The Residential Perception of Real-time Electricity Tariffs

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***Abstract*—This study explores household perceptions of real-time pricing tariffs, focusing on the influence of energy-related financial literacy and perceived tariff complexity. We conducted a large-scale survey with 1,005 participants in a small European country and analyzed the results using hierarchical multiple regression. Our findings indicate that higher financial literacy correlates with increased perceptions of risks over benefits toward real-time pricing tariffs. However, perceived complexity significantly influences this relationship, reducing the impact of financial literacy. Additionally, demographic factors, including photovoltaic ownership, education level, age, and gender, play significant roles in shaping perceptions. We highlight the importance of simplifying real-time pricing tariffs or providing supportive technologies to enhance consumer acceptance. These insights challenge conventional assumptions about energy literacy and suggest that addressing perceived tariff complexity is crucial for aligning consumer behavior with the goals of the green energy transition.**

***Index Terms*—dynamic tariffs, literacy, perceived benefits, perceived complexity, perceived risks.**

I. Introduction

With the accelerating efforts in the European Union to drive a green energy transition, residential demand-side flexibility emerges as a key success variable to align household's energy consumption with the volatile availability of renewables [1]. A policy-favored demand response instrument to incentivize the alignment of electricity consumption and green energy generation is the time-variant pricing of electricity (Electricity Directive 2019/944). The most advanced of these pricing models, offering the closest alignment with market price fluctuations, is the real-time pricing (RTP) tariff.

RTP exposes consumers to hourly changing electricity prices, providing a monetary incentive to avoid peak congestion times in the grid and periods of low renewable integration [2]. In theory, policymakers anticipate that households will actively adjust their consumption by shifting or reducing energy use, delivering systemic benefits such as reduced grid strain while also lowering their electricity bills [3].

Although RTP offers greater economic potential [2] and policy efforts to promote its adoption are intensifying, consumers appear to favor traditional flat-rate tariffs or simpler time-variant alternatives such as Time-of-Use tariffs (TOU) [3]. Several studies indicate that consumers perceive the utility of RTP tariffs as lower than that of flat-rate tariffs, which offer a consistent average price over the long-term [3]. This suggests that the perceived risks of RTP tariffs outweigh their perceived benefits. This relationship between perceived risks and benefits poses a significant barrier to the acceptance of RTP tariffs [2], raising the question of which factors shape these perceptions. Given that the RTP tariffs primarily serves as a pricing instrument, this study builds on the foundational work of Blasch et al. [4], which examines the role of energy-related financial literacy (ERFL) in economic decision-making, and Layer et al. [5], which highlights how the perceived complexity of time-variant pricing schemes significantly shapes behavioral intentions. Building on the proposed influence of ERFL and perceived tariff complexity on household's economic decision-making, this study seeks to address the following research question:

What roles do energy-related financial literacy and perceived tariff complexity play in shaping household perceptions of the risks and benefits associated with real-time pricing tariffs?

To answer this research question, we conducted a large-scale survey with 1,005 participants in 2024 in Luxembourg. We analyzed the survey results using hierarchical multiple regression. This approach allows us to sequentially test the influence of ERFL and perceived tariff complexity on the relationship between the perceived risks and benefits of RTP tariffs. We consider additional control variables such as sociodemographics and ownership of electric vehicles (EV), photovoltaic assets (PV), electricity storage assets, and electric heating systems.

The analysis indicates that consumers with higher ERFL tend to perceive risks as outweighing benefits. However, this effect diminishes when perceived tariff complexity is added to the model specification. The hierarchical regression analysis indicates a significant impact of perceived tariff complexity, driving consumers to perceive risks as outweighing benefits. Additionally, control variables such as PV ownership, education level, age, and gender exhibit significant effects.

The following sections outline the theoretical background of this study, summarize the methodological approach employed, and present a detailed analysis of the results. We then discuss the findings and conclude with the study's implications and limitations.

II. Background

A. Real-time Pricing

One of the most cited works on RTP tariffs has been written by Dutta and Mitra [2]. In their paper, they discuss RTP as a highly dynamic and flexible approach to electricity pricing. RTP adjusts prices on an hourly or more frequent basis to

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reflect real-time supply and demand conditions. This method can lead to significant cost savings for consumers who can shift their usage to lower-priced periods, though it introduces uncertainty and requires them to be more engaged. Effective implementation of RTP tariffs relies on advanced metering infrastructure and smart grid technologies, which provide the necessary real-time data and communication capabilities. The benefits of RTP include enhanced grid stability, reduced demand peaks, and better integration of renewable energy sources. However, challenges such as consumer acceptance, regulatory support, and potential adverse effects on vulnerable populations must be addressed for successful adoption.

Research on household acceptance of RTP tariffs reveals that, while it is seen as crucial for managing demand with high renewable penetration [6], residential consumers are not interested in it. In Spain, the first large-scale RTP programme found no significant difference in behavior between RTP and non-RTP households, possibly due to low potential gains or high non-monetary costs [7]. Another study by Schlereth et al. [3] finds that consumers generally neglect time-variant pricing plans, particularly dynamic pricing plans with unpredictable price variations. Additionally, the low acceptance of RTP may be due to consumers' lack of experience with such plans and the difficulty in forming expectations about usage flexibility [3].

The adoption of RTP tariffs can be analyzed through the lens of the Expected Utility Theory (EUT) [8]. EUT posits that individuals make decisions by evaluating the expected utility of different options, and weighing the potential benefits against the risks. In the context of RTP tariffs, consumers assess potential economic benefits (e.g., cost savings during off-peak hours) and risks (e.g., higher costs during peak hours). By studying the ratio between perceived risks and benefits, we can understand how consumers calculate the expected utility of adopting RTP tariffs. If the perceived benefits outweigh the risks, the expected utility is positive, leading to higher adoption rates. Conversely, if the risks are perceived to be greater, the expected utility is negative, resulting in lower adoption rates.

EUT assumes rational decision-making, but advancements in behavioral economics show that individuals often deviate from this ideal due to biases and heuristics [9]. However, when individuals have more knowledge, they are better positioned to rationally evaluate complex pricing schemes, potentially leading to more rational and informed decisions [10]. This leads us to investigate the role of ERFL in shaping household perceptions of the risks and benefits associated with RTP tariffs.

B. Energy-related Financial Literacy

ERFL includes both the knowledge of energy costs needed for informed decisions and the skills to process this information, similar to those required for long-term investment planning [4]. Concretely, this implies that people with high levels of this literacy can better understand their energy bills, are more aware of their energy consumption, and are better at budgeting in the long term. Research has confirmed that these capabilities can encourage households to invest in solutions to increase energy efficiency in their homes either by choosing more efficient appliances [4, 11] or by retrofitting their building [12].

Although ERFL has been examined especially in relation to investment in energy efficiency improvements, there are studies suggesting that ERFL, or, in general knowledge about dynamic tariffs, could play a role in shaping households' perception of the risks and benefits of RTP tariffs. In fact, Reis et al. [13] found that higher energy and graphical literacy increase the willingness to adopt dynamic tariffs. In addition, respondents with lower literacy levels were more affected by the framing effect when choosing their tariff. In another study, Dütschke and Paetz [14] observed that consumers are more willing to embrace dynamic tariffs if they have prior familiarity or experience with them or smart home technologies.

In the context of energy efficiency, financially literate individuals demonstrate a greater willingness to pay for discounted operating costs and make more consistent choices that align with standard consumer preferences [15]. However, the relationship between financial knowledge and energy use is complex. One study found that households with high financial awareness exhibited higher energy use and carbon emissions, albeit with lower energy efficiency[16]. Factors such as income and education also influence financial decision-making [17].

C. Perceived Complexity

Besides ERFL, perceived complexity also plays a role in the evaluation of risks and benefits of electricity tariffs, in this case, RTP tariffs. Homburg et al. [18] defined price complexity as the degree to which a price or tariff creates a mental burden for the consumer to understand its components and calculate the total bill. Previous studies found that, when it comes to electricity tariffs, consumers tend to choose the simplest solutions, such as flat-rate tariffs or TOU tariffs [3].

This is supported by Ruokamo et al. [19], who studied households' preferences for RTP tariffs and confirmed that these were not attractive to consumers. They suggest this may be due to the difficulty in understanding the contracts and the related price risks that they represent.

Furthermore, Layer et al. [5] explored how consumers perceive the complexity of dynamic energy tariffs and how this perception affects their behavior. They found that the cognitive effort required to understand these tariffs influences consumer reactions and their willingness to adopt such tariffs. Specifically, they found that higher perceived complexity reduces detailed analysis, leading consumers to rely on heuristics and overestimate the total bill, and therefore associated price risks. This also decreases their confidence in evaluating the tariff, ultimately reducing their intention to select complex dynamic tariffs.

III. Method

A. Survey Design and Descriptive Statistics

This study's survey is part of a larger research project, which explores residential preferences and decision-making related to dynamic electricity tariffs. We designed the survey and collaborated with a specialized market research agency to distribute it in the field[1]. 1,027 responses were collected, all from individuals older than 18 years of age living as a resident in the country. After excluding participants who failed the attention check questions or did not provide complete sociodemographic profiles, 1,005 valid survey responses remained. Table I summarizes the descriptive statistics for the sociodemographic characteristics and ownership of technology of the representative survey sample.

TABLE I
SUMMARY OF DESCRIPTIVE STATISTICS

Demographical Variables	**Share [%]**
Age <65 years	82.10
Female	49.55
Male	50.45
Income per month >5,000€	56.68
With bachelor's degree or higher	42.53
Living in a household with 1-4 people	91.30
Household with children	32.74
Owner of dwelling	81.11
Owner of photovoltaic asset	26.31
Owner of electric vehicle	17.80
Owner of storage or charging station	14.84
Owner of electric heating system	22.35

To evaluate how risky or beneficial households perceive RTP, participants first read a comprehensive definition and explanation of RTP tariffs, after which they rated perceived risks and benefits using a 5-point low-to-high Likert scale. To investigate the relationship between these perceptions, we created a new variable by calculating the ratio of risk to benefit for each participant. Although we lose insights from the absolute difference between perceived risks and benefits, the ratio provides a more nuanced understanding by reflecting the relative weight participants assign to risks versus benefits. The ratio enables us to examine how participants balance these two perceptions and facilitates exploratory analysis of how ERFL and tariff complexity may influence the economic decision-making process.

In addition to the risk and benefit rating, participants were asked to rate perceived tariff complexity according to a 5-point low-to-high Likert scale. While 15% perceived the complexity as low or rather low, 50% rated it as high or rather high. 35% of the sample were uncertain. To assess ERFL, we implemented the evaluation framework and rating system of Blasch et al. [4], which consists of 9 open and single-choice questions assessing a participant's financial and energy-related knowledge. Ultimately, a minimum ERFL score of 0 and a maximum score of 9 can be achieved. On average, the sample scored 4.65.

B. Data Analysis

We apply a hierarchical multiple regression approach to sequentially test the effects of ERFL and perceived tariff complexity. This approach defines four regression models, each adding independent variables step by step to assess their effect on the perceived risk-benefit ratio. The results per model can be interpreted as the estimated change in the perceived risk-benefit ratio for a one-unit increase in each independent variable while holding all other independent variables in the model constant.

- The baseline model, Model 1, examines the isolated influence of ERFL on the perceived risk-benefit ratio, establishing the direct effect of this key variable. To offer greater granularity of the results, we distinguish within the ERFL construct between energy-related literacy (EL) and financial literacy (FL) [4].
- Building on the first model, Model 2 incorporates technology ownership variables to explore whether ownership moderates or enhances the relationship.
- Extending Model 2, Model 3 adds sociodemographic factors to account for possible background influences, providing a broader context to understand variations in the perceived risk-benefit ratio.
- Model 4 integrates perceived tariff complexity as an additional independent variable, capturing its unique contribution to risk-benefit perception while controlling for all previously included variables.

Therefore, the final regression model is calculated as:

$$\begin{aligned} y = {} & \beta_0 + \beta_1 x_{\text{EL}} + \beta_2 x_{\text{FL}} \\ & + \sum_{j}^{m} \beta_j x_{\text{T},j} + \sum_{i}^{k} \beta_i x_{\text{S},i} + \beta_{k+1} x_{\text{C}} + \epsilon \end{aligned} \tag{1}$$

where:

- y: Dependent variable - the perceived risk-benefit ratio.
- x_{EL}: Energy-related literacy.
- x_{FL}: Financial literacy.
- $x_{\text{T},j}$: Technology ownership factors (e.g., PV and EV ownership), indexed by j.
- $x_{\text{S},i}$: Sociodemographic factors (e.g., age and gender), indexed by i.
- x_{C}: Perceived tariff complexity.
- β_0: Intercept.
- β_1, β_2: Coefficients for energy-related literacy and financial literacy.
- β_j: Coefficients for technology ownership.
- β_i: Coefficient for sociodemographics.
- β_{k+1}: Coefficient for perceived complexity.
- ϵ: Residual error.

Prior to the regression, we verified that the prerequisites for linear regression are met, including linearity and normality. Given that our analysis indicates the presence of heteroscedasticity, we employ robust standard errors in our regression models [20, 21]. This approach ensures that the standard errors are consistent and provide valid inferences despite heteroscedasticity. Variance inflation factors were used to check for multicollinearity, indicating that it was not a concern in the analysis.

[1]The full survey outline is available upon request.

IV. RESULTS

This section summarizes the results of the hierarchical multiple regression. Table II shows the effect of ERFL, technology ownership, sociodemographics, and perceived tariff complexity on the ratio between perceived risks and benefits of RTP tariffs.

TABLE II
HIERARCHICAL REGRESSION

Variables	Model 1	Model 2	Model 3	Model 4
Financial Literacy (FL)	0.11*** (0.04)	0.11*** (0.04)	0.10*** (0.04)	0.06 (0.04)
Energy Literacy (EL)	-0.01 (0.02)	0.00 (0.02)	-0.01 (0.02)	-0.01 (0.02)
Photovoltaic (PV)		0.23*** (0.08)	0.27*** (0.08)	0.28*** (0.08)
Electric Vehicle (EV)		0.05 (0.11)	0.09 (0.11)	0.09 (0.11)
Electricity Storage/Charging		-0.06 (0.13)	-0.06 (0.12)	-0.01 (0.12)
Heating System		-0.13 (0.08)	-0.10 (0.08)	-0.10 (0.08)
Gender			-0.10 (0.07)	-0.14** (0.07)
Age			-0.05** (0.02)	-0.04* (0.02)
Rented House			0 (.)	0 (.)
Owned House			0.16 (0.15)	0.05 (0.15)
Rented Flat			-0.16 (0.17)	-0.21 (0.16)
Owned House			0.13 (0.16)	0.02 (0.16)
Household Size			0.05 (0.12)	0.11 (0.12)
Family (all over 18)			0 (.)	0 (.)
Family with Kids			-0.05 (0.09)	0.01 (0.09)
Single			-0.13 (0.12)	-0.07 (0.11)
Couple			-0.16* (0.09)	-0.13 (0.09)
Non-family (e.g., flatmates)			-0.47 (0.36)	-0.40 (0.34)
Income			-0.02 (0.02)	-0.02 (0.02)
Education			0.11*** (0.03)	0.08*** (0.03)
Perceived Tariff Complexity				0.31*** (0.03)
_cons	1.11*** (0.08)	0.91*** (0.25)	0.94** (0.38)	-0.12 (0.38)
Adj. R^2	0.008	0.014	0.037	0.113

**** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. Standard errors are in parentheses.*

In the initial model, we assessed the impact of FL and EL on the perceived risk and benefit ratio. The results indicate that financial literacy has a significant positive effect on the perceived risk and benefit ratio, with a 10.6% increase per unit increase in financial literacy. However, energy literacy does not show a significant effect, with a negligible change of -0.52%.

When technology-related variables are included in the model, the effect of financial literacy remains significant. Additionally, PV ownership significantly increases the perceived risks and benefits ratio by 23.1%, indicating that households with PV perceive higher risks relative to benefits. Other technology variables, such as EV and electricity storage or charging systems, do not show significant effects.

Incorporating sociodemographic variables into the model, financial literacy and PV ownership continue to have a significant positive effect. Among the demographic variables, age and education show significant effects. Specifically, each additional age class was associated with a decrease of 5.25%. Education has a significant positive effect, with each additional level of education associated with a 10.6% increase in the perceived risks and benefits ratio.

In the final model, we added the perceived complexity of RTP tariffs. The results show that perceived complexity has a significant positive effect on the perceived risks and benefits ratio, with a 30.9% increase per unit increase in perceived complexity. Interestingly, with the inclusion of perceived complexity, the effect of financial literacy becomes non-significant. Additionally, PV ownership, education, and age maintain their effects. Finally, being male is associated with a 13.7% decrease in the perceived risk and benefit ratio.

V. DISCUSSION

The purpose of this paper was to explore the role that ERFL and perceived tariff complexity play in shaping household perceptions of risks and benefits toward RTP tariffs. When breaking down ERFL into its components — EL and FL — we find that only FL remains significant in regression models 1 to 3. This means that people with higher FL are more likely to perceive greater risks than benefits with RTP tariffs. EL, in contrast, does not show a significant effect. Unlike Blasch et al. [4], who found that FL alone has no significant impact on the adoption of energy-efficient lighting, our models indicate that higher levels of FL are linked to an increase in the risk perception of RTP tariffs. This could be because dynamic tariffs are primarily price-based instruments, making financial knowledge more relevant in this context. The results suggest that financially literate individuals have a better understanding of how a time-variant pricing scheme may influence their monthly electricity bills. Ultimately, they may view the risks of dynamic tariffs as outweighing the potential benefits. In contrast, making a decision towards the adoption of energy-efficient lighting, which is relatively inexpensive and comparably simple, may be independent of FL as an antecedent of consumers' decision making.

When we add perceived complexity, the effect of FL decreases and loses importance, and just perceived complexity has a significant positive effect on how people perceive risks compared to benefits. Perceived complexity appears to be one of the most important variables in explaining why risks are perceived as higher than benefits, aligning with studies such as Layer et al. [5], which identify perceived complexity as a major influence on how consumers view dynamic tariffs.

Intuition may suggest that with an increasing FL the perceived complexity of the RTP tariff would decline, indicating a correlation between FL and perceived complexity. However, as we could not identify any concerns regarding multicollinearity and as the Pearson correlation coefficient between FL and perceived complexity is very low (0.137), the intuition was not confirmed. One explanation for the greater influence of perceived complexity over FL in shaping individuals' assessments of the risks and benefits of dynamic tariffs can be found in the dual-system assumption of human thinking [22]. According to this, System 1 represents automatic responses based on intuitions and feelings, while System 2 embodies logic and mental effort. When consumers first encounter RTP tariffs, they may feel overwhelmed due to their familiarity with simple, flat-rate pricing. This strong contrast can trigger a System 1 response, which dominates any attempts to rationally engage with the RTP tariff in the first place. In contrast, FL requires mental effort and develops over time, making it a construct of the rational System 2.

When it comes to sociodemographic factors, we observe that PV owners, women, younger individuals, and those with higher levels of education tend to perceive more risks than benefits associated with RTP tariffs. With greater education or experience, people may have a deeper understanding of the potential consequences of dynamic tariffs, leading them to weigh these risks more heavily. The study by Nakai et al. [23] found that age is related to never choosing a dynamic tariff. This could be because older individuals, who are more accustomed to historically low energy prices and flat-rate pricing, may be less open to switch between tariff types and are less sensitive to price variations.

We find that women perceive greater risks than benefits when it comes to RTP tariffs. This aligns with previous research, which indicates that women are generally more risk averse in various domains, such as gambling, health, and social behaviors [24].

A. Theoretical and Practical Implications

This study offers insights with theoretical and practical implications. On the theoretical side, our study advances the understanding of the perception of RTP tariffs and influencing factors, i.e., perceived tariff complexity and FL.

On the practical side, the relationship between perceived complexity and the risk-benefit ratio indicates that reducing the complexity of tariffs can make the benefits appear more favorable than the risks. However, alternative approaches could be employed since RTP tariffs are inherently complex and cannot always be simplified. For instance, new energy services or smart applications — or enhancements to existing ones — could be developed to help users navigate this complexity more quickly, making flexible electricity consumption within RTP tariffs more accessible and user-friendly.

B. Limitations

This study also has some limitations. First, we cannot be certain that the variables we recorded are exclusive. Further studies could look at additional influential factors, such as personal attitudes and beliefs, but also on how transparent information provision through means such as smartphone applications influences a household's perception of risks and benefits associated with dynamic tariffs.

Second, our sample is from Luxembourg, and while it is representative of the national population, the country's income levels are among the highest in the world. As a result, the generalizability of our findings is somewhat limited. To determine whether the results are valid in other countries and cultural contexts, a similar study could be conducted in different regions.

Third, we assume that the independent variables of literacy, perceived complexity, technology ownership, and sociodemographics influence the dependent variable of the perceived risks and benefits ratio. However, it is a correlative and not a causal relationship. It could be that the relationship is the other way around; e.g., a higher perception of risks compared to benefits leads people to perceive a higher complexity of RTP tariffs.

VI. Conclusion

This study has explored the residential perception of real-time pricing RTP tariffs, focusing on the roles of energy-related financial literacy (ERFL) and perceived tariff complexity. Our findings reveal that higher financial literacy correlates with a heightened perception of risks over benefits associated with RTP tariffs. This relationship, however, is significantly influenced by the perceived complexity of the tariffs. When complexity is accounted for, the impact of financial literacy diminishes, highlighting the critical role of perceived tariff complexity in shaping consumer perceptions and acceptance of RTP tariffs.

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