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What Can Policy-Makers Do to Increase the Effectiveness of Building Renovation Subsidies?

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Abstract: Heating is responsible for a substantial share of global energy consumption and still relies strongly on fossil fuels. In order to reduce energy consumption for heating, subsidies for building renovations are a common policy measure in Europe. Policy makers often combine them with information and advice measures. Policy mixes of this kind have been acknowledged widely in the literature, but their effectiveness needs further empirical examination. Based on a survey of the recipients of renovation subsidies and on four focus groups, we examine the (cost) effectiveness of subsidies, as follows: The effectiveness of renovation subsidies was measured by the extent to which receiving subsidies contributed either to the decision to renovate at all, or to the decision to enhance the quality or scope of the renovation. Fifty percent of the recipients surveyed reported that the subsidies contributed to a more energy-efficient renovation than was initially intended. The other fifty percent must be considered as free riders. Multivariate analyses further show that homeowners who used advice services and attributed outstandingly positive characteristics to the policy implementer were more likely to spend subsidies to improve energy efficiency. The findings demonstrate the importance of applying a combination of financial and persuasive policy measures. Additionally, they illustrate the importance of non-financial and non-technical factors, such as the communication competencies of the implementer, when designing policy measures.

Keywords: building energy policy; freeriding; effectiveness; subsidies; advice services; policy mix; Switzerland

1. Introduction

In light of global warming, the reduction of fossil energy consumption is one of the key challenges facing societies around the world. Heating is responsible for nearly one third of global final energy consumption [1], and fossil fuel remains the main energy source for heating. To reduce energy consumption for heating, governments rely on different mixes of policy measures [2,3] and spend substantial amounts in order to enhance the energy efficiency of building infrastructure. Even though financial support for energy efficiency in buildings is increasing in many European countries [4] and worldwide [5], the renovation rates lag behind the objectives of the European Union resource efficiency agenda [6]. Also, on a global scale, the International Energy Agency (IEA) concludes that "[g]lobal building-related CO_2 emissions have continued to rise of nearly 1% per year since 2010 [. . .]. Concerted global effort is needed to rapidly expand, strengthen and enforce building energy policies across all countries to prevent the lock-in of long-lived, inefficient building investments" ([7], p. 54).

Several concepts help to explain why attempts to reduce energy consumption for heating lag behind their potential; obstacles such as the "lock-in effect" and specific types of free riding are not easy to overcome. The lock-in effect "refers to the fact that once some basic energy efficiency measures have

been implemented, it becomes less cost effective to fit more comprehensive measures in the future" ([8], p. 8). The concept of free riding is generally used to describe dilemmas in the context of the provision of collective goods [9]. However, in the context of energy conservation policies, the term free riding is applied to describe a specific phenomenon, which "appears when the conservation programs finance investments that would have taken place even in the absence of the programs" ([10], p. 80). To reach energy efficiency goals, policy makers are therefore challenged to assure that renovations are substantial (e.g., of high quality and scope), and that they subsidize renovations that would not have been undertaken anyway (without additional financial support).

In this paper, we examine the effectiveness of subsidies, focusing on the decisions made by the homeowners. We asked subsidy recipients if subsidies encouraged them to opt for a more energy-efficient renovation than initially intended. With this, we measure effectiveness considering potential free riding issues, as follows: we consider subsidies as (cost) effective only when they encourage homeowners to increase the quality or scope of the renovation. This measurement approach provides an alternative to the technical approaches that estimate the amount of CO_2 emission reductions due to (subsidized) building renovations. To further explore the factors affecting the effectiveness of subsidies, we examine empirically the effects of advice services and homeowners' perception of the policy implementer. We relate advice services, which is a popular topic in social psychology and other social science research [11], to subsidies, which is a classical topic in economic research. With this, we aim to contribute to a more interdisciplinary discussion of energy policy [12].

In the next paragraphs, we discuss literature with regard to the question of how policy makers and policy implementers can enhance the effectiveness of renovation subsidies. In Section 1.1, we illustrate how effectiveness is conceptualized and measured by an approach that takes potential free riding into account. In Section 1.2, we illustrate that persuasive policy instruments—especially advice services—have the potential to enhance the effectiveness of the renovation processes. In Section 1.3, we discuss the potential influence of the policy implementers on the effectiveness of subsidies. We then shortly state the aim and research questions, before we describe the methods applied in Section 2. In Section 3, we show the empirical results, which we then discuss in Section 4. In Section 5, we provide some concluding remarks.

1.1. Effectiveness of Building Renovation Subsidies and Free Riding

Of the different approaches to conceptualizing and measuring the effectiveness of renovation subsidies, some focus on the CO_2 reduction caused by the subsidized renovations (using building data), and others focus on the effects of the subsidies on the investment decision of the recipients (using survey data). The studies that concentrate on the CO_2 emission reduction achieved by subsidized renovations (e.g., [13,14]) provide important information on the emission-saving potential of different kinds of renovations. However, they do not explicate to what extent these emission savings have been encouraged by the fact that subsidies were provided. People may also apply for subsidies after they have already decided that they want to renovate and how they want to do it [15]. In that case, the benefits of subsidies are likely to be overestimated when they are measured by the CO_2 reductions caused by subsidized renovations. Therefore, to examine to what extent subsidies really induce more energy-efficient renovations than initially intended, not only the final state of the building, but also the decision process of the subsidy's recipients has to be examined.

For policy makers, it is important to consider that the effectiveness—more specifically, the cost effectiveness [16]—of energy conservation programs is hampered by a specific free riding phenomenon, namely: individuals or organizations who would have undertaken conservation actions even if the subsidy had not been available still apply for conservation subsidies [12,17]. Empirical studies report a substantial share of free riding in the context of energy conservation programs. In a review of empirical studies on financial energy policy measures, Rieder and Haefeli [18] report free riding behaviour by 30% to 80% of the recipients. With respect to energy efficiency, specifically in the building sector, Grösche and Vance [19] found free riding in 50% of the recipients of renovation subsidies in Germany.

Rieder [20] estimates that 30% of the recipients of a building renovation program in Switzerland are free riders. Thus, free riding reduces the cost effectiveness of building renovations subsidies substantially.

Policy makers may want to formulate policies that exclude recipients that are prone to free riding. Based on microeconomic considerations, Scharpf [15] concludes that free riding can never be reduced to zero because of a lack of information about the individual willingness-to-pay. However, Scharpf [15] argues that free riding can be reduced by secondary persuasive programs (see Section 1.2) and active implementation (see Section 1.3).

1.2. Enhancing Effectiveness of Subsidies through Energy Policy Mixes

The effectiveness of subsidies may be enhanced by combining subsidies with other policy measures, as the literature on policy mixes elaborates [21,22]. Different types of policy measures are identified, the most prominent of which are regulatory, financial and information measures [21]. Several authors claim to not only examine policies as single entities, but also to study the effectiveness of combinations of policies [2,23–27]. A literature review on energy efficiency policy mixes [2] found that studies often examine how mixes emerge and change over time (see also [24]), or analyse aggregated data and complex policy packages, but do not provide evidence of the effectiveness of the specific combination of subsidies with other policy measures. Referring to policies in the building sector in particular, Kastner and Stern ([11], p. 75) state in their review that the "current situation for existing buildings suggests that funding alone may not be entirely sufficient to promote energy-relevant investment decisions by households. Several empirical studies support this assumption, and suggest that combining funding with other measures is a more effective approach".

Evaluations and studies on energy policy programs in general indicate that the combination of information measures and financial measures is particularly effective in enhancing energy efficiency [28]. Regarding policy mixes in the building sector, we found only a very limited number of studies that examined the effectiveness of financial and information measures for energy-efficient renovations simultaneously. We identified some qualitative and conceptual studies [29,30] and two empirical studies [31,32]: Filippini et al. [31] analysed the aggregated data and found a positive effect of financial measures on residential energy consumption, but no effect of information services. Achtnicht and Madlener [32] found that both energy advisors and funding have a positive effect on willingness to install a new heating system or building envelope insulation. Although the latter provides evidence that subsidies and advice services independently influence people's decision to invest in renovating, our study further examines whether advice services influence the effectiveness of subsidies by encouraging homeowners to use the subsidies to enhance the quality and scope of the renovation.

Although there are few empirical studies available on mixes of information and financial policy measures, studies on the effects of single policy measures for energy efficient renovations report on the positive effects of financial measures on renovation investment decisions. The effects of information measures are a bit more contested. Kastner and Stern [9] identified 29 studies on financial measures affecting renovation investment decisions, and 18 of them showed positive effects on renovation investment decisions. Of the 15 studies on energy consulting measures, only five reported positive associations between energy consulting and energy efficient investment decisions by households. This may be explained by the fact that energy advice aims at tailoring investment strategies, and therefore does not necessarily recommend investment in the examined energy efficiency measure (but an alternative one). Murphy [33] summarized the existing research on energy audits (as one form of energy consulting) and concluded that there is little evidence that energy audits really encourage renovations, with some exceptions (e.g., client-led audits). Ramos et al. [34] also documented the limited effectiveness of energy audits. Both Murphy [33] and Ramos et al. [34] concluded that more research is needed in order to understand the interaction of policies. Thus, although the claim that information measures and financial measures complement each other is widely supported by

theoretical and practical considerations, our study is an empirical examination of the contribution of information measures to the effectiveness of subsidies.

1.3. Enhancing Effectiveness of Subsidies by Policy Implementation

Scharpf's [15] proposition to combine subsidies with active implementation—defined as an active implementation aimed at informing, advising and motivating the potential recipients—may be linked with several strands of literature. In general, the implementation processes of energy policy are examined in the light of governance theory and implementation studies (see [35] for an overview). In contrast to governance theory, which emphasizes the collective level of action of energy policy implementation [36], the focus of our study is on the interaction between the "policy implementer"—agencies, organizations or offices responsible for the implementation of subsidies—and the subsidy recipient's behaviour on an individual level.

Referring to financial incentives for energy-efficient behaviour, researchers emphasize the importance of a credible actor who communicates information in an adequate manner [37–40]. Already in the 1980s, Stern argued, "[t]he financial aspects of a conservation incentive program are not the only important ones. The success of a program may depend on its ability to get the attention of its intended audience [. . .]; communicate in a way that is understandable and credible [. . .]. Success may depend not only on the size of the incentives offered but on the form of the incentives and on the way the programs are organized, marketed, and implemented" ([38], p. 149, referring to [41,42]). Stern encouraged researchers to focus on the marketing and implementation of a residential energy conservation policy (without examining these aspects empirically himself). Wilson and Dowlatabadi [39] reviewed models of decision making and residential energy use, and argued that the perceived trustworthiness and credibility of the service provider are important factors that enhance the effectiveness of information services promoting residential energy efficiency. Our study further examines whether homeowners' perception of the policy implementer is associated with the effectiveness of renovation subsidies.

With our study, we aim to contribute to energy policy research by examining the subsidy's recipients' investment decision, and by enhancing our understanding of free riding behaviour in the recipients of renovation subsidies. Our study is guided by the following research questions:

- How important is free riding? To what extent do subsidies contribute to the decision to renovate and to the improved quality or improved scope of the renovation?
- What factors reduce free riding in the specific context of building renovation subsidies? How can policy makers reduce free riding and thereby increase effectiveness?

In our attempt to illustrate how policy makers can increase the effectiveness of subsidies, we focus on two effects that have so far been underrepresented in empirical studies on the effectiveness of subsidies for building renovations, namely: the positive effect of advice services and homeowners' perception of the policy implementer.

2. Materials and Methods

In this section, we describe the methods used for data collection—including the operationalization of the dependent and independent variables—and the methods for data analysis.

2.1. Data Collection

For data collection, an online survey was sent to the Swiss households that had benefited from subsidies for insulation recently (in the last two years). The data was collected in summer 2015 in collaboration with two public energy offices on the cantonal level (Switzerland is made up of 26 cantons, or states). The questionnaire contained several question blocks and was developed based on the research interests of the energy offices and on our theoretical considerations. We obtained

588 responses of subsidy recipients who answered the questions referring to the effectiveness of the subsidies consistently (see Table 1).

Table 1. Description of the sample of recipients of subsidies.

		Subsample (n = 588)	
		Frequency	
Sex	Male	468	(81.1%)
	Female	109	(18.9%)
Age	Up to age 39	82	(14.2%)
	40–64	375	(65.0%)
	Over 64	120	(20.8%)
Highest education qualification	Apprenticeship	169	(29.6%)
	Upper secondary education	188	(32.9%)
	University degree	214	(37.5%)
Geographic location	Rural	86	(17.8%)
	Agglomeration	354	(73.4%)
	Urban	42	(8.7%)
Federal entity	Centralized implementation of energy and building law	379	(64.5%)
	Decentralized implementation of energy and building law	209	(35.5%)
Acceptance	Acceptance of subsidies:		
	Not at all suitable	5	(0.9%)
	Rather not suitable	13	(2.3%)
	Suitable to some extent	147	(26.4%)
	Very suitable	391	(70.3%)
	Acceptance of advice services:		
	Not at all suitable	6	(1.1%)
	Rather not suitable	24	(4.4%)
	Suitable to some extent	204	(37.7%)
	Very suitable	307	(56.8%)
	Energy efficiency affinity index	Mean	% > 0
	(range: −2 to 2)	0.76	80.5
Policy factors	Perception of the implementer index	Mean	% > 0
	(range: −2 to 2)	1.06	93.3
	Advice services utilized	109	(18.8%)
	No advice services utilized	470	(81.2%)

In addition, we conducted focus groups to contextualize our findings from the survey, and to deepen our understanding of the renovation investment decision process. The data was collected in spring 2016. The participants in the focus groups were recruited by the cantonal energy offices. All of the participants were recipients of subsidies for insulation, and therefore have made some renovation investment decisions; half of them utilized advice services, and the other half did not. The participants varied in age, sex and housing type (single-family dwelling or multiple-family dwelling). We obtained data from four focus groups (two in each canton), with four to eight recipients of subsidies in each group.

2.1.1. The Target Group of Subsidy Recipients

Data collection focused on recipients of subsidies that were provided by the so-called "Gebäudeprogramm" in Switzerland. This program contains several measures, including the financial support of insulation: Since 2010, the insulation of windows, building envelopes and roofs of buildings has been supported by a financial contribution per square meter. The most relevant eligibility

conditions are the following: the age of the building (building licence obtained before the year 2000), a minimal insulation value (U-value) and a minimal scope of the investment (minimal financial contribution applied for). According to the program's estimations, the subsidies finance up to 15% of all investment costs [43]).

2.1.2. Measurement of the Effectiveness of Subsidies (Dependent Variable)

To measure the effectiveness of the subsidies, we used three variables and one control variable. Respondents were asked to indicate whether the following statements applied to their renovation process or not:

- Decision: The subsidies for renovation were essential for the decision to renovate
- Quality: The subsidies contributed to an increased quality of the renovation measures
- Scope: The subsidies contributed to an increased scope of the renovation measures

We consider the subsidies to be effective if at least one of these three variables applied. To control for inattentive responses and bias due to social desirability, we also asked the respondents to agree or disagree with the statement that the subsidies did not have any influence on the renovation of the building. Those respondents who reported the subsidies to be effective, but also reported that the subsidies did not have any influence on the renovation were excluded from the analysis. For further analysis, we used the binominal variable of "effectiveness of subsidies", indicating whether the subsidies led to a more energy-efficient renovation than initially intended or not.

2.1.3. Measurement of the Independent Variables

For the independent variables, we focused on the policy factors that are influenceable by policy makers—namely, the utilization of advice services and homeowners' perception of the policy implementer. In addition, we collected data on the energy-relevant attitudes of the respondents (acceptance of policy measures and affinity for energy efficiency), sociodemographic characteristics (sex, age and highest educational qualification) and the respondents' location (geographic location and federal entity).

Concerning the policy factors, the following two variables were used: utilization of advice services and perception of the implementer. First, respondents were asked whether they benefited from cost-free, publicly funded energy advice services or not, resulting in a binominal variable of "utilization of advice services". Second, the respondents were asked to rate their extent of agreement, with 11 adjectives to describe the policy implementer on a four-point Likert scale (see Appendix A). These adjectives were compiled in collaboration with the cooperation partners (cantonal energy offices) based on theoretical considerations (on credible actors) as well as on the marketing considerations of the cooperation partners. The 11 adjectives were further condensed into a single variable of "homeowners' perception of the policy implementer", so as to gain insights into how the policy implementer is perceived (see Section 3.1).

To describe the respondents' attitudes towards energy-relevant issues, the following two variables were used: acceptance of policy measures and energy affinity. First, we asked the respondents to rate how suitable they considered the specific policy measures involved in enhancing energy efficiency on a four-point Likert scale, resulting in the variables of "acceptance of subsidies" for building renovations, and "acceptance of advice services" for building renovations. Second, we asked the respondents to rate the importance of four aspects of energy efficiency on a four-point Likert scale, namely: efficiency level of home appliances, use of appliances' standby mode, moderate room temperature and preferential use of public transport (see Appendix B). The aspects of energy efficiency were derived from Sütterlin et al. [44], and Schaub and Blumenfeld [45]. The four aspects were further condensed into one variable, "energy affinity", in order to capture the respondents' general affinity for energy efficiency issues (see Section 3.1).

To control for the political and regulatory context, we used the following two variables: geographic location and the federal entity. The respondents' geographic location was captured by the categories of urban, agglomeration and rural. As the sample consisted of data from two Swiss cantons, the sample also contained information about the different federal entities (cantons). The cantons in Switzerland differ regarding the division of responsibilities between the cantonal administration and the administrations of the communes (the 26 cantons are divided into communes). In our sample, one canton was characterized by the centralized implementation of the construction law and the energy law, with few responsibilities given to the communal administration, whereas the other canton had a rather decentralized implementation of construction law and energy law.

Finally, we collected the data on the respondents' sociodemographic characteristics, including sex (male, female), age (grouped in three categories—younger than 40 years old, 40–64 and older than 64) and highest educational qualification (grouped in the categories of apprenticeship, upper secondary education ("Upper secondary education (*Sekundarstufe II*) is not compulsory and varies in length from three to four years. There are two main types of upper secondary schools: academic schools (*Maturitätsschulen*) and vocational schools (*Berufsfachschulen*). Academic upper secondary schools prepare students for entry to universities, and vocational secondary schools prepare students for a wide range of occupations and vocational education and training colleges (*Höhere Fachschulen*) as well as universities of applied sciences (if combined with the vocational baccalaureate)." (http://www.euroeducation.net/prof/switzeco.htm; see also [46])) and university degree).

2.2. Data Analysis

With the survey data, we conducted logit regression analyses. The logit regression analyses are suitable for examining the associations between a dichotomous dependent variable and the independent variables [47]. The inclusion of several independent variables in the regression analysis allows for controlling for the effect of multicollinearity between the independent variables. In our case, we examined whether policy factors and individual characteristics relate to the effectiveness of subsidies; our intention was to learn about the factors that have the potential to reduce free riding.

To complement the statistical analyses, we examined the data from four focus groups (audio files and corresponding transcriptions, notes on flipcharts, short questionnaires and memos) comprised of the recipients of subsidies following a thematic analysis [48,49]. The focus group data was analysed with a special concentration on identifying the drivers and barriers concerning the utilization of energy advice services. We also examined the statements of the recipients in order to increase our understanding of how advice services, the renovations decision process and financial incentives interrelate. The data interpretation by the research team was discussed at a workshop with the cooperation partners (cantonal energy offices), with the aim of enhancing mutual learning and to contextualize the findings.

3. Results

In this section, we show some descriptive results of the survey and elaborate on the reported effectiveness of the subsidies, as well as the factors affecting the effectiveness of the subsidies.

3.1. Descriptive Results

Table 1 shows some of the descriptive statistics of the independent variables used in our analysis. The subsidy recipients that were surveyed were predominantly male, 40- to 64-years-old and living in agglomerations. The high proportion of men may be explained by the tendency that in a household, men are more often the main contact person for building issues. Furthermore, other surveys also indicated that renovations are most often realized by homeowners in the age groups from 40 to 65 [50].

The policy measures were highly accepted. Only very few respondents rated the building renovation subsidies and/or the advice services as not suitable at all or rather not suitable. A prerequisite for the logit regression analysis is to have at least n = 25 per group examined. Hence,

we merged the two variables (not suitable and rather not suitable) into one variable, in order to reach suitable group sizes for further analyses. For the acceptance of subsidies, the group size of the respondents who did not consider the subsidies suitable to enhance energy efficiency remained very small, and the acceptance of subsidies was therefore excluded from further analysis.

For the energy efficiency affinity index, we calculated the arithmetic mean of four variables measuring the importance attached to the efficiency level of appliances, use of appliances' standby mode, moderate room temperature and preferential use of public transport (see Appendix B). We also conducted a principal component analysis, which revealed that all four variables were loaded on a single factor with a Cronbach's alpha of 0.61. For further analysis of the variable "energy affinity", we used the standardized factor score of the principal component analysis, calculated by the regression with a missing replacement by means.

For the homeowners' perception of the implementer index, we calculated the arithmetic mean of 11 variables, measuring to what extent the respondents attributed a positive characteristic (e.g., trustworthiness) to the body implementing the subsidies (see Appendix A). A principal component for the analysis revealed that all of the adjectives were loaded on a single factor with a Cronbach's alpha of 0.92. For further analysis of the variable "homeowners' perception of the implementer", we used the standardized factor score calculated by regression with missing replacement by means.

3.2. Reported Effectiveness of the Subsidies

Table 2 indicates that the effectiveness of the subsidies was hampered by the free-riding behaviour of nearly half of the subsidy recipients surveyed; 49.8% of the respondents did not report any effect of the subsidies on the renovation process, and therefore must be considered as free riders. On the other hand, 50.2% of the recipients reported that the subsidies influenced their decision to renovate and/or influenced them to choose a more energy-efficient renovation than initially intended.

Table 2. Description of the variables informing about the effectiveness of subsidies.

The Subsidies Contributed to . . .	**Frequency**	**Percent**
Decision to renovate (only)	17	2.9%
Increase in quality of renovation (only)	47	8.0%
Increase in scope of renovation (only)	25	4.3%
Decision to renovate and increase in quality	51	8.7%
Decision to renovate and increase in scope	7	1.2%
Increase in quality and in scope	47	8.0%
Decision to renovate and increase in quality and increase in scope	81	13.8%
Incomplete answers but at least one effect	20	3.4%
Total at least one effect = effectiveness beyond freeriding assured	*295*	50.2%
No effect = no effectiveness assured, free-riding behaviour	*293*	49.8%
Total	588	100.0%

The focus groups additionally showed that representatives of the construction planning and construction industry (facade constructors, architects, carpenters, engineers, building physicists, supplier companies, roofers and window manufacturers) played a crucial role in the homeowners' decision-making process. These representatives consulted participants of the focus groups much more often than public advice service providers. Many participants in the focus groups first heard about the possibility to apply for the subsidies from a representative of the construction planning or construction industry. Therefore, representatives of the construction and construction planning industry—but also neighbours, relatives and friends—have an important influence on renovation decisions and probably also on (non-)free-riding behaviour.

3.3. Factors Affecting the Effectiveness of Subsidies

To identify the factors affecting the effectiveness of subsidies, we conducted logit regression analyses. As dependent variable we used the binominal variable of "effectiveness of subsidies beyond freeriding", indicating whether the subsidies led to a more energy-efficient renovation than initially intended or not, as described in Section 2.1.1 and Table 2. Table 3 shows the results.

Table 3. Effects on the effectiveness of subsidies beyond free riding. EXP (B)—odds ratio. Sig.—significance level.

		Model 1		Model 2		Model 3	
Independent Variables		**Exp (B)**	**Sig.**	**Exp (B)**	**Sig.**	**Exp (B)**	**Sig.**
Sex	Male	0.78	0.32	0.82	0.41		
Age	Up to age 39 (reference category)		0.45		0.36		
	40–64	0.90	0.74	0.81	0.49		
	Older than 64	0.68	0.28	0.62	0.17		
Education	Apprenticeship (reference category)		0.08		0.09		
	Upper secondary education	1.00	0.99	1.06	0.82		
	University degree	0.62	0.06	0.65	0.08		
Location	Rural (reference category)		0.45		0.43		
	Agglomeration	0.83	0.59	0.87	0.68		
	Urban	0.58	0.21	0.59	0.20		
Federal entity	Centralized implementation of energy and construction law	1.00	0.99	0.91	0.75		
Energy affinity	Affinity for energy efficiency (standardized factor score)	1.02	0.88	1.08	0.43		
Acceptance of advice services	Not at all or rather not suitable (reference category)		0.27		0.22		
	Suitable to some extent	0.51	0.14	0.66	0.34		
	Very suitable	0.64	0.31	0.93	0.87		
Policy factors	Advice services	1.81	0.02			1.71	0.03
	Perception of the implementer index	1.72	0.00			1.72	0.00
	Df	13		11		2	
	−2Log Likelihood	565.52		595.93		578.37	
	Significance of omnibus test	0.00		0.23		0.00	
	McFadden R2	0.09		0.04		0.06	
	No. of observations	440		440		440	

Model 1 contained all of the independent variables discussed above. The significance level of the omnibus test indicated that the model is significantly more potent in explaining variations in the effectiveness of subsidies than a simple constant. Concerning each variable in particular, the sociodemographic variables and attitudinal variables did not have any significant explanatory effect on the effectiveness of the renovation subsidies. In contrast, the two policy factors were positively associated with the effectiveness of the subsidies; people who utilized advice services and who had a positive perception of the policy implementer were more likely to report that the subsidies contributed to a more energy-efficient renovation than initially intended. Thus, the advice services and the homeowners' perception of the implementer—variables that can be influenced by policy makers—had the potential to reduce free-riding behaviour in the context of building renovation.

In Model 2, the policy factors were excluded. Without the policy factors, the remaining variables did not significantly contribute to the explanation of the effectiveness of the subsidies beyond free riding (see the significance level of the omnibus test). Model 3 included the policy factors only and remained significant. Therefore, we can conclude that the sociodemographic background, location or general attitude towards energy policy did not reveal any explanatory power for the effectiveness of subsidies beyond freeriding. Instead, our findings supported the assumption that the (cost)

effectiveness of subsidies can be enhanced and therefore the free-riding behaviour can be reduced by advice services and by a positive perception of the policy implementer.

The number of respondents without any missing values on all of the variables considered in the main model (n = 440) is smaller than the initial sample (n = 588). This is partly due to the rather extensive questionnaire, which had to serve not only the purpose of this study, but also the additional data collection purposes of the cooperation partners involved in the data collection. We calculated several models, for example, excluding those variables with the most missing values (geographic location) and excluding/including respondents by calculating the variables of "homeowners' perception of the policy implementer" and "energy affinity" with and without a missing replacement by means. These alternative models produced similar results to those presented here, irrespective of the inclusion or exclusion of some cases with missing values (e.g., no change in the statistical significance or effect direction of the policy factors). The models including the index variables instead of the factor score variables for the perception of the implementer and energy affinity produced similar results (e.g., no change in statistical significance or effect direction of the policy factors). Furthermore, including an interaction term between the advice services and the acceptance of advice services did not lead to an improvement of the models.

Exp (B) illustrates the odds ratio. With respect to advice services, we can say that the odds of using subsidies to enhance the energy efficiency in the renovation endeavour of a person who benefited from an advice service is 81% higher than the odds of a person who did not benefit from an advice service. See Table A1 in Appendix C for marginal effects; with respect to advice services, we can say that the probability of using subsidies to enhance the energy efficiency in the renovation endeavour of a person who benefited from an advice service is 13% higher than the probability of a person who did not benefit from an advice service. (Because the perception of the implementer is an index variable (factor score), such a straight forward interpretation of the perception of the implementer variable is not possible).

The data from the focus groups provided some preliminary insights into how advice services support the renovation decision process, and thereby may reduce free-riding behaviour. Advice services support the cost-efficient sequencing of different renovation steps (e.g., insulation before heating replacement), reduce uncertainties concerning the subsidy application process and legal requirements (e.g., preservation order) and address anxieties concerning comfort (e.g., noise level and aesthetics) and harm to health (e.g., mildew) of energetic improvements in buildings. Furthermore, the participants demonstrated a strong consensus that the earlier in the renovation process advice services are provided, the more probably they have an effect on the renovation investment decision. To summarise, advice services play a crucial role in reducing the barriers in the renovation decision process.

To learn more about the characteristics of the advice services suitable for preventing free riding, we asked the focus group participants to describe the characteristics of ideal advice services. Prior to this question, those participants who made use of advice services reported on their experiences with the services, and those participants who did not utilize the advice services were asked why they had not. The participants were then asked to reflect on the characteristics of the energy advice services that had the potential to influence the renovation investment decision. The characteristics can be synthesized along the five dimensions shown in Table 4, namely: provision of facts, independence, integrity, clarity and personalization. Regarding the independence of the advice services provider, the participants were more interested in the person—not the organization—providing advice (e.g., none of the participants found the legal status of the advice services provider—private or public—to be important). Regarding the personalization dimension, participants expressed the expectation that the advice services provider disposes of both expertise and practical experience (of many different cases/solutions/procedures). Hence, the characteristics of ideal advice services indicated that besides specialist knowledge, communication competences played a key role in effective consulting for energy efficient renovations.

Table 4. Dimensions of ideal advice services as described by recipients of subsidies.

Dimension	Characteristics	Examples
Provision of facts	Information on materials, technological possibilities and innovations; interaction between different insulation measures and sequencing; potential difficulties and risks; costs (in relation to future savings); opportunities of subsidies; effectiveness of measures; implementation	"It was very instructive for me to hear that [in my case, with this specific material] an insulation of 8.5 cm of the cellar is enough; I would have done more [. . .] It is important that we can profit from such know-how . . . to learn that an insulation of the wall or the roof is more effective . . . " (FGa, 26:45)
Independence	Objective, neutral, independent from building companies, pointing out several options, holistic perspective on renovation (recommendations not restricted to energy-saving measures), "all-inclusive"	"I expect that they won't try to manipulate me: They should inform me objectively, they should provide me with several options, and they should stay neutral. They should not impose a certain solution on me, and they should be honest." (FGa, 22:12)
Integrity	Honest, fair, (cost-)transparent, does not omit risks	"Sometimes you cannot only put new insulation on the walls, because this can also cause damage. It is important that this is also mentioned." (FGd 56:50)
Clarity	Simple, comprehensible, low threshold (with "open doors"; "sexy"), concrete	"It should be at eye level [on equal terms], in a language that you can actually understand." (FGb, 20:45)
Personalization	Providing concrete examples, including onsite visit, case-specific, situation-specific, adapted to knowledge level, adapted to budget, concrete how-to-advice, recognizing concerns (e.g., mould formation)	"The situation—I mean the building physics—is important and also the level of knowledge of the building owner [. . .] when the advisors start with A and end with Z, I mean, I know about environmental science, I do not want to know why we should do it, I just want to know how I can do it." (FGc 52:50)

Regarding the second policy factor, the homeowners' perception of the policy implementer of the subsidies, the focus groups could not provide any relevant information because of a methodological limitation, namely: the focus groups' participants were recruited by the cantonal energy offices, which are very closely linked to the body implementing the subsidies. Therefore, we expected that social desirability issues would impede the participants in providing a balanced record of their positive and negative perceptions of the implementation bodies. Nevertheless, the focus groups illustrated dimensions of an ideal advice services provider (Table 4). Those dimensions correspond to the dimensions of the scales used to capture the homeowners' perception of the policy implementer (Appendix A), especially the characteristics of trustworthiness, transparency, customer orientation and implementation orientation. Thus, the focus groups and survey data suggest that a service provider (advice or subsidies) who is considered trustworthy, transparent, customer-oriented and implementation-oriented, is more likely to encourage homeowners to enhance the energy efficiency in their renovation endeavor.

4. Discussion

Based on our findings, we argue that free riding substantially reduces the effectiveness—more specifically, the cost effectiveness—of subsidies for building renovations (see Section 4.1). We encourage policy makers to reduce free-riding behavior by providing advice services and by investing in the social and communication competencies of energy advisors, as well as in the credibility of policy

implementation bodies (see Section 4.2). Furthermore, we discuss the limitations of the methods and implications for future research (see Section 4.3).

4.1. How Important Is Free Riding?

Free riding is important; 49.8% of the recipients of subsidies for building renovations report that the renovation subsidies did not affect their investment decision, neither their decision to renovate at all nor the decision to enhance the quality or scope of the renovation. Our study provides additional evidence to the findings by Grösche and Vance [19] (reporting free-riding behaviour amongst 50% of recipients, applying a willingness-to-pay analysis) and Rieder [20] (reporting free riding among 30% of recipients, applying a mixed method approach). It must be assumed that the cost effectiveness of subsidies for building renovations is substantially flawed by free riding. Further research is needed in order to quantify the cost of such free riding behaviour [17,51].

Nevertheless, it should also be considered that subsidies do not only aim at directly influencing individual homeowners, but also at influencing the industry (by so called spill over effects [13]). The subsidies are contingent on the fulfilment of certain quality standards and thereby may effect building material industry. In the case of Switzerland, for example, the quality standards for windows that are required in order to be able to apply for subsidies (U-value) led to a substantial increase in the market share of windows that meet these quality standards [52].

4.2. What Factors Reduce Free Riding in the Specific Context of Building Renovation Subsidies? How Can Free Riding Be Reduced by Policy Makers?

Our findings illustrate that advice services have the potential to reduce free-riding behaviour among the recipients of subsidies for building renovations. We therefore provide additional empirical evidence for the claim that information measures and financial measures interact in a complementary way and increase policy effectiveness [2]. Focus groups indicate that advice services support the cost-efficient sequencing of different renovation steps (e.g., insulation before heating replacement), reduce uncertainties concerning the subsidy application process and legal requirements (e.g., preservation order), and address anxieties concerning comfort (e.g., noise level and aesthetics) and harm to health (e.g., mildew) of energetic improvements in buildings. We recommend that policy makers ensure that financial incentive programs for building renovations are accompanied by advice services, also referring to literature demonstrating that advice services are comparably low cost policies [13] and not prone to hamper the effectiveness of other policies [2].

To influence the renovation investment decision in favour of energy efficient solutions, focus groups indicate that advice services providers should not only emphasize the transfer technical knowledge (content), but should also be transferring it in an independent, honest and clear manner, and providing personalized information (how the content is communicated). These preliminary qualitative findings indicate that not only the technical skills, but also the broader communication skills of advice services providers are important in order to encourage energy efficiency-enhancing building renovations. In addition, representatives of the construction and construction planning industry—but also neighbours, relatives and friends—have an important influence on renovation decisions and probably also on (non-)free-riding behaviour. This is in line with the argumentation of authors, who argue that building professionals are important intermediaries or "middle actors" for infrastructural changes [53–56]. Furthermore, participants of the focus groups emphasize that advice services are especially effective when they reach homeowners in the very early stages of the renovation decision process. This finding accords with other studies [17,28,57], for example, Pettifor et al.'s [57] suggestion to segment the target group of advice services according to the stage of the decision process that the target group is in (see also [40]). Further studies are needed in order to better understand what kind of advice services (from whom) are the most suitable in order to support more energy-efficient renovations in what stage of the renovation process [58,59] (Therefore, we elaborated a future research project in collaboration with our practitioner partners that aims at adjusting existing advice services

and developing new measures in order to better address different target groups, for example, owners of buildings that have not been renovated yet).

Our study furthermore indicates that subsidy recipients who have a positive perception of the body implementing these policy measures are less prone to free ride. We would argue that homeowners are more open to internalize the aims of an implementation body and to enhance their initial renovation plan accordingly when they "like" this implementation body. We measured the extent to which homeowners like the implementation body (the homeowners' perception of the implementation body) by several characteristics (e.g., trustworthiness and transparency) defined in a transdisciplinary process, taking the interests of the cooperation partners into account. Further research is needed to examine how these characteristics are related to the existing literature and theory, for example, to research about information processing [60–62]. We see a strong need for further interdisciplinary studies that focus on how information on policies and communication by policy implementers are processed by homeowners.

Regarding the individual characteristics of the subsidy recipients, our study did not reveal any significant relation between the effectiveness of the subsidies and sociodemographic factors, the location and attitudes about energy. The fact that the energy efficiency affinity level was not significantly related to free-riding behaviour is in line with the findings of Pettifor et al. ([57], p. 161), who conclude that "energy efficiency is of potential appeal to all renovators regardless of their attitudes about energy efficiency". The selection of the individual characteristics of the recipients in our study was guided by the pragmatic interests of the studies' cooperation partners (cantonal energy offices). They wanted to examine the characteristics of the recipients that are easy to identify and measure, so that they can serve target group segmentation purposes. As those characteristics did not significantly relate to the reduction of free riding in recipients, future studies should focus on other variables that have demonstrated explanatory power for household energy investments, for example, the perceived negative consequences of energy use (see [11]).

4.3. Limitations and Implications for Research

With the aim of gathering data about the homeowner's renovation investment decisions and free riding behaviour, we chose an ex-post self-reported survey design. The advantage of this design is that we can directly ask about the effects of the subsidies on the renovation investment decision, but there are also several drawbacks to this methodological approach. Firstly, ex-post evaluations can—strictly speaking—only examine coincidences, for example, the use of advice services and the decision to increase the energy efficiency level of the renovation, without knowing the temporal sequencing of the factors. Secondly, we acknowledge that self-reported measures for effectiveness tend to be "vulnerable to various cognitive biases (e.g., impression management and social desirability effects)" ([48], p. 149). The survey respondents were contacted based on the fact that they were in the database of the cantonal energy office, and were informed that the research was conducted by an independent institute, but in collaboration with the cantonal energy offices. That may make it plausible to assume that the social desirability effects were stronger than the need for impression management (to show independence from the implementer of the subsidies), and therefore one could expect an underestimation of the free riding effect. Thirdly, our approach is limited to qualitative statements with regard to the size of the free riding effect. We show that free riding occurs in 50% of recipients, but further research is needed in order to estimate the size of such free riding effects [17,51]. Fourthly, further research is required to capture the effect size of advice services and credible implementation bodies regarding the effectiveness of the renovation subsidies. Measuring and quantifying the effects of persuasive measures still remains a difficult task and needs further research design development [63]. With regard to the perception of the implementation bodies, our findings suggest that further research on the information processing of homeowners can be a promising approach to design effective policy measures [60–62]. Above all, future interdisciplinary research is encouraged in order to further integrate the psychological or behavioural economics mechanisms (e.g., see [2,64,65]) into the classical theorization of financial

incentives [66]. Finally, we do not know whether our sample contains any cultural-specific factor to the country (Switzerland) the survey was conducted in, which qualifies the generalizability of our findings. The extensive literature on similar issues and surveys in Germany [13,19,32,62,65] indicate at least some cross-border generalizability.

5. Conclusions

Our study adds to a differentiated view on how policy measures contribute to increased energy efficiency in building renovation, and therefore help to reduce CO_2 emissions. We provide evidence that advice services have the potential to reduce free riding behaviour, induce more energy efficient building renovations and therefore enhance the effectiveness—more specifically, the cost effectiveness—of subsidies. Moreover, one may argue that advice services help to avoid lock-in effects by inducing comprehensive renovation measures (at an early stage). Based on our findings, we recommend that policy makers accompany financial measures with persuasive measures. We furthermore show that a positive perception of the policy implementer is positively associated with the probability to utilize subsidies for enhancing the quality and/or scope of renovations. This may indicate that not only technical advice, but also the subjectively perceived credibility of the implementer contributes to increasing the effectiveness of subsidies. We therefore recommend investing in the capacity building of energy advisers and policy implementation bodies, especially in developing social competencies. These findings highlight the importance of interdisciplinary research when examining the effectiveness of persuasive and financial measures simultaneously, as well as the role of the policy implementer.

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Appendix A

Variables of the perception index:
Please indicate to what extent you attribute the following adjectives to the policy implementer. The [name of the policy implementation body] is . . . .

. . . committed, cooperative, customer-oriented, efficient, enthusiastic, friendly, helping, implementation-oriented, reliable, transparent, trustworthy.
Scale: *not . . . at all*, *rather not . . . , rather . . . , fully . . .*

Appendix B

Variables of the energy affinity index are as follows:
Please indicate to what extent you agree or disagree with the following statements:

- When buying new devices, I pay attention to their power consumption.
- I switch off the standby operation of electrical appliances in my household.

- When heating, I pay attention to a moderate room temperature.
- Whenever possible, I use public transport.

Scale: *I do not agree at all; I rather not agree; I rather agree; I fully agree*

Appendix C

Table A1. Marginal effects on the effectiveness of subsidies beyond free riding.

Independent Variables		Marginal Effects (dy/dx)	Std. Err.	z	$p > \|z\|$	95% Conf. Interval	
Sex	Male	−0.057	0.057	−1.00	0.32	−0.168	0.054
Age	Up to age 39 (reference category)						
	40–64	−0.023	0.070	−0.33	0.74	−0.160	0.114
	Older than 64	−0.088	0.081	−1.08	0.28	−0.247	0.071
Education	Apprenticeship (reference category)						
	Upper secondary education	0.001	0.058	0.02	0.99	−0.113	0.115
	University degree	−0.108	0.057	−1.88	0.06	−0.220	0.005
Location	Rural (reference category)						
	Agglomeration	0.043	0.079	−0.54	0.59	−1.98	0.113
	Urban	−0.122	0.095	−1.28	0.20	−0.310	0.065
Federal entity	Centralized implementation of energy and construction law	−0.001	0.074	−0.01	0.99	−1.45	0.144
Energy affinity	Affinity for energy efficiency (standardized factor score)	0.003	0.024	0.15	0.88	−0.043	0.050
Acceptance of advice services	Not at all or rather not suitable (reference category)						
	Suitable to some extent	−0.151	0.098	−1.54	0.12	−0.342	0.041
	Very suitable	−0.100	0.096	−1.04	0.30	−0.289	0.089
Policy factors	Advice services	0.134	0.058	2.30	0.02	0.020	0.249
	Perception of the implementer index	0.123	0.024	5.14	0.00	0.076	0.170

Note: dy/dx for factor levels is the discrete change from the base level.

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