogen et al., 2014; Borenstein, 2009; Energie Wasser Bern, 2010; Leuser, 2014; Li et al., 2014; Lin and Jiang, 2011, 2012; Mizobuchi and Takeuchi, 2012; Nikodinoska and Schröder, 2016; Okajima and Okajima, 2013; Reiss and White, 2003, 2005; Wirtshafter Associates, 2006; Zhou and Teng, 2013).

Figure 2. Effectiveness of ESFIT (all households) compared with effectiveness of PT in different regions. (Data from tables 1 and 3b).

5. Discussion and policy implications

5.1. Psychological loss aversion and its implications for ESFIT and PT

A central finding of our research is that disincentives are more effective in promoting electricity saving than incentives (see section 4.3). A potential explanation for this is found in literature on loss aversion. *Loss aversion* refers to the fact that people evaluate possible changes as losses and gains relative to a neutral reference point, and show greater sensitivity to losses than to gains (Kahneman and Tversky, 1979). Deviating from rational choice theories such as expected utility theory (Samuelson and Zeckhauser, 1988; Savage, 1954; Von Neumann and Morgenstern, 1944), people weigh potential losses higher than potential gains, and go to greater lengths to avoid them. For example, experienced stock market investors have been shown to sell well-performing stocks too early and hold losers too long, to avoid the negative affect related to realization of the loss (Shefrin and Statman, 1985). Customers perceive price increases as losses and give larger weight to them in their decisions as compared to price decreases (Ahrens et al., 2017).

These effects have been systematized in *prospect theory*, a widely accepted model of decision-making under risk and uncertainty (Kahneman and Tversky, 1979). The central aspect of prospect theory is the *value function* (see figure 3), which postulates that values are perceived as changes relative to a reference point (e.g., gains and losses) rather than absolute magnitudes or states. *Loss aversion* is reflected in the fact that the function for losses is steeper than for gains: the displeasure associated with losses is perceived about twice as intensely as the pleasure associated with gains. Prospect theory and loss aversion thus offer a theoretical framework to explain the observed differences in the effectiveness of the two types of electricity saving tariffs.

Figure 3: The Value Function as predicted by prospect theory: Illustration of the differential psychological value of gains versus losses in energy incentive schemes.

The impact of ESFIT and PT on consumer behaviour and decision –making can be described in terms of the value function: The average annual/monthly costs for residential electricity consumption represents the reference point. Any positive or negative deviations from this reference point are perceived as losses or gains, respectively. Hence, ESFITs which incentivize energy-saving by paying out a bonus to the consumer if a target saving is reached are perceived as representing potential gains. In contrast, PTs which penalize overconsumption by increasing the electricity price with increasing consumption are perceived as representing potential losses. Facing a potential disincentive (i.e. loss) under PT will thus act as a stronger motivator for reaching a set target (e.g. saving a certain amount of electricity) than potentially foregoing an incentive under ESFIT.

The observed stronger impact of PT on electricity saving comes with a price, which is especially relevant in the context of liberalised electricity markets: the potential losses associated with PT will drastically reduce the attractiveness of the tariff to consumers who can freely choose between electricity tariffs (which may or may not include a penalty for overconsumption). In contrast, ESFIT may be perceived more attractive due to the inherent potential for a reward. If consumers can freely choose between ESFIT and a flat rate charge (simple tariff), the hypothesis is that they will tend to choose ESFIT because they can only win. Moreover, if consumers can freely choose between PT and a flat rate charge (simple tariff), the hypothesis is that they will tend to remain with the flat rate unless the PT also incorporates an option to gain (first block of PT charged less than simple tariff).

5.2. Proposal for a tariff which applies a combined approach or a bonus/malus program

Given the effects of potential losses on tariff attractiveness, it would thus be important to explore potential factors that could motivate customers to voluntarily subscribe to a tariff to save electricity that contains a penalising element. Previous research in behavioural sciences has shown that people are indeed willing to voluntarily sign up and operate under a loss-framed contract, which may be linked to the anticipation that they will perform better and thereby increase their financial benefit (Imas et al., 2015). It may thus be worthwhile to explore whether such a choice pattern can be observed in the context of voluntary PT subscriptions, and even promoted by providing information about the average electricity saved under such a tariff. Here, we suggest that PTs could be made attractive to consumers through a combined approach of offering both an incentive for reaching an energy saving goal and a disincentive for failing to reach this goal (e.g., a three-block PT with the first block being lower than the flat rate charge and the last block being higher). This strategy is related to the so-called "feebate" system (a portmanteau of fee and rebate) used by the automobile industry to promote environmentally efficient vehicles. Feebate systems (also referred to as Bonus/Malus programs (see Bunch et al., 2011), simultaneously impose a fee on inefficient technologies and rebates on efficient technologies. Feebate systems are designed such that fees on inefficient technologies are perceived as losses, and rebates paid on efficient technologies are perceived as gains. They were conceived as an alternative to higher fuel taxes, which evoke strong public opposition. Despite their potential applications, feebate systems have so far received only little application (e.g., Greene et al., 2005). In our case, the modified PT (with bonus/malus) could be used as an alternative to increasing the tax on electricity. Further detailed studies are needed to map the potential factors (and combinations thereof) that may influence consumer acceptance of this proposed tariff.

Keeping in mind that household electricity consumption is additionally related to the use of electricity for heating or cooling, a suitably structured PT might be one method to encourage households to switch to more efficient solutions (e.g. heat pumps, district heating), rather than pay a higher price for direct electric heating[3]. With the growth in distributed renewable generation (e.g. photovoltaic (PV) panels installed on buildings), it is relevant for policy makers to consider electricity tariffs which could minimise additional grid load by incentivizing local self-consumption of electricity. A modified PT which would essentially offer a rebate (lower price per kilowatt) for lower *net* electricity consumption and charge a fee (higher price per kilowatt) for higher electricity consumption could be a promising solution.

6. Conclusions

Our results show that electricity saving tariffs in the form of ESFIT and PT are effective in motivating households to save electricity. We find PT to be clearly more effective than ESFIT when the saving is measured over the total population. The range of typical price elasticity and incentive elasticity is -0.100 to -0.885 and -0.005 to -0.263 respectively (table 4), indicating that even a substantial increase in electricity prices might result in limited energy saving, depending on the local context. At the same time, this finding calls for further research because the elasticities found in literature generally only refer to low to moderate increases in electricity price.

In Western Europe, ESFITs are more common than PTs; this may be related to electricity market liberalization in Europe, resulting in a highly competitive retail market. While PT has been considered for adoption in several countries (France, Spain, Germany, etc.), limited experience and lack of understanding about their wider impacts could be some reasons why they have not been adopted more broadly. As yet, PTs do not exist in any country as a voluntary tariff and there seems to be a consensus among utility experts that a meaningful implementation of PT would require policy or legislative support.

[3] Low-income renters living in inefficient homes would on the other hand need to be compensated for the higher energy cost incurred.

Several countries have put in place policy measures to reduce energy consumption in the residential sector, for example; energy efficiency obligations, energy performance contracting, and purchase of efficient appliances. However, renovation rates remain low and adoption of new, efficient technologies is slow. Also, gains from energy efficiency are often compensated due to greater demand for comfort, growth in the number of electrical appliances, and other factors. A PT (with a bonus/malus mechanism) could act as a driver for households to save electricity. Based on the literature reviewed in this paper, PTs are found to be effective, provide persistent saving over a large population, and fairly simple to implement (without smart meter infrastructure). To conclude, an energy saving tariff in the form of a suitably structured PT should be considered more seriously by policy makers.

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Table 1

Table 1. Overview of literature and data on PT schemes (BC Hydro, 2014; Beznoska, 2014; Boogen et al., 2014; Borenstein, 2009; Li et al., 2014; Lin and Jiang, 2012; Nikodinoska and Schröder, 2016; Okajima and Okajima, 2013; Reiss and White, 2005; Zhou and Teng, 2013)

	Study	Price before PT	Price increase in percent after PT[1,2]	Elasticity[3]	*Price Level[4] USD/MWh*	Reference
1a.	Canada (lower consumption) (1350-2400 kWh)	6.5 cents CAD/kWh	40%	-0.129	*100*	BC Hydro (2014) Table 7, Model 1 in
1b.	Canada (higher consumption) (over 2400 kWh)			-0.179		Li et al. (2014)
2a.	Japan	0.18 yen/kWh	First block: 32%	-0.397	*242.14*	Table 10,
2b.	Japan (poor regions)		Second block: 53%	-0.383		Short run elasticity in
2c.	Japan (middle regions)			-0.425		Okajima and Okajima (2013)
2d.	Japan (rich regions)			-0.479		
3a.	California (first block)	6.55 cents USD/kWh	13%[5]	-0.460	*121.16*	Table 6, GMM method in
3b.	California (second block)		95%	-0.350		Reiss and White (2005)
3c.	California (third block)		170%	-0.320		
3d.	California (fourth block)		209%	-0.330		
3e.	California (average population)			-0.120		Table 3, 2004-2006 change in Borenstein (2009)
4a.	China (second block)	N.A.	36%	-0.250	*107*	Lin and Jiang (2012)
4b.	China (third block)		87%	-0.158		

4c.	China (fourth block)		155%	-0.100		
4d.	China (low household income)		N.A.	-0.396		
4e.	China (high household income)			-0.370		Table 8 in
4f.	China (young household)			-0.289		Zhou and Teng (2013)
4g.	China (old household)			-0.414		
5a.	Germany (average)	N.A.	N.A.	-0.680	*387.63*	Table 8 in Beznoska (2014)
5b.	Germany (average)			-0.811		Table 2 and table 5 in
5c.	Germany (0-25% income quartile)			-0.822		Nikodinoska and Schröder
5d.	Germany (25-50% income quartile)			-0.749		2016
5e.	Germany (50-75% income quartile)			-0.885		
5f.	Germany (75-100% income quartile)			-0.523		
6	Switzerland (short run)	N.A.	N.A.	-0.540	*203.69*	Table 6, column 4 in Boogen et al., (2014)

1 Price increase calculated from baseline usage, or compared to first block.

2 Percentages stated in order of increasing blocks; i.e. first block increase, second block increase, etc.

3 Elasticity stated for the different blocks in order, i.e. first block elasticity, second block elasticity, etc.

4 IEA world energy balances 2014

5 Data shown for PG&E (SCE pricing schedule: 16%, 82%, 112%, 142%; SGD&E pricing schedule: 17%, 68%, 87%).

Table 2

Table 2. Overview of ESFIT case studies (Bertholet et al., 2014; Bishop et al., 2010; Energie Wasser Bern, 2015; Leuser, 2014; Mizobuchi and Takeuchi, 2012; Reiss and White, 2003; Stadt Frankfurt am Main, 2015; Wirtshafter Associates, 2006).

	Country	Context	Savings target	Incentive offered	No. of Households	Participant selection	Methodology[1]	Time period (months)
1.	Canada	Toronto Hydro	10%	10%	5281	Opt-in	2	2 (summer)
2.	US	Multiple Utilities, California	20%	20%	721982	All households	1	4 (summer)
3.	US	SDG&E, San Diego	15%	20%	70000	All households	1	4 (summer)
4.	Japan	Field study	10%, 20%	10.4% to 29.1%	52	All households	1	3
5.	Germany	Municipal utility (Stadtwerke) of Heidelberg	15%	2%	8842	Opt-in	1 and 2	12
6.	Germany	Municipal utility of Frankfurt	10%	8%	140000	Opt-in	1	12
7.	Switzerland	EWB, Berne	10%	15%	70000	All households	1	12
8.	Switzerland	SIG, Geneva	N.A.	Equal to the electricity savings in %	50000	Opt-in	1	12

1 The methodology used to determine savings indicated in table 1 are classified as:

1: Comparison with own consumption from previous year and 2: Comparison of savings of participants with savings of non-participants.

Table 3a

Table 3a. Incentive elasticity of ESFIT calculated for enrolled participants (Bertholet et al., 2014; Bishop et al., 2010; Energie Wasser Bern, 2015; Leuser, 2014; Mizobuchi and Takeuchi, 2012; Reiss and White, 2003; Stadt Frankfurt am Main, 2015; Wirtshafter Associates, 2006)

	Country	No. of Households	No. of opt in households	Percentage of participants receiving bonus	Total savings achieved (%)[1]	Incentive elasticity of enrolled participants[2]	Reference
1.	Canada (Toronto)	479167	5281	42	4.2	-0.420	Bishop et al. (2010)
2.	United States (California State)	721982	N.A.	11	2.2	-0.110	Wirtshafter Associates (2006)
3.	United States (San Diego)	700000	N.A.	35	5.3	-0.263	Reiss & White (2003)
4a.	Japan	52	N.A.	25	2.5	-0.240	Mizobuchi & Takeuchi (2012)
4b.	Japan	52	N.A.	3.8	0.8	-0.026	Mizobuchi & Takeuchi (2012)
5.	Germany (Heidelberg)	100000	8842	13.5	2	-1.013	Leuser (2014)
6.	Germany (Frankfurt)	140000	3521	16.2	4	-0.506	Stadt Frankfurt am Main (2015)
7.	Switzerland (Berne)	70000	N.A.	15.3	1.5	-0.102	Energie Wasser Bern (2015)
8.	Switzerland (Geneva)	240000	50000	20.8	0.5	-0.208	Bertholet et al. (2014)

1 Calculated using equation 3.

2 Calculated using equation 2.

Table 3b

Table 3b. Incentive elasticity of ESFIT calculated for all participants in selected countries

	Country	Incentive elasticity of **opt in** households[1]	Incentive elasticity of **all households**[2]	Price Level (USD/MWh)[3]	Electricity expenditure as a share of disposable income[4]
1.	Canada (Toronto)	-0.420	-0.005	100.00	6-10%
2.	United States (California)	-0.110	-0.110	121.16	3-4%
3.	United State (San Diego)	-0.263	-0.263	121.16	3-4%
4a.	Japan	-0.240	-0.240	242.14	4.4-9.1%
4b.	Japan	-0.026	-0.026	242.14	4.4-9.1%
5.	Germany (Heidelberg)	-1.013	-0.090	387.63	3.2% / 5%
6.	Germany (Frankfurt)	-0.506	-0.013	387.63	3.2% / 5%
7.	Switzerland (Berne)	-0.102	-0.102	203.69	1%
8.	Switzerland (Geneva)	-0.208	-0.042	203.69	1%

1 Calculated using equation 4
2 Calculated using equation 5
3 IEA world energy balances 2014
4 Calculated using data from OCED for the relevant year

Table 4

Table 4. Comparison elasticity PT and incentive elasticity ESFIT (all households)(BC Hydro, 2014; Bertholet et al., 2014; Beznoska, 2014; Bishop et al., 2010; Boogen et al., 2014; Borenstein, 2009; Energie Wasser Bern, 2015; Leuser et al., 2014; Li et al., 2014; Lin and Jiang, 2012; Mizobuchi and Takeuchi, 2012; Nikodinoska and Schröder, 2016; Okajima and Okajima, 2013; Reiss and White, 2003, 2005; Wirtshafter Associates, 2006; Zhou and Teng, 2013)

Country	Elasticity Category	Elasticity PT	Incentive Elasticity Category	Incentive Elasticity ESFIT
Canada	Lower consumption (1350-2400 kWh)	-0.129	BC Hydro Summer Program	-0.005
	Higher consumption (over 2400 kWh)	-0.179		
US	Average population	-0.120	Statewide California Summer Program	-0.110
	First block	-0.460	San Diego region	-0.263
	Second block	-0.350		
	Third block	-0.320		
	Fourth block	-0.330		
Japan	Poor regions	-0.383	Matsuyama 10% saving target	-0.240
	Middle regions	-0.425	Matsuyama 20% saving target	-0.026
	Rich regions	-0.479		
	Average population	-0.397		
Germany	Average population	-0.680	Heidelberg	-0.090
	Average population	-0.811	Frankfurt	-0.013
	0-25% income quartile	-0.822		
	25-50% income quartile	-0.749		
	50-75% income quartile	-0.885		
	75-100% income quartile	-0.523		
Switzerland	Short run	-0.540	Berne	-0.102
			Geneva	-0.042

Figure 1

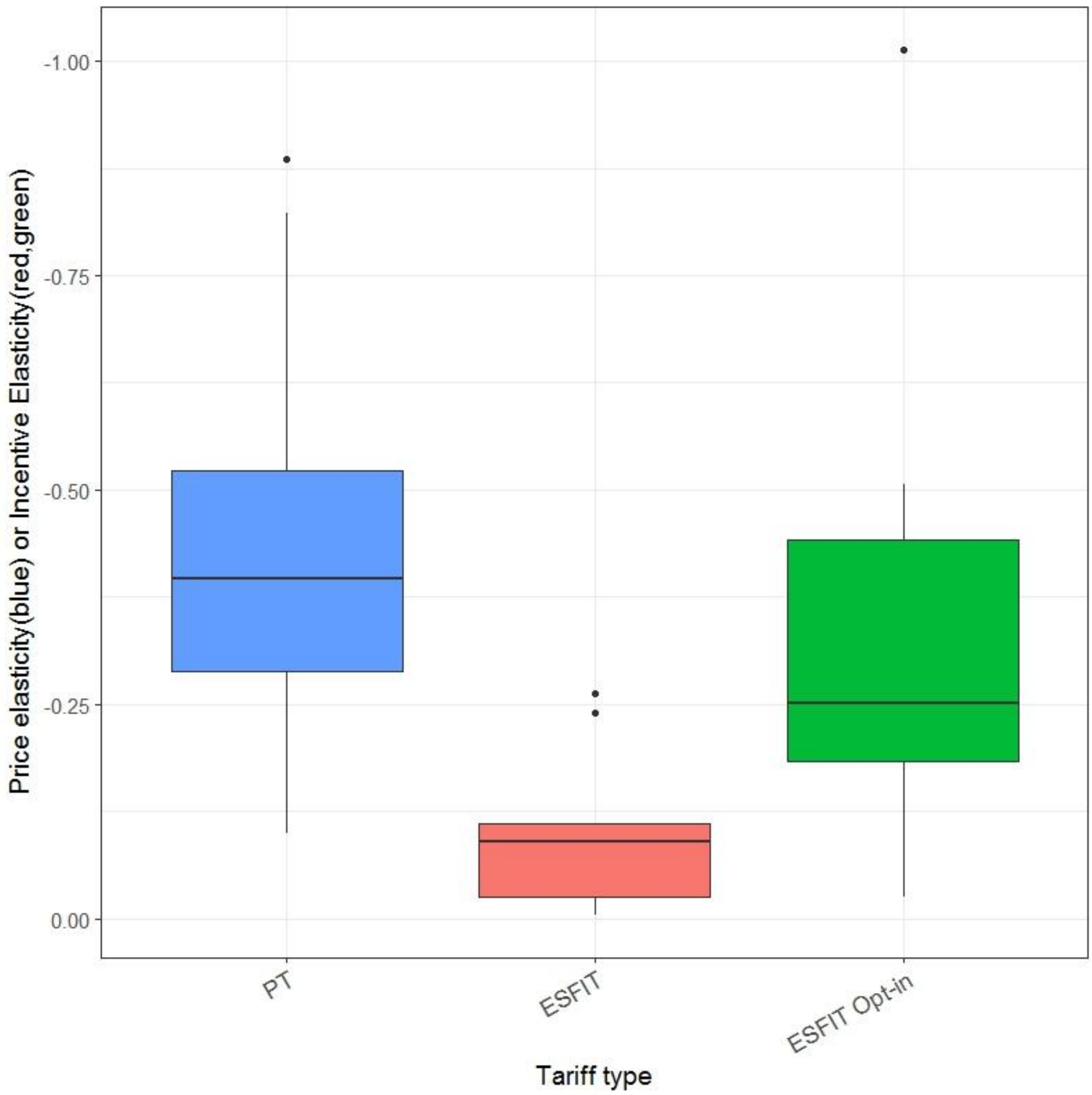

Figure 1. Price elasticity under PT, incentive elasticity with ESFIT (for all households) and (opt-in households only). Data from tables 1 and 3b.

Figure 2

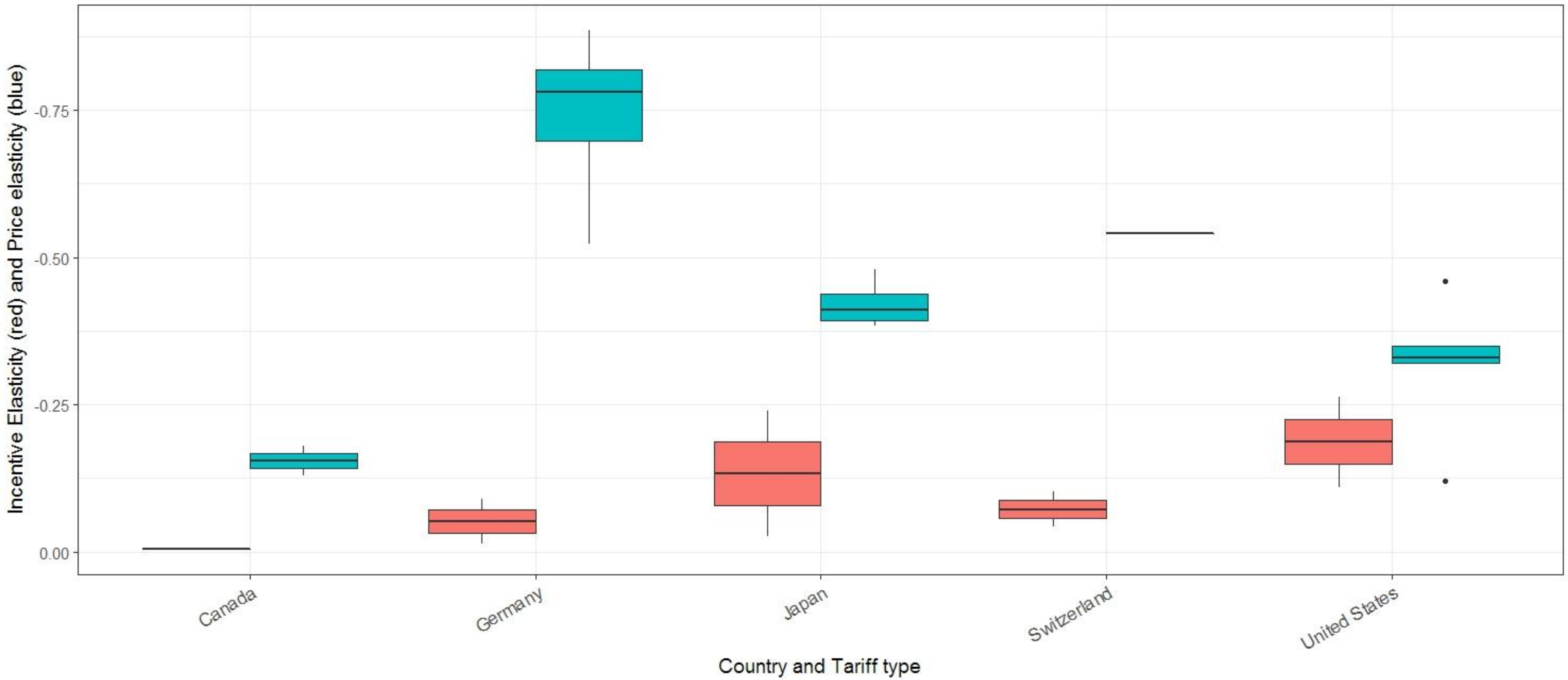

Figure 2. Effectiveness of ESFIT (all households) compared with effectiveness of PT in different regions. (Data from tables 1 and 3b).

Figure 3

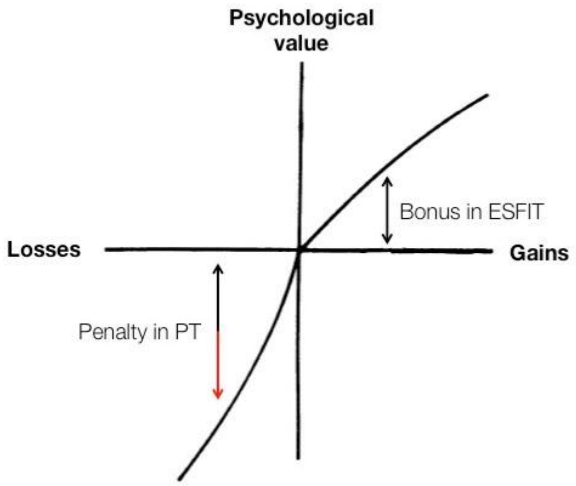

Figure 3: The Value Function as predicted by prospect theory: Illustration of the differential psychological value of gains versus losses in energy incentive schemes.

Figure A1

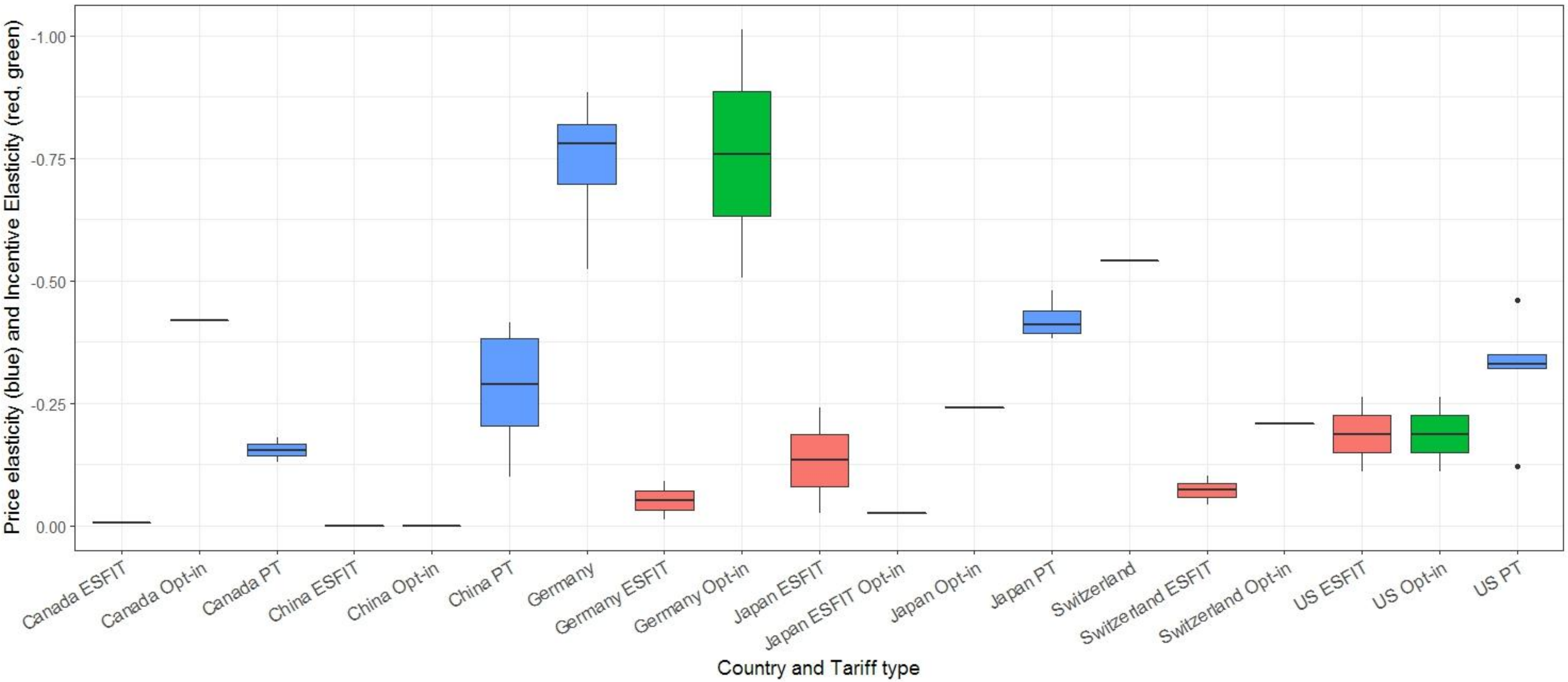

Figure A1. Effectiveness of ESFIT (all households), ESFIT (opt-in households), and PT in different regions (Data from tables 1 and 3b).

Appendix A

Click here to download Supplementary Material: Appendix.docx