Energy Research & Social Science 78 (2021) 102154

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Maybe tomorrow: How burdens and biases impede energy-efficiency investments

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ARTICLE INFO

Keywords:
Administrative burden
Sludge
Transaction costs
Energy-efficiency
Present bias
Behavioural economics

ABSTRACT

Investments in energy-efficient technologies can save money over time and reduce environmental impacts. Accordingly, governments worldwide provide grants to encourage household investments in clean, energy-efficient technologies at scale. Although many households state intentions to avail of these grants and to invest in energy-efficient technologies, uptake of the grants is low. This perspective suggests that administrative burden is one major reason for the low levels of economically beneficial investments. Using a theoretical model, and a simulation with building energy data, we illustrate that administrative burden can strongly reduce investments in energy-efficient technologies if present-biased preferences lead people to procrastinate over completing the administrative tasks. We discuss the implications of these findings for the design of governments grants and recommend the reallocation of resources from grants to measures that explicitly reduce administrative burden to increase the effectiveness of these government policies.

1. Introduction

Cost-benefit analyses have consistently shown that various domestic energy-efficiency technologies provide a high internal rate of return and are socially beneficial [1–3]. Nevertheless, studies also find that many households do not invest in energy-efficient technologies. Three reasons for this energy-efficiency gap have been suggested [2,4–11]. First, market failures can create a divergence between private and social net benefits of energy-efficient retrofits.[1] Second, measurement errors might have led to an overestimation of the gap's actual size.[2] Finally, investment inefficiencies and behavioural factors, such as imperfect information, uncertainty about the benefits of the investments, and decision-making biases, may have resulted in energy-efficiency gaps. There is a growing literature on these decision-making biases suggesting that present bias, bounded rationality, loss aversion, status-quo bias, risk aversion, inattentiveness, energy and investment illiteracy, and other behavioural biases might lead to fewer investments in energy efficient technologies [12–17]. Our objective is to contribute to this literature.

The focus of this perspective is on the effects of administrative burden, which is an investment inefficiency that is frequently discussed in the public administration literature [18,19]. This literature distinguishes between search costs, compliance costs, and psychological costs as the three sub-components of administrative burden [20]. Administrative burden is also receiving more and more attention from behavioural scientists who use the phrase "sludge" to describe excessive or unjustified frictions such as administrative burden [21,22]. A recent paper specifies how administrative burden and sludge are related [23] and another paper links sludge with transaction costs and suggests

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[1] Key market failures discussed in the literature are the presence of externalities, whereby the private household may not benefit to the same extent as society from reduced emissions as a result of the deployment of the technologies; principal-agent issues, such as, where households may not have the property rights or tenure to make the investments possible or financially attractive; differentials between the private costs of capital and the social rate of discount such that investments are less attractive in a private financial analysis in comparison to a social benefit-cost analysis; consumer heterogeneity and distributional issues, for example, energy-poor households most in need of retrofits tend to be less able to finance such investments; and rebound effects whereby cost-benefit analyses sometimes overestimate the reduction in demand for energy (and, consequently, emissions), for example, by ignoring comfort benefits that may be traded off against energy savings [8,60].

[2] For example, recent research [61] evaluates a large residential energy-efficiency program and shows that the upfront investment costs of that program are about twice the actual energy savings and that the model-projected savings are more than three times the actual savings.

https://doi.org/10.1016/j.erss.2021.102154
Received 22 March 2021; Received in revised form 2 June 2021; Accepted 4 June 2021
Available online 15 June 2021

defining sludge as aspects of the choice architecture that lead to the experience of costs [24]. The same paper also distinguishes between four types of costs that can result from sludge: search costs, evaluation costs, implementation costs, and psychological costs.

These four types of sludge-induced costs might also explain the energy-efficiency gap, why some households abandon their grant applications midway [25], or abandon the entire process of investing in energy-efficient technologies. For example, search costs are present when it is unnecessarily complicated to find reliable information about financial grants and when finding the right contractors is cumbersome. Evaluation costs are present when it is difficult to evaluate the probability of success when applying for government grants and when there are many different technologies to choose from. Implementation costs arise once a previously-made decision to apply for a government grant to invest in a new technology needs to be implemented. These costs include the costs related to organising assessment visits and organising the paperwork for the grant and the contractors which can be a hassle. Finally, psychological costs include potential frustration and other emotions that can be present when one's home and life is disrupted by on-site contractors. Overall, perceived hassle can be a psychological barrier to a green home [26], and perceived bureaucratic and administrative barriers in this context can result in fewer investments in energy-efficient technologies [27,28].

Behavioural scientists argue that administrative burden and sludge can have particularly strong effects on behaviour when people are unrealistically optimistic, overwhelmed by too many choice options, influenced by reduced cognitive functioning due to a "scarcity mindset", limited in their available attention, prone to inertia, present-biased, or show other deviations from rationality identified in the behavioural sciences [20,21,29,30]. For example, one study shows that, although many people optimistically anticipate that they would redeem a mail-in rebate, actual redemption rates are low, which could be explained by a high paperwork burden [31]. Another study finds that reducing administrative burden, in the form of complexity and uncertainty in college pricing, increases application and enrolment rates of low-income students, which the authors explain by the presence of behavioural biases such as loss aversion and present bias [32].

In this paper, we focus on present bias as one particular bias identified in the behavioural sciences that can interact with administrative burden and sludge to impede energy-efficiency investments. Present bias describes people's tendency to myopically overvalue the immediate short-term costs as compared to the long-term gains [33,34]. Present bias is strongest when people make decisions about spending effort as shown in a literature suggesting that present bias over effort is stronger than present bias over money [35–37]. While recent studies seem to suggest that present bias over money does not play a role in energy-efficiency investments [26–28], this has not been shown for present bias over effort.

As a result of present bias over effort, people often prefer to postpone effortful tasks into the future [35,36]. For example, people procrastinate on going to the gym [38], searching for jobs when unemployed [39], and saving for retirement [34] despite these decisions having adverse long-run consequences. There is, therefore, reason to predict that people may be present-biased when it comes to investing in energy-efficiency technologies as well [15,40]. Present bias can lead to substantial procrastination when people are not aware of their present bias [41], and most of the literature assumes that people are, indeed, not aware of their present bias [e.g., 36,37]. Due to present bias, the short-term effort costs that result from sludge and administrative burden (e.g., when paperwork is unnecessarily complicated) may become a critical barrier to energy-efficiency investments.

To illustrate the potential effects of administrative burden and sludge in the presence of present-bias over effort, this paper presents a simple model that separates the decision to invest in energy-efficiency technologies into two sub-components. First, households engage in an analysis of the monetary costs and benefits of the investment and decide to invest or not to invest (in other words, they establish an *intention*). Second, if they have decided to invest, households decide about *when* to complete the administrative paperwork for the investment, i.e., when to bear the upfront costs that arise partly due to sludge and administrative burden (in other words, they *behave* in line with their intention). Present-biased households are particularly likely to prefer to postpone administrative tasks from today to tomorrow. In the extreme, this tendency to procrastinate can lead to intention-behaviour gaps where households never make the investment despite having intentions to do so.

We then present the results of a calculation of the potential real-world effect of administrative burden by calibrating the model with common parameter assumptions for present bias and using data on the Irish housing stock for a specific energy-savings technology: Air Source Heat Pumps (ASHPs). We chose ASHPs as they are an important retrofit technology in the context of climate policy and the electrification of the heating sector. ASHPs can reduce emissions, improve comfort, health, and air quality, and provide substantial energy savings to the household [42,43]. Improved indoor warmth and air quality can reduce excess winter morbidity and mortality and reduce energy poverty [44–46]. Reducing solid fuel use for home heating also offers the potential to reduce aggregate emissions of NO_X, CO_2, and particulates in the built environment sector [47–49]. As such, ASHPs are an important element of many climate and air related strategies to reduce emissions.

The calibration of the model allows for the prediction of the share of households that will invest in ASHPs under different assumptions about householders' present bias and the size of the administrative burden. We use the model to predict the effects of policies, such as financial grants, on this share of households, assuming that households are present-biased and prefer completing paperwork tomorrow over completing it today. A key result of this simulation is that reducing administrative burden can be a more effective policy as compared to increasing financial incentives in the form of retrofit grants.

The perspective makes a conceptual contribution to the literature illustrating the importance of formally and, in so far as possible, quantitatively considering administrative burden when designing government schemes such as financial grant provisions. We note, however, that the illustrative model and the simulation should not be taken at face value because the model is simplified and some parameter estimates in the simulation are not measured in the target population but simply assumed based on the relevant literature. The paper's quantitative predictions of the effectiveness of different types of grant designs should, thus, be interpreted as suggestions, and future quantitative research is needed. However, our calibration suggests that when individuals are present-biased (and there is good evidence to suggest they are), administrative burden and sludge can have massive effects. This suggests that whilst administrative burden is often recognised in policy design, the scale of its impact on reducing new energy-efficient technology uptake does not seem adequately recognised in terms of the design of those supports that seek to accelerate technology uptake as an essential avenue to achieving the significant energy and emissions reductions required to achieve ambitious climate and energy policy targets. While there is a growing literature on the use of behavioural insights, including nudge-techniques, to change energy behaviour in the home [50], this perspective suggests the need to focus more on the reduction of administrative burden and sludge in future research and policy design. Similarly, the paper highlights the importance of integrating behavioural factors, such as present bias, when analysing decisions to invest in energy-efficient technologies.

The remainder of this paper is structured as follows: Section 2 presents our theoretical model, section 3 presents the simulation and its results, and section 4 discusses the model and its implications for policymaking. The last section concludes and suggests avenues for future research. The Supplementary Information includes more details on the theoretical framework and the calculations needed for the simulation.

2. Theoretical framework

This section sketches a theoretical model to illustrate the effects that administrative burden can have on investments in energy-efficient technology when people are present-biased over effort and thus tend to procrastinate. We make several assumptions and simplifications that are necessary to calibrate the model in the next section with building energy report data. For example, we abstract from liquidity constraints, taxes, other investment opportunities, heterogeneity in preferences and biases, uncertainty, etc., and assume a lack of self-awareness about present bias to keep the perspective manageable and its message focused. Whilst section 3 illustrates the decision to invest in one particular energy-savings product, air source heat pumps, the model sketched in this section generalises to the uptake of any energy-efficient technologies that require households initially to expend some effort to make the investment happen. The model is informed by recent formal models [37,42,51].

2.1. Decision 1: The intention to invest

In the model, we assume that households need to make two sequential decisions that might, or might not, lead to an investment in an energy-efficient technology. First, households decide whether to make an investment in an energy-efficient technology (they form an *intention*). When making this decision, they think in terms of years and disregard costs related to sludge and administrative burden. We view the decision to invest in an energy-efficient technology as a binary decision and assume that households establish an intention to invest in the present if the present value of the savings, which can be obtained from period $t = 1$ until period T, is higher than the initial capital costs. This can be formalised as the decision rule:

Decision 1: Invest if

$$\delta s_A \frac{1-\delta^{T}}{1-\delta} > (C-G), \tag{1}$$

for exponential discount factors $\delta \neq 1$. In equation (1), s_A describes the annual savings from the energy-efficient technology, T the planning horizon, C the initial capital costs of the investment, and G the government grant available for the technology. The term $\delta s_A \frac{1-\delta^{T}}{1-\delta}$ represents the present value of the savings from the investment from $t = 1$ until T. If equation (1) holds, it is worth it for the households to invest in the energy-efficient technology immediately, which we interpret as forming the intention to invest. The Supplementary Information derives Eq. (1) and makes underlying assumptions explicit.

2.2. Decision 2: Arranging the investment today

Once households have formed the intention to invest in an energy-efficient technology, they need to decide *when* to start making the necessary arrangements for the investment (they have to *behave* in line with their intention). When making this second decision, households think in terms of days and explicitly consider the costs related to administrative burden. We assume that the relevant time-period for this decision is not a year as it was in the first decision, but, rather, a day.[3] Hence, households must decide on which day they want to make the arrangements, i.e., on which day they want to 'pay' the costs related to wading through the paperwork, phone calls, and other administrative burden.

As described in more detail in the Supplementary Information, we can summarise the decision-rule of present-biased households who are not aware of their present bias regarding dealing with the initial administrative work today or postponing the work to the future as:

Decision 2: Make the arrangements today if the present value of making the arrangement today is higher than the present value of making the arrangement tomorrow. Otherwise never make the investment. As shown in the Supplementary Information, this can be represented formally by: Arrange the investment today if

$$-\xi - \delta_D (C-G) + \delta_D^2 s_D > -\beta \delta_D \xi - \delta_D^2 (C-G), \tag{2}$$

where ξ is the costs related to the administrative burden, δ_D the daily discount factor, C the initial capital costs, G the government grant, s_D the daily savings from investing in the air source heat pump, and $\beta (\leq 1)$ the present bias parameter assuming quasi-hyperbolic discounting over effort [33,35].[4]

To understand the intuition of equation (2), assume that $\delta_D = 1$ so that equation (2) simplifies to $s_D > \xi(1-\beta)$. This suggest that households arrange the investment today if the daily savings are larger than the costs related to administrative burden multiplied by $(1-\beta)$. If households are not present-biased ($\beta = 1$), households will always arrange the investment today (if daily savings are positive). However, the stronger present bias becomes (the smaller β gets), the higher the daily savings need to be for households to administer the investment today over tomorrow. For example, with a common present bias parameter ($\beta = 0.9$), and administrative costs (ξ) of €100, the household would need to save €10 daily to make the investment.

This simple model illustrates the importance of present bias in situations where initial administrative tasks are perceived as burdens. Present-biased households who are not aware of their future present bias weight the costs of having to deal with the administration today higher than the costs of having to deal with them tomorrow and hence require higher compensation for completing the tasks in the present. As a result, they are more likely to prefer postponing the arrangements to invest to the future.

3. Simulation

Rather than analytically deriving for which parameter values both Eqs. (1) and (2) hold so that households invest in the new technology, we calibrate the model using Irish housing stock data. Since some of the values needed for this simulation are technology-specific, we focus on a specific energy-efficient technology, an air source heat pump (ASHP). In the simulation, we predict the number of households that invest in an ASHP by calculating the households for which Eqs. (1) and (2) hold. Several calculations and assumptions are necessary to identify the values for the variables in both equations. Below we mention the most relevant calculations and assumptions and the Supplementary Information provides all details.

3.1. Main calculations and assumptions

To calculate the savings potentials from the air source heat pumps,

[3] We could equally specify a week or a month as the temporal unit for the second decision. The results would not change but we would calibrate the model differently.

[4] In the quasi-hyperbolic discounting model [33], the discount function $D(\tau)$, with τ indicating the delay after which outcomes are realized, can be written as: $D(\tau) = \begin{cases} 1 if \tau = 0 \\ \beta\delta^{\tau} if \tau > 0, \end{cases}$ where β and δ are two discount factors. δ (usually ≤ 1) is a measure of impatience that is constant. The parameter β reflects present bias (if it is below one). Everything that does not happen in the present is once multiplied by β so that immediate costs and benefits are given more weight compared to future costs and benefits. The smaller β is, the stronger the present bias. Present-biased individuals are relatively patient when they make intertemporal decisions involving only future options (e.g., when deciding to go to the gym *tomorrow*), but relatively impatient or impulsive when they make intertemporal decisions involving some costs or benefits in the present (e.g., when deciding to go to the gym *right now*).

we follow the approach described in previous research on ASHPs [42] and use data on the Irish Building Energy Ratings (BER) managed by the Sustainable Energy Authority of Ireland [52,53]. The BER dataset, as accessed in March 2021, included 949,064 records of homes inspected since January 2009. We analyse a subset of 376,417 households for which the ASHP investment is likely particularly beneficial. Specifically, we focus on houses currently heating with oil as these homes are a focus of current government policy for ASHPs. To calculate the initial costs of the ASHP (ranging from €8700 to €9800), we calculate the maximum heat required for each household (ranging from 8 kW to 16 kW) and assume prices for different sizes of ASHPs in line with those used in previous research [42].[5] We set the lifetime of these appliances at 20 years.

The simulations assume several different values for the size of the administrative costs (up to €50). This corresponds to the amount of time spent on the first day to start the process. We assume that this might take about 2 h on the first day and value these two hours at the rate of average hourly earnings in Ireland (€22.94 based on 2016 data from the Central Statistics Office Ireland, 2018). We simulate the model using three different present-bias parameters (0.7, 0.9, and 0.99). This is in line with a literature that aims to measure present bias either indirectly, by estimating structural models using secondary datasets, or in surveys and experiments directly [37,54]. The most relevant papers measure present bias over effort [35,38,39], and find present bias parameters varying between 0.7 [38] and 0.9 [35,36,39].[6] For the annual exponential discounting factor, we assume the value of 0.99, which is a common assumption in calibrations of the quasi-hyperbolic inter-temporal choice model.

3.2. Results

The results of the simulations are summarised in Table 1. Column (1) assumes that there are no costs related to administrative burden. The simulation predicts that in the absence of administrative burden and with no government funding about 69% of the households in our dataset (or 246,239 households) can benefit from the investment. This number reflects our estimate for the potential market for ASHPs in our sample. Moreover, in the scenario without administrative costs described in column (1), government grants are relatively effective policies. For example, a grant of €5.500 increases the number of households the model predicts to benefit from the investment to 353,273 (or 97%).

Columns (2) to (6) of Table 1 present the share of households the model predicts to invest in the ASHP for different values of the grant and different positive values of administrative costs. For example, for column (6) the administrative costs are set to $\xi = €50$ and the model predicts that only 28,024 households (or 7%) would invest in the ASHP without any government support. This number increases to 39,215 (or 10%) when the government support is increased to €5.500. As such, the grant is much less efficient in this scenario. Table 1 suggests that reallocating grant money to reduce the costs related to administrative burden can therefore be a particularly efficient policy.

Fig. 1 presents the results of further sensitivity analyses of these predictions to modifications of parameter assumptions about β. Fig. 1, panel A replicates the data presented in Table 1. Panel B assumes that there is very weak present bias of $\beta = 0.99$. It shows that different assumptions about administrative costs do not matter much. Administrative costs are only relevant when people are present-biased and prone to procrastination. Panel C assumes very strong present bias of $\beta = 0.7$. It shows that even fewer households invest in the ASHP if at least some administrative costs are present. Comparing the three panels illustrates that assumptions about present bias do not change the number of households investing if there are no administrative costs (as represented by the solid black line). As such, to test empirically the role played by present bias for the association between administrative burden and the uptake of energy-efficient technology, one would include present bias as a moderator in the analysis.

4. Discussion

4.1. Main argument: Administrative costs can reduce investments in energy-efficient technology if people are present-biased

This paper suggests that administrative costs (referred to as administrative burden, sludge, or transaction costs) can have strong and negative effects on investments in energy-efficiency technologies. When decision-makers in households are present-biased, and tend to procrastinate (i.e., they repeatedly prefer the effort tomorrow over the effort today), they might never invest in energy-efficient technology despite their awareness of the personal economic and even the wider societal benefits of these investments. The paper illustrates the role of administrative costs using a simple formal model and a simulation, which show that government policies might be much improved by reallocating some money from financial grants towards the reduction of administrative burden.

4.2. Realism and validity of the model and the simulations

To what extent do the model and the simulation reflect real-world decisions to invest in air source heat pumps (ASHPs)? First, there is a substantial amount of evidence for the relevance of administrative hassles when it comes to retrofitting one's home and investing in energy-efficient technology [27,28,55]. Moreover, psychological research highlights the importance of the intention-behaviour gap [56], and the model presented here provides one explanation for this gap. While the paper's simulation focuses on the role of administrative burden and procrastination for investments in ASHPs, the model's logic applies more broadly for analysing many decisions with upfront hassle costs and later saving potentials, e.g., fabric retrofit of a home, or investments in solar PV [57]. Thus, the paper contributes to the literature by highlighting the importance of formally considering administrative burden when analysing decisions to invest in all energy-efficient technologies. While there is a growing literature on the behavioural determinants of energy-efficiency investments,[7] comparatively little behavioural-change research deals with technology adoption, and even less so in the field of heat consumption [50].

Second, the model assumes that many households are actively deciding about whether to invest in a new heating technology. The most common trigger for such a decision is when the old technology breaks down (e.g., when the old heating boiler stops working). The model can accommodate this situation when assuming that more administrative burden is involved in arranging a new heating system rather than just purchasing a new version of the heating system that is already installed. Moreover, the current policy climate in many countries suggests another, policy-induced, trigger to consider investments in energy-

[5] The ASHP grants are not given to homes that do not meet certain home insulation requirements so that some fabric retrofitting may be needed before availing of the grants. Fabric retrofit involves improving the energy efficiency of a building by enhancing the building fabric through, for example, thermal insulation upgrades, reducing air leakages, and fixing or replacing windows. The model we propose could easily incorporate these higher initial costs and higher long term energy savings.

[6] There are a few studies on the links between time preferences and energy-efficiency upgrades or the adoption of energy-efficient technologies [15,62]. However, these studies measure time preferences in the financial domain, which can be quite different from time preferences over effort.

[7] For example, present bias, bounded rationality, loss aversion, status-quo bias, risk aversion, inattentiveness, and energy and investment literacy might lead to fewer investments in energy efficient technologies [12–17].

Table 1
Model predictions for the percentage of households from our sample that invest in the air source heat pump for different grants (G) and costs related to administrative burden (ξ).

	(1)	(2)	(3)	(4)	(5)	(6)
Grant(in €)	% Benefitting($\xi = 0$)	% Investing($\xi = 10$)	% Investing($\xi = 20$)	% Investing($\xi = 30$)	% Investing($\xi = 40$)	% Investing($\xi = 50$)
0	69	62	36	20	12	7
500	71	64	37	21	12	8
1.000	74	65	39	21	12	8
1.500	77	67	41	22	13	8
2.000	80	69	42	23	13	8
2.500	83	71	44	24	14	9
3.000	85	72	46	25	14	9
3.500	88	74	48	26	15	9
4.000	91	76	50	27	16	9
4.500	94	78	52	29	16	10
5.000	96	79	54	30	17	10
5.500	97	81	55	31	17	10

Assumptions: $\beta = 0.9$, $\delta = 0.95$, $T = 20$.

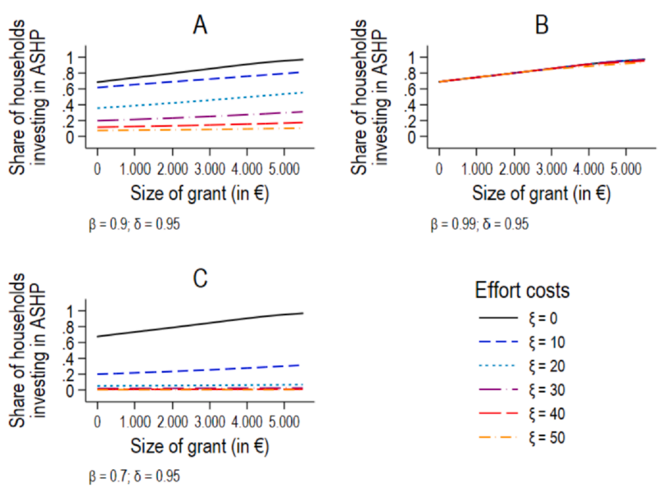

Fig. 1. Share of households the simulation predicts to invest in the Air Source Heat Pump (ASHP) for different levels of present bias (across the panels) and different levels of grants and effort costs (within each panel).

efficient technologies. There are ambitious policy targets for fast investments in energy-efficiency all over the world,[8] and, to reach these targets, governments are actively encouraging householders, with carrots (e.g., grants) and sticks (e.g., the carbon tax), to consider investments in their houses. This is triggering households to make decisions about investing in energy-efficient heating solutions. Understanding the best ways for governments to trigger, influence, and enable decisions about investing in new energy-efficient heating systems is, thus, essential for policy.

Third, any model is a simplification of reality, and we have made many simplifying assumptions. For example, the model focusses on present bias only, and ignores other behavioural factors (such as other non-standard preferences, non-standard beliefs, and non-standard decision-making) that can prevent households from investing in energy-efficient technology [50]. Moreover, we assume some parameters (e.g., for present bias and for costs related to administrative burden) without being able to rely on existing data on whether these parameters reflect true parameters in the sample we used in the calibration. We also assume that householders are not aware of their present bias, i.e., that they are naïve. This assumption is commonly made and considered a good starting point for analyses such as ours [36,37]. There is supporting experimental evidence of naiveté about present bias over effort [23] suggesting that naiveté is a sensible approximation. Additionally, evidence of procrastination, inertia effects, overconfidence, and lack of demand for commitment devices suggests that people are not aware of their present bias [51]. It would also be possible to formalise the technical assessment that is needed in many countries to make homes "heat-pump ready" before government grants are given, but this would not lead to new insights on the role of administrative burden and present bias for these investments.

4.3. Policy implications

The paper suggests that ignoring behavioural aspects of how households make decisions (e.g., the tendency to procrastinate over making the effort now to arrange an investment) can lead to mistaken predictions of the effectiveness of government policies. Governments who disregard the existence of these behavioural insights may be too optimistic about the effectiveness of financial grants in encouraging investments in energy-efficient technology. The paper also suggests that situations may exist where governmental resources are better spent on reductions of the costs related to administrative burden than on simply giving out higher value grants. Reducing behavioural barriers might be a more effective policy than adding further monetary incentives. This suggestion follows from the high sensitivity of investment behaviour to the size of the administrative costs in our model and simulations, which is in line with other research [26]. To reduce administrative costs, the behavioural literature suggests at least four broad principles: "make it easy", "make it attractive", "make it social", and "make it timely" [58]. Based on these principles, as well as audits of the administrative processes involved [21,24], a re-design of the processes through choice simplification, changing the temporal and spatial structure of costs and benefits, or rehearsal of conscious behavioural cues [50] have the potential to be very effective.

5. Conclusion and future research

This paper suggests a need for empirical studies to quantify the effects of administrative costs for investments in energy-efficient technologies. Field experiments could compare, for example, the uptake of green grants across different treatments with varying administrative costs. Data from these studies can then be used to compare the cost-

[8] For example, the Irish Government has published a Climate Action Plan that indicates a clear ambition for a transformative shift in energy performance and heating systems for Irish homes. Specifically, it calls for 600,000 heat pumps to be installed by 2030. This ambitious goal includes 200,000 installations in new build homes and 400,000 installations as retrofits into the existing stock. Furthermore, the Irish Government has established a carbon tax that affects residential home heating costs, and which will rise threefold from €33.50 in 2021 to €100 per tonne by 2030.

effectiveness of interventions that reduce administrative costs as compared to various levels of financial grants. These studies should also measure individual differences, such as the strength of present bias, as a new way of behavioural targeting where homes are not only approached based on where grant provider surplus can be maximized [59], but also where those people live who might be willing and able to invest as identified by large-scale surveys or structural estimation exercises of behavioural factors such as present bias. Most generally, the paper suggests that it is particularly important to formally consider behavioural variables, such as present bias, when predicting the effectiveness of different policy support options to drive technology adoption. In an era where there is a clear imperative for substantial and rapid technological change, driven largely by the urgency of environmental action, the importance of accelerating the adoption of energy-efficient investments needs all the help it can get.

Funding

This research has been supported by a grant from the Irish Environmental Protection Agency (Project name: Enabling Transition; Project number: 2017-CCRP-FS.32) and by the Department of Environment, Climate and Communications (DECC). The opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of funders.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We like to thank Karen Arulsamy, Michael Hanemann, Tensay Meles, Diane Pelly, Karl Purcell, Lisa Ryan, Sina Shahab, Margaret Samahita, Till Weber, the participants at the UCD Behavioural Science and Policy Seminar, and the participants at the 24th Annual Conference of the EAERE in Manchester, 26-29 June 2019, and the participants at the UCD Energy Institute seminar for helpful comments.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2021.102154.

References

[1] R. Chapman, P. Howden-Chapman, H. Viggers, D. O'Dea, M. Kennedy, Retrofitting houses with insulation: A cost–benefit analysis of a randomised community trial, J. Epidemiol. Community Health. 63 (4) (2009) 271–277, https://doi.org/10.1136/jech.2007.070037.
[2] J.P. Clinch, J.D. Healy, Cost-benefit analysis of domestic energy efficiency, Energy Policy. 29 (2) (2001) 113–124.
[3] P. Webber, A. Gouldson, N. Kerr, The impacts of household retrofit and domestic energy efficiency schemes: A large scale, ex post evaluation, Energy Policy 84 (2015) 35–43, https://doi.org/10.1016/j.enpol.2015.04.020.
[4] H. Allcott, M. Greenstone, Is there an energy efficiency gap? J. Econ. Perspect. 26 (1) (2012) 3–28.
[5] J.P. Clinch, J.D. Healy, Domestic energy efficiency in Ireland: correcting market failure, Energy Policy 28 (1) (2000) 1–8, https://doi.org/10.1016/S0301-4215(99)00080-4.
[6] T.D. Gerarden, R.G. Newell, R.N. Stavins, Assessing the Energy-Efficiency Gap, J. Econ. Lit. 55 (4) (2017) 1486–1525, https://doi.org/10.1257/jel.20161360.
[7] K. Gillingham, R.G. Newell, K. Palmer, Energy efficiency economics and policy, Annu. Rev. Resour. Econ. 1 (1) (2009) 597–620, https://doi.org/10.1146/annurev.resource:102308.124234.
[8] K. Gillingham, K. Palmer, Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence, Rev. Environ. Econ. Policy. 8 (1) (2014) 18–38, https://doi.org/10.1093/reep/ret021.
[9] A.B. Jaffe, R.N. Stavins, The energy-efficiency gap What does it mean? Energy Policy 22 (10) (1994) 804–810, https://doi.org/10.1016/0301-4215(94)90138-4.
[10] S. Sorrell, E. O'Malley, The economics of energy efficiency, Books (2004).
[11] K. Anderson, M. Nevrly, E. Elgqvist, M. Bazilian, Optimality versus reality: Closing the gap between renewable energy decision models and government deployment in the United States, Energy Res. Soc. Sci. 76 (2021) 102061, https://doi.org/10.1016/j.erss.2021.102061.
[12] J. Blasch, N. Boogen, M. Filippini, N. Kumar, Explaining electricity demand and the role of energy and investment literacy on end-use efficiency of Swiss households, Energy Econ. 68 (2017) 89–102, https://doi.org/10.1016/j.eneco.2017.12.004.
[13] J. Blasch, M. Filippini, N. Kumar, Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances, Resour. Energy Econ. 56 (2019) 39–58, https://doi.org/10.1016/j.reseneeco.2017.06.001.
[14] E.R. Frederiks, K. Stenner, E.V. Hobman, Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour, Renew. Sustain. Energy Rev. 41 (2015) 1385–1394, https://doi.org/10.1016/j.rser.2014.09.026.
[15] F. Fuerst, R. Singh, How present bias forestalls energy efficiency upgrades: A study of household appliance purchases in India, J. Clean. Prod. 186 (2018) 558–569, https://doi.org/10.1016/j.jclepro.2018.03.100.
[16] G. Heutel, Prospect theory and energy efficiency, J. Environ. Econ. Manag. 96 (2019) 236–254, https://doi.org/10.1016/j.jeem.2019.06.005.
[17] M. Stadelmann, Mind the gap? Critically reviewing the energy efficiency gap with empirical evidence, Energy Res. Soc. Sci. 27 (2017) 117–128, https://doi.org/10.1016/j.erss.2017.03.006.
[18] B.C. Burden, D.T. Canon, K.R. Mayer, D.P. Moynihan, The effect of administrative burden on bureaucratic perception of policies: Evidence from election administration, Public Adm. Rev. 72 (5) (2012) 741–751, https://doi.org/10.1111/puar.2012.72.issue-510.1111/j.1540-6210.2012.02600.x.
[19] P. Herd, D.P. Moynihan, Administrative Burden: Policymaking by Other Means, 1 edition, Russell Sage Foundation, New York, 2019.
[20] D. Moynihan, P. Herd, H. Harvey, Administrative burden: Learning, psychological, and compliance costs in citizen-state interactions, J. Public Adm. Res. Theory. 25 (1) (2015) 43–69, https://doi.org/10.1093/jopart/muu009.
[21] C.R. Sunstein, Sludge audits, Behav. Public Policy (2020) 1–20, https://doi.org/10.1017/bpp.2019.32.
[22] R.H. Thaler, Nudge, not sludge, Science. 361 (2018) 431–431.
[23] J.K. Madsen, K.S. Mikkelsen, D.P. Moynihan, Burdens, sludge, ordeals, red tape, Oh My!: A user's guide to the study of frictions, Public Adm. n/a (2021), https://doi.org/10.1111/padm.12717.
[24] S. Shahab, L.K. Lades, Sludge and transaction costs, Behav. Public Policy (2021) 1–22, https://doi.org/10.1017/bpp.2021.12.
[25] M. Collins, J. Curtis, An examination of the abandonment of applications for energy efficiency retrofit grants in Ireland, Energy Policy 100 (2017) 260–270, https://doi.org/10.1016/j.enpol.2016.10.030.
[26] G. de Vries, M. Rietkerk, R. Kooger, The hassle factor as a psychological barrier to a green home, J. Consum. Policy. 43 (2) (2020) 345–352, https://doi.org/10.1007/s10603-019-09410-7.
[27] N. Murtagh, A.M. Owen, K. Simpson, What motivates building repair-maintenance practitioners to include or avoid energy efficiency measures? Evidence from three studies in the United Kingdom, Energy Res. Soc. Sci. 73 (2021) 101943, https://doi.org/10.1016/j.erss.2021.101943.
[28] M.E. Biresselioglu, M.H. Demir, M. Demirbag Kaplan, B. Solak, Individuals, collectives, and energy transition: Analysing the motivators and barriers of European decarbonisation, Energy Res Soc. Sci. 66 (2020) 101493, https://doi.org/10.1016/j.erss.2020.101493.
[29] C.R. Sunstein (Ed.), On Freedom, Princeton University Press, 2019.
[30] J. Christensen, L. Aarøe, M. Baekgaard, P. Herd, D.P. Moynihan, Human capital and administrative burden: The role of cognitive resources in citizen-state interactions, Public Adm. Rev. 80 (2020) 127–136.
[31] J. Tasoff, R. Letzler, Everyone believes in redemption: Nudges and overoptimism in costly task completion, J. Econ. Behav. Organ. 107 (2014) 107–122, https://doi.org/10.1016/j.jebo.2014.08.011.
[32] S. Dynarski, C.J. Libassi, K. Michelmore, S. Owen, Closing the gap: The effect of reducing complexity and uncertainty in college pricing on the choices of low-income students, Am. Econ. Rev. 111 (6) (2021) 1721–1756, https://doi.org/10.1257/aer.20200451.
[33] D. Laibson, Golden eggs and hyperbolic discounting, Q. J. Econ. 112 (2) (1997) 443–478.
[34] T. O'Donoghue, M. Rabin, Present bias: Lessons learned and to be learned, Am. Econ. Rev. 105 (2015) 273–279.
[35] N. Augenblick, M. Niederle, C. Sprenger, Working over time: Dynamic inconsistency in real effort tasks, Q. J. Econ. 130 (2015) 1067–1115, https://doi.org/10.1093/qje/qjv020.
[36] N. Augenblick, M. Rabin, An Experiment on Time Preference and Misprediction in Unpleasant Tasks, Rev. Econ. Stud. (2018). https://doi.org/10.1093/restud/rdy019.
[37] S. DellaVigna, Structural Behavioral Economics, in: B.D. Bernheim, S. DellaVigna, D. Laibson (Eds.), Handb. Behav. Econ. Appl. Found. 1, North-Holland, 2018: pp. 613–723. https://doi.org/10.1016/bs.hesbe.2018.07.005.
[38] S. Della Vigna, U. Malmendier, Paying not to go to the gym, Am. Econ. Rev. 96 (3) (2006) 694–719.
[39] S. DellaVigna, M.D. Paserman, Job search and impatience, J. Labor Econ. 23 (3) (2005) 527–588.
[40] S.C. Lillemo, Measuring the effect of procrastination and environmental awareness on households' energy-saving behaviours: An empirical approach, Energy Policy 66 (2014) 249–256, https://doi.org/10.1016/j.enpol.2013.10.077.

[41] T. O'Donoghue, M. Rabin, Doing it now or later, Am. Econ. Rev. 89 (1) (1999) 103–124.

[42] J.A. Kelly, M. Fu, J.P. Clinch, Residential home heating: The potential for air source heat pump technologies as an alternative to solid and liquid fuels, Energy Policy 98 (2016) 431–442, https://doi.org/10.1016/j.enpol.2016.09.016.

[43] A.S. Gaur, D.Z. Fitiwi, J. Curtis, Heat pumps and our low-carbon future: A comprehensive review, Energy Res. Soc. Sci. 71 (2021) 101764, https://doi.org/10.1016/j.erss.2020.101764.

[44] B. Boardman, Fixing Fuel Poverty: Challenges and Solutions, Routledge, 2013. https://doi.org/10.4324/9781849774482.

[45] J.P. Clinch, J.D. Healy, Housing standards and excess winter mortality, J. Epidemiol. Community Health. 54 (2000) 719–720, https://doi.org/10.1136/jech.54.9.719.

[46] J.D. Healy, Excess winter mortality in Europe: a cross country analysis identifying key risk factors, J. Epidemiol. Community Health. 57 (10) (2003) 784–789, https://doi.org/10.1136/jech.57.10.784.

[47] M. Sugiyama, Climate change mitigation and electrification, Energy Policy 44 (2012) 464–468, https://doi.org/10.1016/j.enpol.2012.01.028.

[48] P. Nejat, F. Jomehzadeh, M.M. Taheri, M. Gohari, M.Z. Abd, Majid, A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries), Renew. Sustain. Energy Rev. 43 (2015) 843–862, https://doi.org/10.1016/j.rser.2014.11.066.

[49] M.D.P. Pablo-Romero, R. Pozo-Barajas, R. Yñiguez, Global changes in residential energy consumption, Energy Policy 101 (2017) 342–352, https://doi.org/10.1016/j.enpol.2016.10.032.

[50] R.J. Hafner, D. Elmes, D. Read, Promoting behavioural change to reduce thermal energy demand in households: A review, Renew. Sustain. Energy Rev. 102 (2019) 205–214, https://doi.org/10.1016/j.rser.2018.12.004.

[51] H. Allcott, M. Greenstone, Measuring the welfare effects of residential energy efficiency programs, National Bureau of Economic Research (2017), https://doi.org/10.3386/w23386.

[52] SEAI, SEAI National BER Register, (2019). https://ndber.seai.ie/pass/ber/search.aspx (accessed January 15, 2019).

[53] G. Schuitema, C. Aravena, E. Denny, The psychology of energy efficiency labels: Trust, involvement, and attitudes towards energy performance certificates in Ireland, Energy Res. Soc. Sci. 59 (2020) 101301, https://doi.org/10.1016/j.erss.2019.101301.

[54] Charles Sprenger, Judging experimental evidence on dynamic inconsistency, Am. Econ. Rev. 105 (5) (2015) 280–285.

[55] Meredith Fowlie, Michael Greenstone, Catherine Wolfram, Are the non-monetary costs of energy efficiency investments large? Understanding low take-up of a free energy efficiency program, Am. Econ. Rev. 105 (5) (2015) 201–204, https://doi.org/10.1257/aer.p20151011.

[56] Anja Kollmuss, Julian Agyeman, Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environ. Educ. Res. 8 (3) (2002) 239–260, https://doi.org/10.1080/13504620220145401.

[57] Luis Mundaca, Margaret Samahita, What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden, Energy Res. Soc. Sci. 60 (2020) 101319, https://doi.org/10.1016/j.erss.2019.101319.

[58] The Behavioural Insights Team, EAST: Four Simple Ways to Apply Behavioural Insights, 2014. https://www.behaviouralinsights.co.uk/publications/east-four-simple-ways-to-apply-behavioural-insights/ (accessed October 8, 2018).

[59] Matthew Collins, John Curtis, Value for money in energy efficiency retrofits in Ireland: grant provider and grant recipients, Appl. Econ. 49 (51) (2017) 5245–5267, https://doi.org/10.1080/00036846.2017.1302068.

[60] J.P. Clinch, J.D. Healy, Valuing improvements in comfort from domestic energy-efficiency retrofits using a trade-off simulation model, Energy Econ. 25 (5) (2003) 565–583, https://doi.org/10.1016/S0140-9883(03)00051-3.

[61] M. Fowlie, M. Greenstone, C. Wolfram, Do energy efficiency investments deliver? Evidence from the weatherization assistance program, Q. J. Econ. 133 (2018) 1597–1644, https://doi.org/10.1093/qje/qjy005.

[62] J. Schleich, X. Gassmann, T. Meissner, C. Faure, A large-scale test of the effects of time discounting, risk aversion, loss aversion, and present bias on household adoption of energy-efficient technologies, Energy Econ. 80 (2019) 377–393, https://doi.org/10.1016/j.eneco.2018.12.018.