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Title: Conceptualising the role of personality traits in making investment decisions: The case of residential energy efficiency

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Personality traits and energy efficiency in the UK residential market

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Abstract

The limitations of simple payback and investment profitability models for energy efficiency investments are well established in the literature. This paper investigates whether personality traits play a significant role in the decision-making process of investing in energy efficiency in the residential sector. Using the Understanding Society UK survey data, we apply structural equation modelling to examine if personality traits may explain why certain individuals choose to invest in energy efficiency measures while others do not, even under almost identical financial conditions. The results show that the link between personality traits and energy efficiency measures are primarily mediated trough risk preferences and/or attitudes toward the environment. Similar mediation effects are found for pro-environmental habits. However, an important difference is that households with higher incomes have a higher propensity to invest in energy efficiency while the opposite is the case for other pro-environmental behaviours and habits. The findings of this analysis underline the need for differentiated and targeted products and policies in the market for residential energy efficiency.

Along with most other developed economies, the United Kingdom has pledged to reduce greenhouse gas emissions by a large margin. The Climate Change Act sets out the goal to cut these emissions by 80% by 2050, compared to 1990 levels. In 2014, residential buildings accounted for 22% of total UK greenhouse gas emissions (Committee on Climate Change, 2014). Improving energy efficiency in homes offers a promising route towards achieving the emissions reduction goals along with smaller and cheaper-to-implement changes such as conserving energy and using public transport.

Global energy generation capacity from wind and solar installations has been on the rise and amounted in 2015 to 64 GW and 57 GW respectively, according to February 5, 2016 *Nature Energy* Editorial. It has been estimated that by 2020 about 10 million homes in the UK will have solar panels on their roofs (Harvey, 2014 as cited in Parag and Sovacool, 2016). However, the uptake of energy-efficient (EE) measures remains moderate in spite of their apparent financial profitability and benefits to environment's well-being. Stern et al. (2016) stress the importance of considering behavioural and social factors to improve the uptake. In this paper, we pick up their suggestion and show empirically that a homeowners' economic decision to invest in energy efficiency or forgo the investment can be partially predicted by certain personality traits of the decision-maker. We also compare EE investments to environmental habits and behaviours and find similar results. However, income levels appear more important for predicting EE investments which typically entail larger capital investments than they are for low-cost environmental behaviours.

It is well documented that market failures such as imperfect information or unpriced externalities can prevent optimal allocations of resources into energy efficiency (Gerarden et al., 2015; Bardhan et al., 2014). More recently, researchers have increasingly turned to behavioural approaches for explaining EE investment decisions (Ramos et al., 2015a; Allcott and Mullainathan, 2010). Gerarden et al. (2015) point out at several behavioural anomalies (such as inattention, loss aversion, myopia, among others) that are responsible for the energy efficiency gap. In the residential energy efficiency realm, researchers have found that differences in social norms do matter for energy saving behaviour (Allcott and Rogers, 2014). It has been also shown that households with pro-environmental habits are more likely to invest into EE appliances (Ramos et al. 2015b). As far as we are aware, this paper presents the first empirical attempt to predict energy efficiency investments using data on individual psychological characteristics (personality traits).

More specifically, a structural equation model (SEM) is employed to data on UK homeowners, to predict EE investments (i.e. solar and wind turbine installations for electricity generation and water heating) and low-cost environmental habits (i.e. switching off appliances when not in use, carpooling, using public transport, among other). The results contribute to a better understanding of the energy efficiency gap and why providing financial support or information about EE options may not be sufficient for achieving higher levels of energy efficiency in the residential sectors in line with carbon emissions targets.

Heterogeneous consumers and the energy efficiency gap

The microeconomic determinants of EE investments are investigated in a number of studies to understand better why some households choose to invest while others do

not under seemingly identical financial circumstances (Ramos et al., 2015a; Allcott et al., 2014). Two factors emerge as particularly salient: EE investments entail uncertainty as these benefits may or may not occur in the future while costs occur in the present (Fischbacher et al., 2015). Uncertainty arises from market risk, e.g. future energy prices might fall and idiosyncratic factors, e.g. a household may have lower energy demand in the future than anticipated. In addition, different consumers' beliefs such as cultural and ideological factors may be of importance (Ramos et al., 2015a). If the influence of energy consumer heterogeneity is ignored, the estimated energy saving potential might be biased upwards and the energy efficiency gap may be overstated (Gerarden et al., 2015).

Several empirical studies in the residential sector evidence that different attitudes of environmental concern or behaviour influence the use of energy and households' energy efficiency. Ramos et al. (2015b) find in a survey of Spanish households that eco-friendly behaviour is associated with higher investments into EE appliances, low-consumption bulbs and double glazing. Lange et al. (2014) evidence a positive relationship between a set of pro-environmental behaviour (PEB), such as wearing a jumper instead of increasing the thermostat settings, and heating expenditures in the UK.

Although researchers observe heterogeneity among energy consumers, little is known about the causes for these differences. One of the possible explanations of heterogeneity is the diversity of individual psychological characteristics, specifically personality traits. Numerous researches show that personality traits affect investors' behaviour and certain economic outcomes, including employment status and wages, households' financial asset allocation, and regional entrepreneurship rates (Gherzi et al., 2014; Fletcher, 2013; Brown and Taylor, 2014; Obschonka et al., 2015). Other researchers find significant influence of empathy, locus of control, autism, and selfism (Ovchinnikova et al., 2009), trust and empathy (Czap and Czap, 2010), empathy and selfism (Czap et al., 2012) on conservation behaviour in framed laboratory experiments. And yet the others, e.g. Brick and Lewis (2014) in a large sample of the U.S. consumers, demonstrated that openness to experience, conscientiousness, and extraversion are associated with environmental attitudes and behaviour.

Existing studies on personality traits and energy usage focus on energy-saving and environmental conservation behaviour. Although energy saving and energy efficiency seem to be related and previous literature has used the terms often interchangeably, important differences exist. Energy saving is related to repeated daily behaviour in energy conservation, whereas energy efficiency refers to infrequent technological adoptions that lead to a structural long-term change in energy usage and which require a significant financial outlay (Karlin et al., 2014). Hence, the following empirical analysis is designed to compare both non-regular discrete events such as EE investments and regular frequently recurring events such as pro-environmental behaviour (PEB) and habits.

A model for the integration of personality traits into energy efficiency decisions

We use a modified utility maximisation model for energy efficiency based on the work of Allcott and Greenstone (2012) to test the impact of personality traits on EE

investments. In line with basic financial mathematics, this model assumes that individuals invest into EE technology if discounted savings exceed additional discounted costs. However, the relationship between savings and costs is moderated by a number of individual attitudes and general externalities in the following form:

$$PV_{Savings} \times \gamma(\alpha(\Psi), \varphi(\Psi)) > PV_{\Delta Costs},$$

where γ is a behavioural factor that adjusts the benefits either to the up- or downside, depending on the individual's risk attitudes, α, and externalities φ. The variable α expresses individuals' propensity to take risks, whereas φ describes the degree to which individuals consider environmental and social costs generated by energy production, such as environmental pollution. Importantly, the model assumes that externalities (φ), which can be measured with environmental concern, and risk preferences (α) are implicitly a function of personality traits Ψ. Hence, personality traits (Ψ) are mediated through risk (α) and environmental concern (φ) on EE investments. In the same vein, it is assumed that consumers compare the benefits of PEB, including personal and environmental benefits, with the associated costs, such as effort and time invested (e.g. recycling) (Young et al., 2010).

The underlying mediation mechanisms for the model are derived from previous research on the links between personality traits and risk preferences and environmental attitudes, respectively. To measure personality traits, we use the Big Five which is a broadly recognised framework with five core dimensions (Costa and MacCrae, 1992): Openness to experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism. Researchers have found significant correlations between the Big Five and risk as well as between the Big Five and environmental attitudes. We construct two mediation models: M1 and M2 (Figure 1)

Figure 1: Mediation Models M1 and M2

In both models, we assume a direct effect and two indirect effects through risk and environmental concern (mediators) for each personality trait. In M2, we additionally assume that the mediators can only be translated to EE investments or PEB (for example, buying more expensive organic products) if households' income is sufficiently high, i.e. the translation of the mediators is modelled conditionally on households' income.

Based on previous literature, we derive hypotheses for how each of the Big Five traits should affect EE investments and PEB (see Methods & hypotheses derivation):

Table 1: Hypotheses

These hypotheses are then tested empirically using the Understanding Society survey in the UK, formerly known as the British Households Panel Survey. The data is nationally representative and covers a wide range of households' attributes, including EE investments and individuals' personality traits, attitudes and environmental behaviour.

Results

Big Five and EE investments: Model 1 (M1)

Table 2: Mediation effects of the Big Five traits on EE investments (M1)

The results for M1 (Table 2) reveal that the specific indirect effects through risk and environmental concern are significant for each of the traits except for the mediation path of Conscientiousness through risk and the path of Extraversion through environmental concern.

Openness to experience and Extraversion increase the probability to invest in energy efficiency through the mediation channel of risk, whereas Agreeableness and Neuroticism have a negative impact, providing support to 4 out of our 5 hypotheses for risk (Table 1). In absolute terms, the effects of Openness to experience (0.017) and Neuroticism (-.018) are the strongest.

For the mediation through environmental concern, Openness to experience is found to have the largest positive statistically significant effect (0.035) on the probability to invest in energy efficiency. The environmental-concern-mediated effects of Agreeableness and Neuroticism are also positive and significant, while the effect of Conscientiousness is negative, providing support for 3 out of 5 hypotheses (Table 1). The result that more conscientious and environmentally concerned individuals are less likely to adopt EE investments is intriguing. It cannot be ruled out that these individuals weigh the opportunity cost of EE investments against other pro-environmental investments and conclude that the latter are more financially viable and more environmentally friendly. Another surprising result is that neurotic and environmentally concerned individuals are more likely to invest into energy efficiency. One of the possible explanations is that such individuals are disturbed by the environmental threats and respond to that by implementing substantial changes in their houses.

Due to the opposing mediation effects through risk and environmental concern, most of the total indirect effects are not significant with the exception of Openness to experience and Conscientiousness. Notably, the effect of Openness to experience on EE investment is almost entirely (0.052/0.055*100%=94.5%) mediated by risk and environmental concern.

Overall we conclude that: (1) the importance of the Big Five personality traits is in their indirect influence on the EE investments through the channels of risk and environmental concern, and (2) except for Openness to experience, the mediation by risk preferences and environmental concern is influencing the Big Five-EE investments relationship in opposite directions.

Big Five and EE investments in the context of income heterogeneity: Model 2 (M2)

Table 3: Mediation effects of the Big Five traits on EE investments, conditionally on households' income (M2)

In M2, we test whether the mediated effect of Big Five varies with financial capacity. Specifically, we consider households income heterogeneity and test for the effects in a low-income (L), medium-income (M), and high-income scenario (H). The estimation results in Table 3 show that the effects mediated by risk preferences are statistically significant only for H level of income. The effects mediated by environmental

concern are statistically significant for M and H level of income.

The results point out at a number of behavioral insights related to EE investments in the context of income. Firstly, for low-income households the decision to invest in energy efficiency does not depend on the mediation of personality traits through risk preferences, and environmental concern. It is likely that the perceived financial capacity pays the major role in such investments. Secondly, for medium-income households the decision to make EE investments depends on the personality traits and it is guided by the environmental concern. Intriguingly, the decision seems to be more along the lines "walk-the-talk", rather than financial, as it does not depend on the risk preferences. Third, for high-income households the EE investment decision depends on the personality characteristics mediated by both risk preferences and environmental concern. These households are likely evaluating the costs and benefits of EE investments against other eco- and non-eco-investments.

Big Five and PEB: Model 1 (M1)

Table 4: Mediation effects of the Big Five traits on pro-environmental behaviour (M1)

The estimation results of M1 with PEB as a dependent variable (Table 4) show that only the mediation effects through environmental concern are significant, but not the effects through risk. We found support for 5 out of 10 hypotheses (Table 1) regarding the mediation of the Big Five and PEB relationship: The risk mediation for Conscientiousness, Extraversion, and Neuroticism and regarding environmental concern, the mediation for Openness to experience and Agreeableness. Also, the direct and total effects for Conscientiousness and Extraversion show significant impact. The direct effects of these two traits are considerably stronger than the mediating effects, thus indicating a straightforward impact on PEB. Overall we conclude that: (1) depending on the trait, Big Five have a direct and indirect influence on the PEB through the channel of environmental concern, and (2) the mediation by risk preferences does not influence the Big Five – PEB relationship.

Big Five and PEB in the context of income heterogeneity: Model 2 (M2)

Table 5: Mediation effects of the Big Five traits on pro-environmental behaviour, conditionally on households' income (M2).

In this section, we test again whether the mediated effect of Big Five varies with financial capacity in the context of PEB based on M2. As above, we consider household income heterogeneity and test for the effects in a low-income (L), medium-income (M), and high-income scenario (H) which are presented in Table 5. The estimation results suggest that the effects mediated by risk preferences are statistically significant for low and medium level of income. The effects mediated by environmental concern are statistically significant only for medium incomes.

The results point out at a number of behavioral insights related to PEB in the context of income. First, for low-income households, engagement in PEB depends on Big Five personality traits as mediated by the risk preferences. The financial scarcity is usually accompanied by the time scarcity (Mullainathan and Shafir, 2013). It is possible that low-income households perceive PEB as more costly in terms of

requiring both time and money to achieve them and the risk of this investment appears higher to households who are more constrained with regard to either or both of these resources. As a result, preference for risk is a factor mediating the personality-PEB relationship. Second, for medium-income households involvement in PEB depends on the personality traits mediated by both the risk and environmental concern. The environmental concern mediation suggests that these households are willing to "walk-the-talk", while the risk mediation implies that, similarly to the above, PEB requires possibly breaking established habits and as such carries some perceived risk. Third, high-income households PEB does not depend on the mediation of personality traits through risk preferences, and environmental concern. The result regarding the insignificance of the environmental concern link is surprising and disappointing as it means that the environmentally-friendly behaviour that was surveyed is either overlooked or potentially seen as not glamorous or not worthy of the effort.

Conclusions and policy implications

The results from M1 and M2 show that personality traits as measured by the Big Five do matter for EE investments and for PEB. In M1, risk preferences have a principal function for the mediation of personality traits in the case of EE investments, whereas they are of minor importance for PEB. For PEB, the main mediator of personality traits is environmental concern and some traits exert a direct impact. However, taking into account financial capacity in M2 reveals that the mediation channels of personality traits on EE investments and PEB depend on households' income level.

The estimation results for EE investments increase with household income and are only significant for medium- and high-income households. This implies that personality traits are translated into EE adoptions only if the households' financial capability allows it. There might be untapped investment potential in individuals with favourable personality profiles that could be released if sufficient financial incentives (e.g. governmental subsidies, tax breaks) were made available and these target groups were made sufficiently aware of their existence.

Interestingly, the effects for EE investments show that for medium-income households personality traits manifest themselves only through environmental concerns, while for high-income households they are also mediated through risk. On one hand, these results are good news for the policy makers. Since arguably, it is easier to influence environmental concern (as compared to risk preferences), environmental policy can focus on nudging the medium- and high-income households towards more sustainable EE investments. On the other hand, these results caution the policy makers. It is reasonable to expect that the high-income households, who have the highest financial capacity to invest into EE technology, would be more willing to adopt it. However, their sensitivity to risk implies that environmental policy needs to provide additional guarantees and/or financial incentives in order to make the EE investments less risky and thus more appealing to them.

Given the crucial role of risk perception in a household's EE investment decision, and inefficacy of changing personality traits due to its fixed nature, greater emphasis could be placed on risk-sharing mechanisms when devising government policies or private-sector investment products. The extensive portfolio of a government or company allows a better absorption of risk. Risk reduction could be also achieved by

increasing the range of lending products for EE measures that are currently offered by some liquidity providers. Such loans could be tailored specifically to mitigate the risk inherent in EE projects, for example by the use of floating rate loans that link interest rate payments to energy prices. In such a scenario, the interest rate is adjusted downwards/upwards on a regular basis in line with fluctuations in energy prices. As such, losses in EE projects caused by energy price declines are compensated with lower interest rate payments.

Similarly, the personality traits can guide the design of pro-environmental programmes that try activating environmental concern. According to the energy conservation studies, direct provision of information does not lead to significant changes in energy saving behaviour (Steg, 2016). Following this we propose, that instead of simply informing people about environmental issues, the interested parties (e.g. policy makers and environmental organizations) tailor-fit the messages to different target audiences. For instance, since Openness to experience influences EE investments also through environmental concern, eco labels could be designed with visual effects that engage with the typical openness facets of inner feelings and emotions. Instead of using alphabetical letters or figures of carbon emissions, the levels of energy efficiency could be visualised with pictures ranging from polluted cities (low energy efficiency) to green landscapes (high energy efficiency). Such visualisations might be more effective for openness-prone people than just highlighting the financial value of energy savings.

In contrast to the effects of EE investments, the coefficients for PEB sensitivity to personality traits diminish with increased household income, which implies that policies will be more successful with low- and medium-, rather than high-income households. The policies to decrease the perceived risk of pro-environmental habits are rather limited (e.g. increase the reliability of public transportation, make it safer to ride and park bicycles). Thus, policy-makers should capitalise on the sensitivities of PEB to personality traits rather through environmental concern by making the impact of PEB more salient. This can be done for example, by providing readily available information about the savings from switching off the lights directly on the lightswitch or displaying the savings from keeping the temperature down/up by 1 degree on the thermostat.

Overall, our study demonstrates that differentiated and targeted products and policies are needed to encourage higher levels of residential energy efficiency investments and PEB.

Methods & derivation of hypotheses

To derive the hypotheses (Table 1), the following paragraphs introduce each of the Big Five personality traits and discuss their causal impact on risk preferences and environmental concern, based on the existing risk and environmental attitudes literature.

Openness to Experience. Openness to Experience *(O)* is associated with higher willingness to undertake new actions, which very often involves a degree of uncertainty. Previous work has demonstrated strong evidence for a positive relationship between *O* and risk preferences in domains such as household asset allocations and entrepreneurship rates (Brown and Taylor, 2014; Obschonka et al., 2013).

As stated by Brick and Lewis (2014), flexible and abstract thinking, two main facets of *O*, are required

to anticipate long-term environmental consequences. Support for this causality is given by empirical research that evidences a positive correlation between O and environmental concern (Brick and Lewis, 2014; Hilbig et al., 2013; Markowitz et al., 2012; Hirsh and Dolderman, 2007; Hirsh, 2010).

Conscientiousness. People with a high degree of Conscientiousness *(C)* tend to be responsible and strive for achievement. Such achievement, however, is not aimed at random environments, such as gambling, for example. Rather, goals are strived for under controlled conditions. This aversion to uncontrolled or uncertain environments is evident in the analysis conducted by Brown and Taylor (2014), who found that households with a high C level have a lower willingness to acquire debts.

Causality discussions on the link between C and environmental concern bring out arguments both in favour of and against pro-environmental engagement (Markowitz et al., 2012). Results from empirical studies evidence a consistent positive relationship, though some show very small influences and minor inconsistencies (Milfont and Sibley, 2012; Hirsh, 2010; Markowitz et al., 2012; Hilbig et al., 2013). Swami et al. (2010) justify the causality for the positive relationship with the need for achievement in pro-environmental values.

Extraversion. Extraversion (E) directs people's interest towards the outer world. Individuals who score highly in E values are assertive, ambitious, energetic and optimistic. These attributes provide a strong basis to deal with uncertain decisions. E was found to be a typical characteristic of entrepreneurship-prone individuals who face a significant amount of uncertainty (Zhao et al., 2010; Caliendo et al., 2014).

Previous analyses have found no, or only a very small influence of E on pro-environmental attitudes and therefore, no relationship is derived between E and environmental concern (Hirsh, 2010; Milfont and Sibley, 2012; Markowitz et al., 2012).

Agreeableness. People with a high degree of Agreeableness (A) tend to be cooperative and more group- than self-oriented. On the other hand, individuals with low A tend to be antisocial and egocentric. Self-centered individuals are often inclined towards over-confidence by overestimating their own abilities and knowledge. This can lead to a higher propensity for risk (Chui et al., 2010; Mihet, 2013).

Related to environmental concern, previous work indicates a positive link between A and environmental concern. Several analyses report a robust and positive impact of A on biospheric concern and pro-environmental goals (Hirsh and Dolderman, 2007; Hirsh, 2010; Milfont and Sibley, 2012; Swami et al., 2010).

Neuroticism. Finally, Neuroticism (N) should have a negative influence on risk-taking. Neurotic people have a tendency for a high degree of anxiety and susceptibility to stress. The literature reports a strong and consistently negative link between N and risk-taking (Borghans et al., 2009; Zhao et al., 2010).

On the other hand, results on the link between N and environmental beliefs were mixed, ranging between no, negative and positive correlations (Hirsh, 2010; Brick and Lewis, 2014; Markowitz et al., 2012). Hence, no clear associations can be derived between N and environmental concern.

EE investment as affected by Big Five, risk, and environmental concern

Investing in EE technology is associated with significant ambiguity and risk. The fact that markets for EE technology are immature is one of the reasons for this (Ryan et al., 2012). The lack of information, and the resulting shortfall in knowledge about the technology effectiveness and financial profitability among consumers, create a state of ambiguity and a defensive attitude towards investments. The expected efficiency increases may also be uncertain because the technology is new and the experience from comparable EE projects is rare. Furthermore, the profitability of the investment depends on future energy use and price patterns, which are unknown (Epper et al., 2011; Linares and Labandeira, 2010).

Additionally, pro-environmental attitudes and environmental concern facilitate pro-environmental decisions. This also includes the decision of a household to adopt EE technology. Therefore, it follows that higher risk preferences and environmental concern should relate positively with EE investments. Consequently, the Big Five should influence EE investments in the same direction as they affect each of the two mediators.

Pro-environmental behaviour as affected by Big Five, risk, and environmental concern

This research joins Markowitz et al. (2012, p.83) in uncovering "underlying, situationally stable factors that motivate individuals to perform many different types of PEB" [pro-environmental behaviour]. PEB includes a wide range of individual choices and can be grouped into three categories: (1) every-day purchases (e.g. locally-sourced goods, organic or green products), (2) short-time-consuming habits (e.g. switching off the lights, putting a sweater instead of adjusting up the thermostat, recycling, using public transport), and (3) long-time-consuming actions (e.g. eco-activism, voluntarism, and engagement in environmental organisations). The previous studies demonstrated significant influence of some Big Five traits on PEB (Quintelier, 2014; Markowitz et al., 2012; Milfont and Sibley, 2012; Fraj and Martinez, 2006b).

For the first category, Quintelier (2014) found that for the young people in Belgium Openness to experience leads to more political consumer behaviour for every-day purchases (i.e. boycotting environmentally-damaging products and buycotting green or fair-trade products); Conscientiousness and Extraversion leads to less, while Agreeableness and Neuroticism has no influence on such behaviour. For the second category, according to Study 2 of Milfont and Sibley (2012) conducted in New Zealand, Conscientiousness, Agreeableness, and Neuroticism are strongly linked to home electricity conservation, while the links to Extraversion and Openness to Experience are not statistically significant. In contrast, Markowitz et al. (2012), using the U.S.A. samples, found that only Openness to experience and its facets are consistently and positively linked to environmental practices/behaviour (such as using public transportation, carpooling, composting food scraps, recycling, etc.). For the third category, Fraj and Martinez (2006b) using the data collected in Spain found that extraversion, Agreeableness, and Conscientiousness are positively linked to the actual commitment to ecological behaviour (the actual commitment subscale includes items like joining a clean-up drive, attending ecology meetings, keeping track of public official voting record on environmental issues, etc.).

In this paper we concentrate on PEB in the second category that includes everyday energy savings and conservation habits that are relative cheap to implement and do not require large time commitment or a specific purchase. In contrast to the EE investment, PEB and habits involve relatively little objective risk. However, depending on the habit (switching off the lights when not in use and putting on more clothes instead of adjusting up the thermostat vs. using public transport and biking to work) individuals may evaluate the subjective risk differently. Some individuals may believe that a personal car is more reliable than a bus and a sudden change in weather may make their bike ride uncomfortable. Similarly to the EE investment (Fischbacher et al., 2015; Qiu et al., 2014), consumers may evaluate the benefits of PEB, including personal benefits and the impact on the environment, as uncertain. In addition, risk averse individuals prefer to stick to old habits and defaults and judge them as low risk, while being reluctant to switch to the new habits. These factors suggest that the risk averse individuals are less likely to engage in PEB leading to the risk-related hypotheses in Table 1.

PEB is also positively linked to environmental concern: individuals behaving environmentally friendly (in their conservation decisions) are more concerned about the environment (Czap and Czap, 2010). Along the same lines, Fraj and Martinez (2006a) found that individuals following ecological lifestyle are scoring higher on the actual commitment subscale of ecological behaviour mentioned above. However, while environmental concern leads to a higher intent to behave environmentally-friendly, it does not necessarily translate into an actual pro-environmental consumer behaviour (Quintelier, 2014). One explanation of it is that environmental concern affects PEB (such as requesting a green-electricity brochure) rather indirectly via situation-specific cognitions (Bamberg, 2003). In this paper we are interested in the role of the stable personality factors in environmental decisions and we posit that personality traits will be mediated by environmental concern in their influence on PEB, which leads us to the second set of hypotheses for PEB in Table 1.

Data

We draw on data from the "Understanding Society" survey in the UK, which is the successor of the British Household Panel Survey (BHPS) after 2008. Since 2009, almost 50,000 households and 100,000 individuals have been repeatedly interviewed on an annual basis. The survey covers all regions in the UK and is nationally representative. The data consists of a wide range of variables ranging from individual attitudes to households' financial features. It also covers the necessary variables to test the

suggested mediation mechanism of personality traits on EE investments and PEB:

EE Investments. The survey asks on an annual basis whether households have a solar panel or wind turbine installation for heating or electricity purposes. For our analyses, we use the answers from Wave 4 (2012) on the question "Have you installed or are you seriously considering any of the following": 1) "solar panels for electricity?", 2) "solar water heating?", 3) "wind turbine to generate electricity?". Based on the answers, we derived a binary variable for EE investments (EE). If any of the questions was answered with a "Yes-fitted" we coded EE with a 1. We also assigned a 1 if the household chose "Yes-seriously considering" in order to increase the number of "1" observations. Otherwise, the data would be too concentrated around zero to see any effects of explanatory variables. The causal relationship in the theoretical model presented above between EE investments and risk attitudes and environmental concerns, respectively, should also hold for the "Yes-seriously considering" outcome, thus justifying its inclusion: The higher the risk preference and environmental concern, the higher is the probability to consider an investment into energy efficiency seriously.

Personality Traits. Wave 3 in 2011 includes questions related to personality traits that allow to derive the five main personality factors according to the Big Five framework: Openness to experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism. Each personality trait is assessed with three item questions. For each question, participants were asked to rate themselves from (1) "does not apply to me at all" to (7) "applies to me perfectly". Except for Openness to experience, one of the questions for each of the traits is formulated in the opposite way so that we reversed the scale accordingly. Because personality was not measured in 2012, we mapped EE investment figures with traits from 2011. We tested for invariance of personality traits and the results show that they can be expected to stay stable over time (Supplementary material A.). The personality traits and other individual-level variables were mapped to household variables with the help of households' heads.

Risk Preferences. The first channel of the supposed personality traits mediation is risk preference. Wave 1 (2009) includes a question that asks for participants' risk affiliation, R. Surveyees can choose between answers on an 11-item Likert scale from "I am not prepared to take risks at all" (0) to "I am fully prepared to take risks" (10). Since we are matching risk attitudes from 2009 with 2012 figures, we tested for invariance of risk attitudes using the data from 2008 and 2009. The results show that the risk preferences are likely to be stable across the 3-4 years timespan with some tendency to go down as people age (Supplementary material B.).

Environmental Concern. The second channel of the supposed personality traits mediation is environmental concern. Wave 4 (2012) also includes a module related to environmental attitudes. Respondents self-assess their attitudes to environment on a 5-itmes Likert scale from "strongly agree" (1) to "strongly disagree" (5):

1. "My behaviour and everyday lifestyle contribute to climate change."

2. "If things continue on their current course, we will soon experience a major environmental disaster."

3. "Climate change is beyond control it's too late to do anything about it."

4. "The effects of climate change are too far in the future to really worry me."

5. "It's not worth me doing things to help the environment if others don't do the same."

6. "It's not worth the UK trying to combat climate change, because other countries will just cancel out what we do."

A lower score ("strongly agree") for the first two questions means a higher environmental concern, whereas for the remaining four questions there is an inverse relationship. We reversed the answers of question one and two to enable a congruent increasing tendency of the impact on environmental concern with a higher score. Subsequently, we averaged the scores to each question to construct an index for environmental concern, EC.

Pro-environmental behaviour (PEB). Wave 4 (2012) includes a series of questions regarding

environmental habit of the households. The respondents choose an answer on a 5-itmes scale ranging from "Always" (1) to "Never" (5). We reversed the answers to questions 2 and 4-10, so that the higher score on the scale corresponds to more engagement in PEB. The PEB index was calculated as an average of the answers to:

1. "Leave your TV on standby for the night."

2. "Switch off lights in rooms that aren't being used."

3. "Keep the tap running while you brush your teeth."

4. "Put more clothes on when you feel cold rather than putting the heating on or turning it up."

5. "Decide not to buy something because you feel it has too much packaging."

6. "Buy recycled paper products such as toilet paper or tissues."

7. "Take your own shopping bag when shopping."

8. "Use public transport (e.g. bus, train) rather than travel by car."

9. "Walk or cycle for short journeys less than 2 or 3 miles."

10. "Car share with others who need to make a similar journey."

Control Variables. Based on existing energy efficiency and PEB literature, we include the following control variables into the analyses: income, age, gender, education, and number of children in a household (Hamilton et al., 2014; Mills and Schleich, 2012; Chen et al., 2011; Nair et al., 2010; Poortinga et al., 2003). We also account for different solar irradiance levels households are exposed to by including a variable that measures yearly average solar irradiance per Government Office Region in the UK[1].

After we matched the explanatory variables with the EE investments and PEB, we obtained 6,083 and 3,665 observations, respectively.

Estimation

We use Structural Equation Modeling (SEM) assuming no joint-normality (Byrne, 2013) and bootstrap the estimated effects according to Preacher and Hayes (2008). EE investments EE_i is the dependent variable, risk preferences (R_i) and environmental concern (EC_i) depict the mediators, and personality traits, X_{ij}, denote the independent variables with $j = \{1, \dots, 5\}$ representing the five traits Openness to experience, Extraversion, Conscientiousness, Agreeableness and Neuroticism for each individual $i = \{1, \dots, 6,063\}$ (Figure 2). Path c_j in Figure 2A is the total effect of X_{ij} on EE_i. In Figure 2B, it is decomposed into the direct effect c'_j and the indirect effects of X_{ij} on EE_i via the two mediators R_i and EC_i. a_{1j} and a_{2j} depict the effects of X_{ij} on the two mediators, while path b_1 and b_2 represent the effects of the mediators on EE_i. The total indirect effect of X_{ij} on EE_i is the sum of both specific indirect effects $a_{1j}b_1$ and $a_{2j}b_2$.

Figure 2: Mediation of personality traits on EE investments

Two types of models are run. The first, Model 1 (M1), assumes that the mediation mechanism of personality traits works equally well across different households. The corresponding equations to estimate the coefficients are as follows:

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[1] The figures for the irradiance levels are taken from http://contemporaryenergy.co.uk/insolation-map/ for Northern Ireland and from http://www.theecoexperts.co.uk/freebook/appendix-solar-insolation-values-uk for the remaining Government Office Regions (03.03.2016).

$$R_i = d_1 + \sum_{j=1}^{5} a_{1j}X_i + \gamma_1 Z_i + \varepsilon_{i1}$$

$$EC_i = d_2 + \sum_{j=1}^{5} a_{2j}X_i + \gamma_2 Z_i + \varepsilon_{i2}$$

$$EE_i = d_3 + \sum_{j=1}^{5} c'_j X_i + b_1 R_i + b_2 EC_i + \gamma_3 Z_i + \varepsilon_{i3}$$

where $\gamma_k Z_i$ denotes the product of the vector for the control variables, Z_i, with the corresponding coefficient vector γ_k, d_k is the intercept, and ε_{ik} is the error term for the equations $k = \{1, \dots, 3\}$. Due to different scales of the observations, the variables are standardised.

In Model 2 (M2), M1 is extended by introducing households' income as a moderator on path b_1 and b_2, meaning that coefficients b_1 and b_1 are calculated conditionally on households' income I_i (Figure 3).

Figure 3: Mediation of personality traits on EE investments including income as moderator (M2)

The effect of personality traits via the two mediators can be only translated into the decision to seriously consider or undertake an investment if income conditions of households allow to do so. Formally, the third equation is adjusted as follows:

$$EE_i = d_3 + \sum_{j=1}^{5} c'_j X_i + b_1 R_i + b_2 EC_i + \gamma_3 Z_i + \beta_I I_i + \beta_{RI} RI_i + \beta_{ECI} ECI_i + \varepsilon_{i3}$$

where β_I is the coefficient for income, β_{RI} constitutes the coefficient for the product of risk preferences and income, RI_i, and β_{ECI} represents the coefficient for the product of environmental concern and income ECI_i.

To estimate the coefficients, a fitting process of the first an second moments (mean, variance) is run by applying maximum-likelihood estimation, conditionally on the independent values as given (non joint-normality assumption). The assumption of non-joint normality is necessary because of dummy variables included in the equation system. It further allows to better assess the stability of coefficients in case of non-normal variables.

To test for significance of the estimated coefficients, 95% bias-corrected bootstrapping confidence intervals are used. The advantage of bootstrapping is that it does not impose any specific distribution of the coefficients when testing for significance. The bias-corrected confidence intervals account for any skewness and bias present in the distribution of the estimated coefficients[2].

We apply the same estimation procedure for PEB.

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[2] For further details about bootstrapping, see Preacher et al. 2007.

References

Allcott, H., Greenstone, M., 2012. Is there an energy efficiency gap? The Journal of Economic Perspectives 26, 3–28.

Allcott, H., Mullainathan, S., 2010. Behavior and Energy Policy. Science 327, 1204–1205.

Allcott, H., Rogers, T., 2014. The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. American Economic Review 104, 3003–37.

Bamberg, S., 2003. How does environmental concern influence specific environmentally related behaviors? A new answer to an old question. Journal of Environmental Psychology 23, 21–32.

Bardhan, A., Jaffee, D., Kroll, C., Wallace, N., 2014. Energy efficiency retrofits for U.S. housing: Removing the bottlenecks. Regional Science and Urban Economics 47, 45–60.

Borghans, L., Heckman, J.J., Golsteyn, B.H.H., Meijers, H., 2009. Gender differences in risk aversion and ambiguity aversion. Journal of the European Economic Association 7, 649–658.

Brick, C., Lewis, G.J., 2014. Unearthing the "green" personality: Core traits predict environmentally friendly behavior. Environment and Behavior. doi:10.1177/0013916514554695.

Brown, S., Taylor, K., 2014. Household finances and the "Big Five" personality traits. Journal of Economic Psychology 45, 197–212.

Byrne, B. M. Structural equation modeling with AMOS: Basic concepts, applications, and programming. Routledge, 2013.

Caliendo, M., Fossen, F., Kritikos, A.S., 2014. Personality characteristics and the decisions to become and stay self-employed. Small Business Economics 42, 787– 814.

Chen, X., Peterson, M., Hull, V., Lu, C., Lee, G.D., Hong, D., Liu, J., 2011. Effects of attitudinal and sociodemographic factors on pro-environmental behaviour in urban China. Environmental Conservation 38, 45–52.

Chui, A.C., Titman, S., Wei, K.J., 2010. Individualism and momentum around the world. The Journal of Finance 65, 361–392.

Committee on Climate Change, 2014. Buildings factsheet. Report. Committee on Climate Change (CCC).

Costa, P.T., MacCrae, R.R., 1992. Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO FFI): Professional manual. Psychological Assessment Resources.

Czap, N.V., Czap, H.J., 2010. An experimental investigation of revealed environmental concern. Ecological Economics 69, 2033–2041.

Czap, N.V., Czap, H.J., Khachaturyan, M., Lynne, G.D., Burbach, M., 2012. Walking in the shoes of others: Experimental testing of dual-interest and empathy in environmental choice. The Journal of Socio-Economics 41, 642–653.

Epper, T., Fehr-Duda, H., Schubert, R., 2011. Energy-Using Durables: The Role of Time Discounting in Investment Decisions. IED Working paper 11-16. IED Institute for Environmental Decisions, ETH Zurich.

Fischbacher, U., Schudy, S., Teyssier, S., 2015. Heterogeneous Preferences and Investments in Energy Saving Measures. Discussion Paper 2015-11. Münchener Wirtschaftswissenschaftliche Beiträge, Ludwig Maximilian University of Munich.

Fletcher, J.M., 2013. The effects of personality traits on adult labor market outcomes: Evidence from siblings. Journal of Economic Behavior & Organization 89, 122–135.

Fraj, E., Martinez, E., 2006a. Environmental values and lifestyles as determining factors of ecological consumer behaviour: an empirical analysis. Journal of Consumer Marketing 23, 133–144.

Fraj, E., Martinez, E., 2006b. Influence of personality on ecological consumer behaviour. Journal of Consumer Behaviour 5, 167–181.

Gerarden, T.D., Newell, R.G., Stavins, R.N., 2015. Assessing the Energy-Efficiency Gap. NBER Working Paper No. 20904. National Bureau of Economic Research.

Gherzi, S., Egan, D., Stewart, N., Haisley, E., Ayton, P., 2014. The meerkat effect: Personality and market returns affect investors portfolio monitoring behaviour. Journal of Economic Behavior & Organization 107, Part B, 512–526.

Hamilton, I.G., Shipworth, D., Summerfield, A.J., Steadman, P., Oreszczyn, T., Lowe, R., 2014. Uptake of energy efficiency interventions in English dwellings. Building Research & Information 42, 255–275.

Harvey, F. 2014. UK should have 10 million homes with solar panels by 2020, experts say. The Guardian, January 29. http://www.theguardian.com/environment/2014/jan/29/uk-10-million-homes-solar-panels-2020 (accessed on May 12, 2016).

Hilbig, B.E., Zettler, I., Moshagen, M., Heydasch, T., 2013. Tracing the path from personality – via cooperativeness – to conservation: Honesty-humility and ecological behaviour. European Journal of Personality 27, 319–327.

Hirsh, J.B., 2010. Personality and environmental concern. Journal of Environmental Psychology 30, 245–248.

Hirsh, J.B., Dolderman, D., 2007. Personality predictors of consumerism and environmentalism: A preliminary study. Personality and Individual Differences 43,

1583–1593

Karlin, B., Davis, N., Sanguinetti, A., Gamble, K., Kirkby, D., Stokols, D., 2014. Dimensions of conservation exploring differences among energy behaviors. Environment and Behavior 46, 423–452.

Lange, I., Moro, M., & Traynor, L. (2014). Green hypocrisy?: Environmental attitudes and residential space heating expenditure. Ecological Economics, 107, 76–83.

Linares, P., Labandeira, X., 2010. Energy efficiency: economics and policy. Journal of Economic Surveys 24, 573–592.

Markowitz, E.M., Goldberg, L.R., Ashton, M.C., Lee, K., 2012. Profiling the "pro-environmental individual": A personality perspective. Journal of Personality 80, 81–111.

Mihet, R., 2013. Effects of culture on firm risk-taking: a cross-country and cross-industry analysis. Journal of Cultural Economics 37, 109–151.

Milfont, T.L., Sibley, C.G., 2012. The big five personality traits and environmental engagement: Associations at the individual and societal level. Journal of Environmental Psychology 32, 187–195.

Mills, B., Schleich, J., 2012. Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries. Energy Policy 49, 616–628.

Mullainathan, S., Shafir, E., 2013. Scarcity: Why having too little means so much. Time Books, New York, NY.

Nair, G., Gustavsson, L., Mahapatra, K., 2010. Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy 38, 2956–2963.

Nature Energy Editorial of February 5, 2016. Green gold. Nature Energy 1, 16011.

Obschonka, M., Schmitt-Rodermund, E., Silbereisen, R.K., Gosling, S.D., Potter, J., 2013. The regional distribution and correlates of an entrepreneurship-prone personality profile in the United States, Germany, and the United Kingdom: A socioecological perspective. Journal of Personality and Social Psychology 105, 104.

Obschonka, M., Stuetzer, M., Gosling, S.D., Rentfrow, P.J., Lamb, M.E., Potter, J., Audretsch, D.B., 2015. Entrepreneurial regions: Do macro-psychological cultural characteristics of regions help solve the "knowledge paradox" of economics? PloS one 10, e0129332. doi:10.1371/journal.pone.0129332.

Ovchinnikova, N.V., Czap, H.J., Lynne, G.D., Larimer, C.W., 2009. "I don't want to be selling my soul": Two experiments in environmental economics. The Journal of Socio-Economics 38, 221–229.

Parag, Y., Sovacool, B.K., 2016. Electricity market design for the prosumer era. Nature Energy 1, 16032.

Poortinga, W., Steg, L., Vlek, C., Wiersma, G., 2003. Household preferences for energy-saving measures: A conjoint analysis. Journal of Economic Psychology 24, 49–64.

Preacher, K.J., Hayes, A.F., 2008. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior research methods 40, 879–891.

Preacher, K.J., D.D. Rucker, A.F. Hayes, 2007. "Addressing moderated mediation hypotheses: Theory, methods, and prescriptions." Multivariate behavioral research 42, 185-227.

Ramos, A., Gago, A., Labandeira, X., Linares, P., 2015a. The role of information for energy efficiency in the residential sector. Frontiers in the Economics of Energy Efficiency 52, Supplement 1, S17–S29.

Ramos, A., Labandeira, X., Löschel, A., 2015b. Pro-environmental Households and Energy Efficiency in Spain. Environmental and Resource Economics 63, 367–393.

Ryan, L., Selmet, N., Aasrud, A., 2012. Plugging the energy efficiency gap with climate finance, in: International Energy Agency Insights Series 2012. IEA. Paris, France.

Qiu, Y., Colson, G., Grebitus, C., 2014. Risk preferences and purchase of energy-efficient technologies in the residential sector. Ecological Economics 107, 216–229.

Quintelier, E., 2014. The influence of the Big 5 personality traits on young people's political consumer behavior. Young Consumers 15, 342–352.

Steg, L. (2016). Behaviour: Seeing heat saves energy. Nature Energy, 1, 15013.

Stern, P. C., Janda, K. B., Brown, M. A., Steg, L., Vine, E. L., & Lutzenhiser, L. 2016. Opportunities and insights for reducing fossil fuel consumption by households and organizations. Nature Energy, 1, 16043.

Swami, V., Chamorro-Premuzic, T., Snelgar, R., Furnham, A., 2010. Egoistic, altruistic, and biospheric environmental concerns: A path analytic investigation of their determinants. Scandinavian Journal of Psychology 51, 139–145.

Young, W., Hwang, K., McDonald, S., Oates, C.J., 2010. Sustainable consumption: green consumer behaviour when purchasing products. Sustainable Development 18, 20–31.

Zhao, H., Seibert, S.E., Lumpkin, G.T., 2010. The relationship of personality to entrepreneurial intentions and performance: A meta-analytic review. Journal of

Management 36, 381–404.

Tables and figures

Table 1: Hypotheses

	EE investment		PEB	
	Risk	EC	Risk	EC
Openness	+	+	+	+
Conscientiousness	-	0/+	0/-	+
Extraversion	+	0	0	+
Agreeableness	-	+	-	+
Neuroticism	-	0	0	0

Note: This table presents the hypotheses for the mediation of the Big Five traits through risk and environmental concern (EC) on EE investment and pro-environmental behaviour (PEB), respectively (+/-/0: positive/negative/neutral relationship).

Table 2: Mediation effects of the Big Five traits on EE investments (M1)

Log-odds	Risk	EC	Risk+EC	Direct	Total
Openness to experience	0.017*	0.035*	0.052*	0.003	0.055
	0.001; 0.034	0.024; 0.051	0.03; 0.074	-0.083; 0.091	-0.03; 0.142
Conscientiousness	0	-0.008*	-0.007*	0.05	0.043
	-0.002; 0.004	-0.016; -0.001	-0.016; 0	-0.034; 0.138	-0.043; 0.131
Extraversion	0.01*	-0.006	0.004	-0.013	-0.008
	0.001; 0.024	-0.014; 0.001	-0.009; 0.018	-0.095; 0.075	-0.09; 0.083
Agreeableness	-0.007*	0.014*	0.007	-0.065	-0.059
	-0.015; -0.001	0.006; 0.023	-0.005; 0.018	-0.154; 0.018	-0.149; 0.024
Neuroticism	-0.018*	0.011*	-0.007	0.008	0.001
	-0.036; -0.002	0.003; 0.019	-0.026; 0.011	-0.08; 0.095	-0.084; 0.081

*$p < 0.05$

Note: This table presents the mediation effects through risk, environmental concern (EC), the direct and total effects (Risk+EC+Direct effect) in log-odds for each personality trait on EE investments, based on Model 1 ($N = 6,083$). Bias-corrected 95% confidence intervals from 5,000 bootstrap samples are reported under each of the effects.

Table 3: Mediation effects of the Big Five traits on EE investments, conditionally on households' income (M2)

Log-odds	Risk			EC			Risk+EC			Direct	Total		
	L	M	H	L	M	H	L	M	H		L	M	H
Openness to experience	-0.012	0.007	0.025*	0.029	0.034*	0.039*	0.018	0.041*	0.064*	0.003	0.021	0.044	0.067
	-0.066; 0.047	-0.017; 0.032	0.001; 0.049	-0.041; 0.102	0.015; 0.057	0.001; 0.083	-0.066; 0.102	0.01; 0.073	0.021; 0.109	-0.088; 0.099	-0.091; 0.145	-0.044; 0.137	-0.028; 0.166
Conscientiousness	0	0	0.001	-0.006	-0.007*	-0.008*	-0.007	-0.007*	-0.008	0.05	0.043	0.042	0.042
	-0.008; 0.003	-0.001; 0.004	-0.003; 0.006	-0.033; 0.007	-0.018; -0.001	-0.026; -0.001	-0.034; 0.007	-0.018; -0.001	-0.025; 0.001	-0.038; 0.137	-0.046; 0.132	-0.046; 0.13	-0.047; 0.13
Extraversion	-0.007	0.004	0.016*	-0.005	-0.006*	-0.007	-0.012	-0.002	0.009	-0.015	-0.027	-0.016	-0.006
	-0.043; 0.029	-0.011; 0.021	0.001; 0.032	-0.028; 0.005	-0.016; 0	-0.023; 0	-0.051; 0.03	-0.019; 0.016	-0.014; 0.027	-0.102; 0.08	-0.124; 0.077	-0.105; 0.083	-0.093; 0.09
Agreeableness	0.005	-0.003	-0.01*	0.011	0.013*	0.015*	0.016	0.01	0.005	-0.064	-0.048	-0.054	-0.06
	-0.019; 0.029	-0.014; 0.007	-0.022; -0.001	-0.014; 0.045	0.005; 0.026	0.001; 0.037	-0.023; 0.057	-0.004; 0.026	-0.015; 0.029	-0.147; 0.023	-0.141; 0.046	-0.138; 0.032	-0.144; 0.026
Neuroticism	0.012	-0.007	-0.027*	0.009	0.01*	0.011*	0.021	0.003	-0.015	0.008	0.029	0.011	-0.007
	-0.048; 0.07	-0.034; 0.018	-0.052; -0.001	-0.01; 0.038	0.003; 0.022	0.001; 0.032	-0.048; 0.086	-0.026; 0.03	-0.044; 0.018	-0.08; 0.095	-0.076; 0.13	-0.076; 0.096	-0.095; 0.08

*$p < 0.05$

Note: This table presents the mediation effects through risk, environmental concern (EC), the direct and total effects (Risk+EC+Direct effect) in log-odds for each personality trait on EE investments, conditionally on the households' income, based on Model 2 ($N = 6{,}083$). The conditional effects for risk and EC are calculated for three different values of the households' income: $1.\ mean(income) - SD(income)$ (**L**) $2.\ mean(income)$ (**M**) $3.\ mean + SD(income)$ (**H**) with $SD = Standard\ deviation$. The bias-corrected 95% confidence intervals from 5,000 bootstrap samples are reported under each of the effects.

Table 4: Mediation effects of the Big Five traits on pro-environmental behaviour (M1)

	Risk	EC	Risk+EC	Direct	Total
Openness to experience	0.002	0.003*	0.005*	0.007	0.012
	0; 0.004	0.001; 0.005	0.002; 0.008	-0.008; 0.02	-0.003; 0.026
Conscientiousness	0	-0.001*	-0.001*	0.02*	0.019*
	-0.001; 0	-0.002; 0	-0.003; 0	0.007; 0.034	0.005; 0.032
Extraversion	0.001	-0.001*	0.001	-0.015*	-0.015*
	0; 0.003	-0.002; 0	-0.002; 0.003	-0.029; -0.002	-0.028; -0.001
Agreeableness	-0.001	0.002*	0.001	0.008	0.009
	-0.002; 0	0.001; 0.003	-0.001; 0.002	-0.005; 0.023	-0.005; 0.023
Neuroticism	-0.002	0.001*	-0.001	0.002	0
	-0.005; 0	0; 0.002	-0.005; 0.001	-0.012; 0.016	-0.013; 0.015

*$p < 0.05$

Note: This table presents the mediation effects through risk, environmental concern (EC), the direct and total effects (Risk+EC+Direct effect) for each personality trait on pro-environmental behaviour, based on Model 1 ($N = 3,665$). Bias-corrected 95% confidence intervals from 5,000 bootstrap samples are reported under each of the effects.
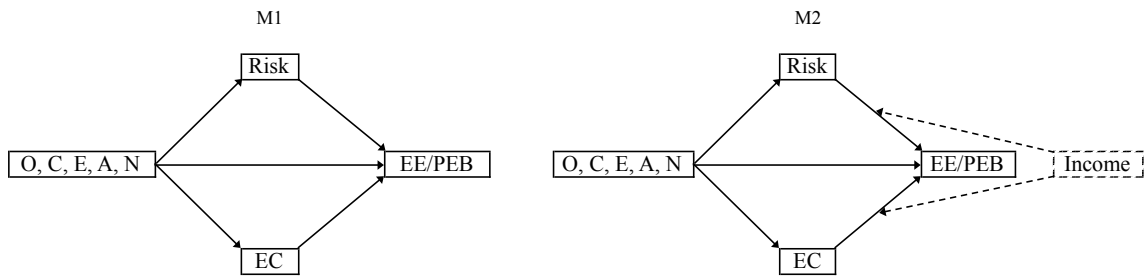
Table 5: Mediation effects of the Big Five traits on pro-environmental behaviour, conditionally on households' income (M2)

	Risk			EC			Risk+EC			Direct	Total		
	L	M	H	L	M	H	L	M	H		L	M	H
Openness to experience	0.011*	0.005*	-0.001	0.005	0.004*	0.002	0.015*	0.008*	0.001	0.006	0.021*	0.014	0.007
	0.001; 0.02	0.001; 0.008	-0.006; 0.002	-0.006; 0.016	0.001; 0.007	-0.004; 0.008	0.001; 0.029	0.003; 0.012	-0.006; 0.008	-0.008; 0.021	0.002; 0.042	-0.001; 0.03	-0.008; 0.023
Conscientiousness	-0.001	0	0	-0.002	-0.001*	-0.001	-0.002	-0.001	-0.001	0.02*	0.018*	0.019*	0.02*
	-0.004; 0.001	-0.002; 0	0; 0.001	-0.006; 0.001	-0.003; 0	-0.004; 0.001	-0.008; 0.002	-0.003; 0	-0.004; 0.001	0.007; 0.034	0.003; 0.033	0.005; 0.032	0.005; 0.033
Extraversion	0.008*	0.003*	-0.001	-0.001	-0.001*	-0.001	0.006	0.002	-0.002	-0.015*	-0.008	-0.012	-0.016*
	0.001; 0.015	0.001; 0.006	-0.004; 0.002	-0.007; 0.001	-0.003; 0	-0.003; 0.001	-0.002; 0.015	-0.001; 0.006	-0.006; 0.002	-0.029; -0.001	-0.023; 0.008	-0.026; 0.003	-0.03; -0.003
Agreeableness	-0.004*	-0.002*	0.001	0.002	0.002*	0.001	-0.002	0	0.002	0.008	0.006	0.008	0.01
	-0.01; -0.001	-0.004; 0	-0.001; 0.003	-0.003; 0.008	0; 0.004	-0.002; 0.005	-0.01; 0.005	-0.003; 0.002	-0.001; 0.006	-0.005; 0.023	-0.009; 0.023	-0.005; 0.022	-0.004; 0.025
Neuroticism	-0.013*	-0.006*	0.002	0.001	0.001*	0.001	-0.011	-0.005	0.002	0.002	-0.01	-0.003	0.004
	-0.024; -0.001	-0.01; -0.001	-0.003; 0.007	-0.001; 0.006	0; 0.003	-0.001; 0.003	-0.023; 0.001	-0.009; 0	-0.003; 0.008	-0.012; 0.015	-0.028; 0.007	-0.017; 0.011	-0.009; 0.018

*$p < 0.05$

Note: This table presents the mediation effects through risk, environmental concern (EC), the direct and total effects (Risk+EC+Direct effect) for each personality trait on pro-environmental behaviour, conditionally on the households' income, based on Model 2 ($N = 3,665$). The conditional effects for risk and EC are calculated for three different values of the households' income: 1. $mean(income) - SD(income)$ (**L**) 2. $mean(income)$ (**M**) 3. $mean + SD(income)$ (**H**) with $SD = Standard\ deviation$. The bias-corrected 95% confidence intervals from 5,000 bootstrap samples are reported under each of the effects.

Figure 1: Mediation Models M1 and M2

M1

M2

Note: Models of the Big Five traits (Openness to experience (O), Conscientiousness (C), Extraversion (E), Agreeableness (A), Neuroticism (N)) mediation through risk and environmental concern (EC) on EE investment (EE) and pro-environmental behaviour (PEB), respectively.

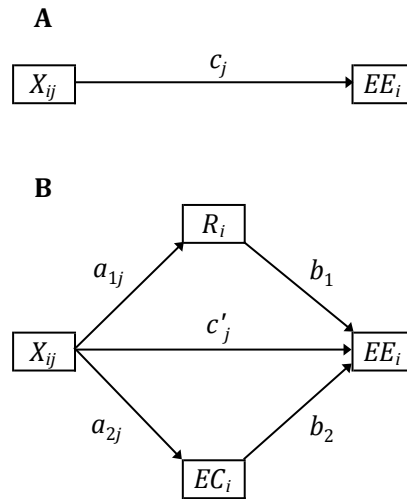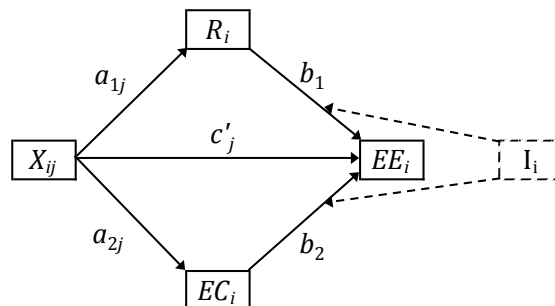## Figure 2: Mediation of personality traits on EE investments

A

B

Figure 3: Mediation of personality traits on EE investments including income as moderator (M2)

Supplementary material

A. Stability of personality traits

We checked the stability of personality traits following Cobb-Clark and Schurer (2013) and Brown and Taylor (2014). Our dataset contains 7,554 participants for whom we were able to match the Big Five responses in BHPS-2005 and in Wave 3 (2011-2012) of Understanding Society. The average responses for each trait are presented in the second and third column of Table 6. For each individual we constructed the measure of the change in a personality trait as $\Delta Trait_j^i = Trait_{j2011}^i - Trait_{j2005}^i$, where i-individual, j=Openness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Each of the Big Five traits is measured on the 7-point scale, which implies that the difference can range from -6 to 6. The mean change (forth column in Table 6) ranges from -0.149 to 0.198 with a standard deviation of about 1. The mean proportional change is very low: between 1.59% and 6.64%. The median of the change (50th percentile) is zero. This suggests that the personality traits measured by Big Five remain stable for a period of at least 6 years. This result is consistent with the conclusions of the Cobb-Clark and Schurer (2013) study using the Australian Household, Income and Labour Dynamics survey and of the Brown and Taylor (2014) study using the British Household Panel Survey and the Understanding Society datasets.

Table 6: Stability of personality traits

| | Level | | Changes between 2005 and 2011 | | | | | | | |
| | Mean | | | | | Percentile of distribution | | | | |
	2005	2011	Mean	St. dev.	% change	1st	25th	50th	75th	99th
Openness to experience	4.490	4.464	-0.028	1.151	4.57	-3.000	-0.667	0.000	0.667	3.000
Conscientiousness	5.291	5.495	0.198	1.079	6.64	-2.667	-0.333	0.000	0.667	3.000
Extraversion	4.477	4.603	0.123	1.079	6.37	-2.667	-0.667	0.000	0.667	3.000
Agreeableness	5.450	5.624	0.175	0.982	5.41	-2.333	-0.333	0.000	0.667	2.667
Neuroticism	3.683	3.538	-0.149	1.182	1.59	-3.000	-1.000	0.000	0.667	3.000

B. Stability of risk preferences

Unfortunately, there is no British longitudinal data on risk preference that would allow us to perform stability analysis of risk preference over 3-4 years similar to personality traits (Cobb-Clark and Schurer, 2013; Brown and Taylor, 2014). Instead, we have to explore the differences in risk preferences between different ages and try to make inferences of what will happen as people get 3-4 years older. We have the risk data for BHPS-2008 (Wave 18) and Understanding Society-2009 (US-2009). We are interested in whether/how their risk preference changed by 2012. In both datasets we find negative and statistically significant at 1% correlation between age and risk, meaning that as people age, they become more risk averse.

In the 2008 dataset, the ages of the respondents vary 15-99 years and in the 2009 dataset, the ages vary 16-98. We cut the ages which have less than 10 observations, which left us with the range of 15-91 in 2008 and 16-94 in 2009. For each age, we calculated the mean risk preference. After that we calculated the difference between the mean scores of people 4 and 3 years apart in the 2008 and 2009 datasets, respectively, to bring them to 2012: $\Delta \overline{Risk}_g^{2008} = \overline{Risk}_g^{2008} - \overline{Risk}_{g-4}^{2008}$ and $\Delta \overline{Risk}_g^{2009} = \overline{Risk}_g^{2009} - \overline{Risk}_{g-3}^{2009}$, where g is the age of the participant. This is done under the assumption that risk preferences will change by the average difference in risk preferences between the age groups 3 years and 4 years apart in 2008 and 2009, respectively.

As evident from the second and third rows of Table 7, the mean differences in risk attitudes are quite small in absolute and relative value (% change). In over 75% of the age groups, the risk preference is lower for older people. We performed a similar analysis on the subset of US-2009 that we are using in the model. After removing the age groups with less than 10 observations, we were left with the range of 26-87 years old. In this subset, the difference in the risk preference is even smaller than in the full sample (see the fourth row of Table 7). We conclude that the risk preferences are likely to be stable across the period of 3-4 years with some tendency to go down as people age.

Table 7: Stability of risk preferences

	Difference in years	# of observations	Mean difference	Standard deviation	% change	Percentiles				
						1st	25th	50th	75th	99th
BHPS-2008	4	12,714	-0.145	0.297	-2.441	-0.836	-0.331	-0.160	-0.008	0.632
US-2009	3	39,419	-0.124	0.243	-2.368	-0.680	-0.244	-0.098	-0.010	0.616
Subset of US-2009	3	6,083	-0.075	0.451	-1.017	-1.015	-0.389	-0.086	0.123	1.050

References

Brown, S., Taylor, K., 2014. Household finances and the "Big Five" personality traits. Journal of Economic Psychology 45, 197–212.

Cobb-Clark, D.A., Schurer, S., 2012. The stability of big-five personality traits. Economics Letters 115, 11–15.