WHAT INFLUENCES THE EFFECTIVENESS OF WATER-SAVING INSTRUMENTS?

Data analysis of the Green Doctor program in South England

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Abstract

This study aims to investigate what determined the kind and type of water saving devices households in the South East of England received during the socalled Green Doctor (GD) program for water conservation. By doing multiple regressions, including control variables, interaction terms and a placebo test, an increase in received devices by households that are more eco conscious was observed. Therefore, trainings for the GDs should work to motivate other households to be more eco-conscious so that these households ask for more devices, ultimately leading to water conservation. Moreover, it was found that households that already had sustainable devices (such as a sustainable toilet and shower head) in place, were predicted to receive less devices. The final significant effect that was found was the large variability between different GDs on the distributed devices. Since previous research showed that technological devices have a stable and persistent effect on water conservation, some GDs that showed negative significant effects could be better instructed in order to install and issue more devices to households, leading to a more efficient functioning program.

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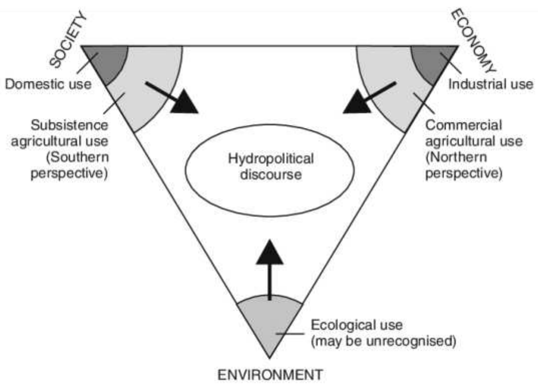
1. Introduction

1.1 Problem statement

Water scarcity is a major global problem. Although 70% of the earth consists of water, growing populations will increase the pressure on the availability to clean tap water (Gosling & Arnell, 2016). Not only rising water demands due to growing populations but also the quantity of available water is affected due to climate change resulting in even larger water shortages. Gosling and Arnell (2016) have used different climate change scenarios and models to calculate water scarcity, and they showed that around 3.1 billion people would be affected by water scarcity by 2050. In addition, water is a crucial resource for promoting sustainable development of countries and regions through better health and environmental quality. Therefore, one of the central United Nations Millennium goals (MDGs) is ensuring availability and sustainable water and sanitation management for everyone (Rieckmann, 2017).

Over the past two hundred years, extensive use of water and pollution due to industrialization has put even greater pressure on the availability of clean water. Moreover, the large-scale global agriculture industry requires large amounts of water for irrigation. This combined demand for water is one of the three dimensions in shaping the so-called hydro political discourse. As illustrated in figure 1, the hydropolitical discourse is affected by 1) the society, 2) the economy, and 3) the environment. These three dimensions should be in balance to manage water scarcity. Political interventions and resource allocations are examples that could be used to manage the water resource in a sustainable way (Mukheibir, 2010).

Figure 1. Hydropolitical discourse (Mukheibir, 2010).



The Intergovernmental Panel on Climate Change (IPCC) warns that climate change will result in significant variability of global weather patterns. This means that particular regions in the world will have to deal with heavy rainfall, while other areas have to deal with great drought. Due to the extensive water use, especially by developed countries, water will become scarcer in the future (Eckstein, 2009). Although industry and agriculture account for the largest share of the water demand, domestic use represents

10 to 30% of overall water consumption in developed countries. Water supply projects are very costly, and therefore interventions and policies focusing on the demand side to promote water conservation are preferred by many countries (Millock & Nauges, 2010). The use of social comparison messages (SCM) and water-efficient technologies have shown to be effective in changing consumer's behavior (Thaler & Sustein, 2008; Bennear & Olmstead, 2008). Also, price policies can promote water conservation. Economists emphasize that the scarcity of water could be addressed by raising water prices. However, due to political or regulatory constraints (zero profit constraints), prices often cannot be easily raised (Brent et al., 2015).

The installation of water meters at households is needed to measure the water consumption of consumers and the impact of providing information on water conservation. Climate change scenarios suggest that drought will occur in the South East of England (Dessay & Sims, 2011). Since households in the UK do not have their own water meters but pay a fixed tariff, it is hard to motivate consumers to change their behavior. Therefore, a Universal Metering Programme (UMP) was launched in South East England, during which water meters were installed in houses between 2010 to 2015. Along with these meters, so-called Green Doctors (GDs) were hired to advise households on saving water and offering households water-saving devices. Previous research done by Ansink, Ornaghi, and Tonin (2021) showed that visits from the GD affect the household's water consumption. However, the impact of the visits is fading over time, resulting in a modest overall reduction (Ansink et al., 2021). Next to the informational component of the visits from the GD, the GD also provides technological water-saving devices to the concerned households. It shows that the effects of these devices, such as save-a-flush bags, shower timers, water flows, and pressure-reducing devices, in the short run are very strong. Moreover, the reduction effects due to mechanical water-saving devices, such as the save-a-flush bags, keep constant and significant in the long run.

1.2 Objective and research questions

The previous research done by Ansink et al. (2021) already showed the effects of the visits of the GD's along with the provision of water devices on the water consumption of households. However, it is not a randomized controlled experiment because the devices handed out to the treated households were not randomly assigned. This could result in an endogeneity problem: the number of devices issued and installed in each household is then determined by the interaction between the household and the GD that visited the household. Therefore, this study aims to capture the endogeneity problem by using the same data as Ansink et al. (2021) and by identifying how the kind and number of water-saving devices were determined for a specific household. The question is whether the amount and type of water-saving devices are dependent on the visit of a particular Green Doctor; whether they dependent on the level of greenness of a household; whether they dependent on the income level of a household; whether they dependent on the devices the households already own? (e.g., a dual flush toilet); whether they dependent on certain kinds of housing characteristics?

The following research questions will be addressed to meet these objectives:

- Does the level of greenness impact the kind and number of water-saving devices that households issued/installed?
- Do specific devices the households already have in place, impact the kind and number of water-saving devices that households issued/installed?
- Does the visit of a particular GD impact the kind and number of water-saving devices that households issued/installed?

Looking at the interaction between these variables and the water-saving devices that have been issued and installed, the degree of impact of specific variables can be determined. This degree of impact is essential for the functioning of the policy. For example, suppose the impact of the GD on the water-saving devices issued/installed turns out to be very strong. In that case, the number of devices being issued/installed is strongly dependent on the type of GD that visited the household. If a lower interaction is found, GDs must be better instructed in order to motivate households to install and use technological devices.

On the other hand, if the type of GD turns out to have no significant effect on the issued and installed devices, which means that this informational component of the program is not as effective as assumed by Ansink et al. (2021). On the other hand, if this study shows that the level of greenness of a household strongly impacts the number of devices this household received, this would have major policy implications. This means that more environmentally conscious households have also received more devices and that the policy of using water-efficient technologies (water-saving devices) works better for them. The program's focus should then be more on motivating households to become more environmentally conscious to save water.

1.3 Outline of the research

As described above, this thesis research aims to elaborate more on the research done by Ansink et al. (2021) on the effect of GD visits and the provision of water-saving devices on the water consumption of households. Therefore, the different designs of water-saving programs will be included in chapter 2. In chapter 3, the methodology follows, which introduces the used datasets and variables, and presents the economics of what criteria the Green doctors may use in distributing devices amongst households. Chapter 4 presents the empirical results of the data analysis. To conclude, the chapter provides the conclusion and discussion with limitations and recommendations for future research.

2. Literature review

To limit the future water shortage, people must change their behavior. Different policies may be adopted, such as technological devices, informational-based instruments, market-based instruments, and regulations. In order to force down the demand for water or energy, traditional economists focused mainly on market-based approaches such as price increases because this instrument causes fewer welfare losses than restrictions on energy or water use (Roibás et al., 2007; Grafton and Ward, 2008). However, policymakers and water utility managers often prefer water use restrictions over higher prices because restrictions on water use would guarantee an immediate response (Ferraro & Price, 2013). Neoclassical economists assume individuals to be rational, have complete information, and maximize their utility, which could mean that informational-based environmental policy strategies are ineffective (Ferraro & Miranda, 2013). However, behavioral economics (BE) has shown that consumers are rational to only a limited extent, have incomplete information, and that their decision-making is firmly dependent on the context of the decision. This makes it possible to bring the complexity of consumer behavior into policymaking (Brent & Ward, 2019). Therefore, information-based environmental policy strategies, such as persuasive messages and changes to default options, have shown to be effective in changing policy-relevant behavior (Bennear and Olmstead, 2008; Allcott and Mullainathan, 2010). There is much evidence of the short-run effects of these policies; however, evidence about the long-run impact is much more limited. Different policies on changing consumer behavior will be shortly discussed below, including some evidence on the short- (+- 2 months after implementation of the policy) and long-run effects(+- 6-12 months after policy implementation).

2.1 Technological devices

Technological devices have turned out to be effective in water conservation for different reasons. Firstly, the water in developed countries is mainly consumed through appliances, which makes it easy to install the devices. Secondly, policies to promote the installation of water-efficient devices have been more accepted than price policies. Third, other non-price policies than devices, such as informational campaigns, seem to be little effective due to consumption habits (Thogersen and Ölander, 2002). Studies show that implementing technological water-saving devices is efficient in water conservation, however less efficient compared to the capacities of the devices themselves. The reason for this could be offsetting behavior. There are also strong suggestions that people are more likely to offset their behavior when they know the devices result in water conservation. Following the studies done by Campbell et al. (2004), Olmstead & Stavins (2009), and Millock & Nauges (2010), the provision of technological water-saving devices would not be as adequate as previously thought due to offsetting behavior. For example, when a low-flow showerhead is provided, consumers may take longer showers without feeling guilty. Also, Alpízar, Del Carpio, Ferraro, and Meiselman (2020) researched the effects of the installation of low-flow water fixtures in Costa Rica in 2015. Their experiment showed that the impact of conserving technologies could be over-or underestimated because these technologies are based on engineering estimates that do not consider consumer behavior. The studies previously discussed also showed that the implementation of technological devices may not be persistent over time. Still, Ansink et al. (2021) showed in their analysis that technological water-saving devices are very effective because devices save water mechanically without any effort by the consumers.

2.2 Informational-based instruments

A widely-known policy in changing behavior is informational messaging. The so-called social comparison messaging (SCM) is used in many studies in energy or water conservation (Allcott, 2011; Allcott & Rogers, Ayres et al., 2013; Brent et al., 2015; Brent et al., 2020; Ferraro & Price, 2013). The findings from these studies have shown small effects of the social comparisons on energy or water consumption and that these effects become more persistent as the messages continue (Allcott & Rogers, 2014). Allcott & Rogers (2014) also show that high-use households show more strong effects, which indicates that the effectiveness of the SCMs depends on the strength of the difference between, e.g., the water use of a household compared to a control group. Brent et al. (2020) have therefore studied what exactly determines the heterogeneity in the treatment effects, for example, the type of household. They used a new sort of SCMs where the comparison between the control and treatment group is made in percentages instead of absolute terms. They find that it is true that for high-use households, the treatment effects are more substantial due to the strength of the normative message the households received.

Moreover, they find that the new SCMs are also effective for low-use households because they have never put any effort into former water conservation policies. However, it is still not clear whether these effects keep persistent over time. Another sort of informational messaging is raising public awareness. Browne, Gazze, and Greenstone (2020) measured the efficiency of using different policies to reduce residential water consumption in California between 2011 and 2017. They find that increases in public awareness, such as making people aware of the drought in California, were associated with declines in water consumption. They use one-time announcements, such as the declaration of being in the State of Emergency due to drought, by the Californian governor. However, Browne et al. (2020) have not researched the long-run effects of this public awareness either.

2.3 Market-based instruments

As mentioned previously, traditional economists believe that price changes are the most effective instruments to change consumer behavior. Browne et al. (2020) researched the effects of changes in marginal, fixed, and average prices. They show that consumers respond more strongly to average prices than marginal prices, which is consistent with other literature findings (Ito, 2013; Ito, 2014; Wichman, 2014). If there is nonlinear pricing, it means that consumers cannot choose optimally. They find that rising water prices explain 40-44% of the water conservation in Fresno between 2013-2016. However, low-income households may be hit harder by these price increases and may be punished harder than higher-income households. There is also much evidence that the price elasticities of water demand are very inelastic, meaning that the water demand will not react strongly to price increases (Olmstead et al., 2007; Worthington & Hoffman, 2008). Olmstead and Stavins (2009) find that raising prices for water conservation is politically complex. For example, in a city in the United States, the city council decided to increase the water prices with the marginal costs after two years of drought. After one year, the council was not re-elected due to the water price increase (Hall, 2000). Wichman et al. (2016) show that a price increase from $10 to $13.40 per thousand gallons, a 34% increase, reflects the same reduction (namely 8.5%) in water consumption as implementing voluntary watering restrictions. They also show that a 52% price increase reflects the same reduction (namely 13%) in water consumption as implementing mandatory watering restrictions. These significant price increases seem to be effective only in the short run and seem to be unrealistic to be implemented by the municipalities (Wichman et al., 2016).

2.4 Regulations

Regulations, either voluntary or mandatory, are behavioral instruments that seek to alter consumer behavior. A study done by Wichman et al. (2016) suggests that mandatory regulations achieve a 13% reduction in water consumption, while voluntary regulations achieve an 8.5% reduction in water consumption. Both mandatory and voluntary regulations could be very effective instruments and could have more homogeneous outcomes amongst households with different incomes than, for example, a price instrument (Wichman et al., 2016). However, the long-run effects have not been studied by Wichman et al. (2016). Thereby, not all the studies on mandatory regulations have shown positive results. Schultz et al. (1997) have studied the effects of mandatory regulations on landscape irrigations and car washing in Texas in 1996 and have shown that these regulations did not reduce water consumption significantly. Likewise, setting mandatory restrictions on water consumption in Sydney, Australia, resulted in a yearly economic loss of $150 per household, 50% of the annual water bill (Grafton and Ward, 2008). Thereby, mandatory regulations have been much criticized (Campbell et al., 2004). The reason for this is that setting mandatory rules does not resemble the actions of the market and hence less efficient. On the other hand, a recent study done by West et al. (2020) has shown that the use of technology-enforced regulations in combination with informational messaging (water use reports) are promising in altering consumer behaviors and reinforce each other to yield water conservation effects. However, automated enforcement is politically susceptible because it can cause complaints from consumers, and the enforcement might affect consumer's intrinsic motivation for water conservation (West et al., 2020).

The previously discussed studies on the effects of instruments to alter consumer behavior towards water conservation have shown complexity. The long-run effects of the tools have been hardly studied, and every tool has its pros and cons. Ansink et al. (2021) studied the impact of the implementation of technological devices in combination with an informational component of the visits of water audits to households in the South East of England. Climate change scenarios suggest that drought will occur in the South East of England (Dessay & Sims, 2011). A questionnaire conducted in 2006 to explore the public perception of drought in the South East of England found that most participants were willing to change their behavior to conserve water (Dessay & Sims, 2011). However, in order to change people's behavior, incentives are needed. An instrument of changing consumer behavior is the provision of information about water consumption. In order to provide feedback to consumers and monitor the water consumption, the usage of water meters is necessary. Throughout the UK, unmetered households do not have their own water meters, but they pay a fixed tariff. This makes it hard to motivate households to change behavior concerning water savings. Therefore, the Universal Metering Programme (UMP) was set up in the South East of England to install more than 400,000 water meters in households. Next to the installation of the water meters, the so-called GD program was set up, including the advisory of a Green Doctor on conserving water use and the provision of water-saving technological devices. This program was aimed to alter high water use households to be more water conserve. The study done by Ansink et al. (2021) shows that the advisory, combined with the provision of technological devices, affects the water use of households in the short- and long run. Especially the technological devices show a persistent long-term reduction, which can be explained by the fact that it does work without any effort by the consumers themselves (Ansink et al., 2021).

However, Ansink et al. (2021) did not research what criteria the GD's used to distribute the devices. Namely, if there are any criteria, this should be included in the regression because of endogeneity. The endogeneity problem could overestimate the impact of the GD visits and provision of water devices on water conservation. If, for example, the type of Green Doctor determines how many and what type of technological devices the household received, then the training the GD's have completed is a crucial component of the program's effectiveness. Another interesting aspect to look at is whether the visits of the GD's are more effective to more eco-consciousness households. This means that the effectiveness of the GD program is not only dependent on the program itself but also on the type of household that received the technological devices. This could be measured by adding a variable called 'the level of greenness.'

3. Methodology

This chapter explains what datasets and variables were used for the analysis. After that, the used statistical techniques are described.

3.1 Datasets

The dataset available is the monthly water consumption of 24,000 households that a GD between 2010 and 2014 has visited. These households are the so-called Green Doctor Households (GDH). The dataset has been filtered to 9,082 households to have at least twelve consecutive monthly observations. The treated GDH group has been compared to the control group that received a water meter but has not been visited by a GD. Then, Ansink et al. (2021) researched the effect of the visits of the GD and provision of water devices on the water consumption of households with a difference in difference model of the following form: $y_{it} = \sum_{k=1}^{N} \beta_k^{GD}\, \beta_k^{GD}\, GD_{i,t}^{k} + \sum_{k=1}^{N} \beta_k^{WD}\, WD_{i,t}^{k} + \sum_{j=1}^{35} \gamma_j\, I_t^{j} + \mu_i + \mu_\tau + u_{it}$.

The provision of water-saving devices shows a stable and persistent effect, as the informational component (the visits of the GDs) shows a reduction but is fading over time. This implies that the number of technological devices received directly impacts the water consumption of households. However, it has not been researched what determines which type and how many water-saving devices a household gets. This could be solved by finding explanatory variables that determine the number of technological devices a household received. The different water-saving devices issued have been divided into three groups: ' water flow and pressure devices', including tap aerators, showerheads and shower regulators, 'save-a-flush bags', and 'shower timers '.

3.2 Index for household's level of greenness

The level of sustainability of a household or the visit of a particular GD could determine the number and kind of devices they received. Therefore, an index was made to measure the level of greenness. Five indicators were selected from the dataset to measure a household's level of greenness with different explanations:

1. <u>What temperature does the household generally wash its clothes at?</u>

About 90% of the energy used is for heating during laundry washing (Trust, 2020). Therefore, the lower the temperature, the lower the energy use during laundry washing. Hence, the temperature of washing is a good indicator of the level of a household's eco-consciousness.

2. <u>Does the household usually wash a full load?</u>

The fuller the load in the washing machine, the more energy is used. However, half loads work less efficiently per garment-washed than full loads. Therefore, washing full load is also a good indicator of eco-consciousness.

3. How many baths does the household take in comparison to the showers taken per week?

A full bath uses more water than taking a shower. For example, a 10-minute shower generally uses 25 gallons of water, while a full bath can use up to 70 gallons of water. Therefore, the number of baths taken compared to the showers taken by the household is a good estimator of being sustainable with water.

4. Does the household run the tap while cleaning their teeth?

If a person would brush two times a day and run the tap while cleaning teeth, it would waste 24 liters of water per day (*Save Water – Waterwise*, 2020). The household receives a 1 if running the tap while cleaning their teeth, or 0 otherwise.

5. Does the household run the tap while washing the dishes?

The same applies here as running the tap while cleaning teeth. If the household keeps running the tap while washing dishes, the household receives a 0. If the household does not run the tap while washing the dishes, it receives a 1.

The treated households received a number between 0 and 1 for all 5 indicators for greenness. Taking the sum of these scores resulted in a 'level of greenness' between 0 and 5. Thus, a household that scored poorly on all five indicators was labeled as 'unsustainable'. Conversely, a household that scored well on all five indicators was labeled 'very sustainable'.

The hypothesis is that greenness can impact the number of technological devices the household has received. If people are more aware of sustainability, it will make sense that they would ask for more technological devices to save water and be more sustainable. Therefore, the formulated hypothesis is: The higher the level of greenness of a household, the more technological devices they receive. Regression analysis was done to check whether this hypothesis holds: $z_{it} = \beta_0 + X_{i,t}^k + u_{it}$, where $z_{it}$is the number of technological devices the household received, and $X_{i,t}^k$ is the level of greenness indicator of a household. Alternatively, another assumption made is that greener households would already have multiple devices, and therefore the greener a household is, the fewer devices the household receives. To test this, another regression was done controlling for the devices the household already has in place.

3.3 What do the households already have in place?

Control variables were added to the simple regression model to check whether the amount and kind of devices households received are dependent on the type of devices the households already have. For example, some households already have a dual flush or a sustainable type of showerhead in place. This could mean that these households would receive less technological devices.

Therefore, a check was needed to find out whether the type of toilet flush that the households already have in place, determines the number of save-a-flush bags the households received. Data of liters used per flush of a household were used to determine the type of toilet flush the households have. However, some households had toilets in place where save-a-flush bags did fit in their toilets. These households were therefore ignored in this analysis. The only households left then were the households where save-a-flush bags fit in their toilet. A dual-flush uses approximately 5 liters per flush, whereas a single flush uses 11 liters on average (Haavelmo, 2009). Also, some of the households already had a save-a-flush bag in place, resulting in a reduction of around 8 litres/day (Ansink et al., 2021). Therefore, a new index was made to make a distinction between 'sustainable toilets' (using < 6 liters per flush) and 'less sustainable toilets' (>6 liters per flush). The assumption made is that households with a sustainable toilet would receive fewer technological devices, more specifically fewer save-a-flush bags.

For the shower heads the households own, a distinction was made between three types of shower heads that the households already possess, namely an electric, power or standard mixer shower head. For the different types of showerheads, data was collected for the liters used per shower. Therefore, a regression was done with the type of shower head on liters used per shower to determine the least water-efficient showerhead, the modest water efficient and the most water-efficient showerhead.

Multiple regression analysis was done to check whether the type of showerhead and type of toilet flush the households already own impact the technological devices issued and installed. When it turned out to have a significant impact, the variable determining the type of showerhead owned by the households should be added to the regression model.

3.4 Measuring the effect of Green Doctors on devices

To calculate whether the type of Green Doctor that visits the houses determines the number of technological devices the household received, data of the specific GD that visited the household was collected. Then, a simple regression analysis was done: $z_{it} = \beta_0 + \beta_1 TGD_{i,t}^{k} + u_{it}$, where z_{it} is the number of technological devices the household received, and $TGD_{i,t}^{k}$ is an indicator of the GD that visited the household.

3.5 Placebo test

Also, it can be tested whether the variable of having a garden or not impacts the devices being installed/issued. The assumption made was that this impact should be equal or close to zero because the water-saving devices being given do not apply to the water used in the garden. Moreover, the rateable value can be used as a proxy for a household's income. It is widely known that people with higher incomes usually consume more water. However, this should not affect the number of issued/installed devices. Therefore, a dummy for having a garden as well as a variable for the rateable value were added to the model as estimators for the placebo test.

3.6 Interaction terms

In the analyses done, interaction effects could potentially influence the relationship between the independent and dependent variables. Therefore, interaction terms were included in the regression model, as well. An interaction term between *sustainable_toilet* and *level_greenness* was created because of the assumption that the impact of having a sustainable toilet in place on the amount of received devices could be different for different household levels. Also, an interaction term was made between *shower types* and *level_greenness* as the effect of having a sustainable shower head in place on the amount of received devices could be different for different levels of greenness. At last, an interaction term was made between *shower types* and *sustainable_toilet,* as the effect of having a sustainable shower head on the amount of received devices could be different for households with a sustainable toilet in place.

4. Results

This chapter presents the results of the data analysis done with STATA.

4.1 The impact of level of greenness

Using the five different indicators to measure a household's eco-consciousness, an index for 'level of greenness' was made. Table 1 shows the levels of greenness in the households, where a level of 0 displays households that are not green at all, whereas a level of 5 displays very green households. As shown in table 1, only 9.5% of the households is not very green (< 2), 75.5% of the households is modest green (2-4), and 15% of the households are quite to very green (4-5).

Table 1. Overview of levels of greenness

Level of greenness

	Percent	Cum.
0	0.00	0.00
1	0.85	0.85
1-2	8.63	9.48
2-3	30.96	40.44
3-4	44.48	84.92
4-5	15.07	100.00
Total	100.00	

To check whether the level of greenness impacts the number of devices being handed out to the households, a linear regression was done. Table 2 column (1) shows the results of the regression. The number of devices handed out is between 0 and 8 devices. The outcomes indicate that if a household is one level greener (so e.g., from level 1 to 2), a 0.129 unit increase in devices issued/installed is predicted. With a p-value < 0.01, this outcome is statistically significant from zero. This corresponds to the assumption that greener households have received more water devices.

Table 2. Regression on devices

	(1) Issued/installed	(2) Is/ins	(3) savefl	(4) watpre	(5) showtime	(6) Is/ins
level_greenness	.129***	.122***	-.013***	.067***	.056***	.02***
	(.009)	(.009)	(.004)	(.005)	(.003)	(.008)
sustainable_toi~t		-.47***	-.735***	.205***	.033***	-.389***
		(.024)	(.013)	(.013)	(.01)	(.023)
Electric		-.444***	.097***	-.545***	.003	-.553***
		(.014)	(.007)	(.008)	(.006)	(.012)
power		1.148***	.171***	.745***	.258***	.502***
		(.045)	(.018)	(.031)	(.016)	(.037)
standard_mixer_		Base (0)	Base (0)	Base (0)	Base (0)	Base (0)
garden_litres						.004
						(.027)
Rateable value						.004***
						(0)
green_dr						Used dummy variables for different GDs (see appendix A)
_cons	1.806***	2.354***	1.221***	.543***	.658***	1.572***
	(.031)	(.041)	(.021)	(.023)	(.016)	(.05)
Observations	47748	47748	47748	47748	47748	47748
R-squared	.005	.061	.105	.112	.013	.347

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Alternatively, an assumption was made that greener households would already have devices in place, and therefore the greener a household would be, the fewer devices the household would receive. This was tested by doing another regression including control variables for the devices the households already have in place. The control variables that were added were a dummy for the type of toilet (*sustainable_toilet)* and a variable for the type of shower (*electric, power or standard_mixer)* the household already has in place. As shown in Table 2 column (2), the greenness level on total issued devices is still significant and positive. This is not in line with the assumption made.

Nonetheless, the effect on save-a-flush bags in column (3) shows a significant, negative effect. This can be interpreted as the more green the household is, the less save-a-flush bags (-0.013) are issued. This could be explained by the fact that greener households are assumed to have a more sustainable toilet in place, and therefore do not need a save-a-flush bag anymore. The effect of greenness in column (3) and (4) on the water pressure devices and shower timers stays significantly positive. An explanation for this is that greener households do not have water pressure devices or shower timers yet in place.

4.2 The impact of what the households already have in place

Households vary in the types of toilets they already have. Therefore, a difference was made between a sustainable and non-sustainable toilet, based on litres used per flush.

As mentioned earlier, a dual flush uses approximately 5 litres per flush, whereas a single flush uses approx. 11 litres per flush (Haavelmo, 2009). Therefore, a new index was made to make a distinction between sustainable toilets (using < 6 litres per flush) and less sustainable toilets (> 6 litres per flush). Table 3 shows that 89.32% of the households own the water-consuming (less sustainable) toilets. Table 2 column (3) shows the effect of having a sustainable toilet on the save-a-flush bag devices being issued/installed.

Table 3. Frequency of households owning a sustainable toilet

Sustainable toilet

	Freq.	Percent	Cum.
0 (=no)	745326	89.32	89.32
1 (=yes)	89084	10.68	100.00
Total	834410	100.00	

Table 4 shows a summary of the showerhead types the households own. 35% of the households own an electric shower head, around 5% own a power shower head and 60% own a standard mixer shower head.

Table 4. Summary of showerhead types

what_type_of_shower_do_you_have	Freq.	Percent	Cum.
electric_	36020	35.30	35.30
power	4788	4.69	39.99
standard_mixer_	61239	60.01	100.00
Total	102047	100.00	

Also, the type of shower that households already have in place could affect the amount of water pressure devices being installed/issued. First, a regression analysis was done to find the most water efficient showerheads, the results of which are displayed in table 5. The table shows that electric shower heads use 27.34 litres less water than the base-level mixed showerheads. Also, power shower heads are predicted to use 16.51 litres less than mixed showerheads. Therefore, in this analysis, the electric shower heads are showed to be the most water-efficient. The power shower heads are quite water-efficient and electric shower heads the most water-efficient, as shown in table 6.

Table 5. Regression of showerhead type on liters used

	Shower liters per use
Electric_	-27.336***
	(.251)
Power_	-16.506***
	(.715)
Standard_Mixer	Base (0)
_cons	115.808***
	(.177)
Observations	102047
R-squared	.092

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 6. Showerhead types

Type of shower head	Water-saving
Standard_mixer	
Power_	
Electric_	

To get predictions of the showerhead type on the amount of water pressure devices issued, table 2 column (4) shows the results of a linear regression done of the showerhead types the households already have in place on the number of water pressure devices being issued and installed. Column (4) shows that households with standard mixer showerheads are the base level.

4.3 Overall regression analysis

Table 2 column (6) shows the results of the regressions done on the number of issued/installed devices in households with many explanatory variables. It describes the regression model with all the explanatory variables added and is therefore an extended version of the regression output in columns (1) and (2). First, looking at the effect of eco-consciousness (*level_greenness*) and controlling for other variables, one level greener predicts that 0.02 more devices are issued and installed. Compared with the first two columns, the prediction of *level_greenness* has become less robust by including more explanatory variables. This is a logical consequence because other variables have been added that lead to higher issued/installed devices and a higher level of greenness. Therefore, these control variables that have a positive relation with both the issued devices and the level of greenness pushed the original relationship down.

Since households with sustainable toilet would imply that they would need fewer devices issued and installed, it was assumed that the variable of having a sustainable toilet (*sustainable_toilet)* has a negative impact on the number of devices issued/installed. Column (6) shows that this assumption is indeed valid: households that already have a sustainable toilet are predicted to receive 0.389 fewer devices than households that do not have a sustainable toilet.

Some households already have sustainable showerheads in advance, and therefore it was assumed that these households also receive fewer devices. The electric shower heads are predicted to receive 0.553 less water pressure devices than the households with standard mixer showerheads, which is in line with the assumption. However, the households that have power showerheads are predicted to receive 0.502 more water pressure devices than the standard mixer, which does not correspond to the assumption made. An explanation for this could be that power shower heads are still not the shower heads which save the most water that are available. Therefore, households that have these shower heads in place would still ask for/receive more water pressure devices to become more water efficient.

Two variables were added to the regression model in column (6), namely the dummy for having a garden yes or no (*having_a_garden)*, and a variable for the rateable value of the house (*rateable value)*. These variables were added to do a placebo test, so it was expected that the effects of these variables are close to zero. In column (6), both of the variables have an effect of 0.004, which is very close to zero and is in line with what was assumed.

25 dummy variables were added to the regression in column (6) to control the differences in GD. Appendix A column (1) shows these differences between Green Doctors. It is found that including dummies for all green doctors does significantly affect the issued/installed devices. For example, visits of Thomas Ware resulted in a prediction of issuing 2.382 more devices than Benjamin James (base). Visits of other green doctors, such as Beverly Humphrey, predicted issuing 1.183 fewer devices than Benjamin James. This indicates that there is a huge difference in the number of devices issued between green doctors. Therefore, the GD that has been visited, impacts the issued/installed devices significantly.

4.4 Checking for interaction effects

Displayed in table 7[1], columns (1), (2), (3) and (4) show the outcomes of regressions done including different interaction terms. Column (5) shows the regression done with all the different interaction terms and dummy variables for the different types of GDs. Adding the interaction terms, the coefficients show that for every level of increase in greenness, a household that has a sustainable toilet and an electric shower (the most water-efficient head) in place, will receive 0.454 (-0.37+0.29-0.159 -0.215) less devices

[1] In Appendix A column (2)-(6), an extended version of table 7 can be found.

than a household that does not have a sustainable toilet and does have the most water-consuming shower in place, namely the standard mixer shower. This corresponds to the assumption that households that already have water efficient devices in place (water efficient toilet + showerhead) are predicted to receive less water devices than households that do not have these water efficient devices in place yet.

Table 7. Regression models including interaction effects

	(1) Issued/installed	(2) Iss/inst	(3) isins	(4) isins	(5) isins
level_greenness	.02***	.094***	.231***	.214***	.152***
	(.008)	(.011)	(.031)	(.03)	(.026)
Electric_	-.553***	-.545***		-.158***	-.37***
	(.012)	(.065)		(.046)	(.064)
power	.502***	-.822***		2.102***	.715***
	(.037)	(.165)		(.149)	(.17)
standard_mixer_	Base (0)	Base (0)			
sustainable_toilet	-.389***		.005	.091	.29***
	(.023)		(.118)	(.115)	(.092)
Showertypes# level_greenness					
Electric		.035*			0
		(.019)			(.015)
power		.584***			.15***
		(.053)			(.042)
standard_mixer_		Base (0)			Base (0)
Sustainable_toilet# level_greenness					
			-.125***	-.108***	-.159***
			(.032)	(.031)	(.026)
Showertypes# sustainable_toilet					
Electric_				-.332***	-.215***
				(.049)	(.04)
power				-1.088***	-.819***
				(.156)	(.115)
standard_mixer_				Base (0)	
Green_doctor					Dummies were used for GDs (see Appendix A)
rv	.004***				.004***
	(0)				(0)
garden_litres	.004				.017
	(.027)				(.027)
_cons	2.125***	2.032***	1.827***	1.869***	1.538***
	(.049)	(.04)	(.114)	(.11)	(.1)
Observations	47748	47748	47748	47748	47748
R-squared	.347	.055	.014	.064	.35

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

5. Discussion & Conclusion

5.1 Discussion of results

This paper aimed to determine whether the technological devices issued in 24,000 households in the South East of England between 2010 and 2014 were dependent on different explanatory variables. To do this, first different variables that could explain the difference in the number of technological devices issued between households had to be found. Four variables were used to capture the different motivations for technological devices being handed out. Through simple regression and correlation methods, it was possible estimate what determines the type and the number of technological devices the households received.

For the first variable, an index was made called the level of greenness. This level was measured based on five indicators that could measure the household's level of eco-consciousness. This variable might be able to explain variability in the amount of issued technological devices because of the assumption that people who are more keen on sustainability, ask for more technological devices to save water to become even more sustainable. The regressions showed positively significant results and therefore it was suggested that this hypothesis is indeed valid. A higher level of greenness does significantly increase the number of devices received.

Alternatively, another assumption was made that greener households would already have devices in place and therefore would receive fewer devices. This was tested by doing another regression including control variables for the devices that households already have in place. The outcome showed that the greener the household is, the less save-a-flush bags were issued, which was in line with the assumption.

The second variable was made based on the type of toilet the households already have. This variable was used because of the assumption that households who already have a sustainable toilet in place will not receive water-pressure devices. Therefore, the assumption made was that having a sustainable toilet would decrease the number of devices issued. Using multiple regressions, indeed a significant negative effect of having a sustainable toilet on the devices issued was found.

The third variable included in the model, was another variable determining the sustainable devices the households already have in advance. For this variable, the type of showerheads was used. The assumption made was that if the household was already in possession of a water consuming shower head, it would receive more water pressure devices. The results of the regression models show indeed a significant positive effect of households having the most water consuming shower (standard mixer shower) on issued devices. However, the households that own a modest sustainable shower (electric), also show a significant positive effect on the issued devices compared to the least sustainable shower head, which was not in line with the assumption made. A potential explanation for this might be that households who have a power shower heads still want to become more sustainable and therefore ask for more devices.

The fourth variable used are different dummy variables for the different green doctors that visited the households. 25 different green doctors were assigned to all the 24,000 households, and therefore 25 dummies were created. The regressions done show that the number of devices being issued/installed is strongly dependent on the type of GD that visited the household. Therefore, GDs have a significant impact on the efficiency of the programme. The regressions show large differences between the different GDs, and therefore, there is a significant difference in issued devices between households that have been visited by different GDs. To let the program work better, GDs should be trained better to issue more devices and thereby making households more water-efficient.

By including interaction terms to determine the relationship between the independent variables, the regression could have been influenced. Three interaction terms between *level_greenness*, *sustainable_toilet*, and *shower types* were added to the multiple regression model. The coefficients show that for every level increase in greenness, households that had a sustainable toilet and a sustainable shower head in place, will receive 0.454 fewer devices than households that did not have these sustainable devices yet in place. This outcome corresponds to the assumption that households receive less devices because they already had sustainable devices in place.

5.2 Limitations & further research

It is essential to acknowledge that the set-up of the research and the used methodology and data have limitations on the interpretation of the results. As the research has used the data of the green doctor programme in the South East of England, only the high-use households were targeted. Therefore, this research cannot be generalized for all households. Earlier studies showed that water saving programs are the most effective for high users, so therefore the expectation is that the results of this research will be less effective for the general water users (Ferraro & Price, 2013; Brent et al., 2015). A second limitation of the research is that the motivation variables are hard to measure. For example, the variable for the level of greenness, based on five indicators such as the temperature the household wash its clothes at, does say something about how sustainable the household is. However, there are many more indicators to measure this level of greenness, such as if the household is vegetarian/vegan or not. Nevertheless, there was no data available on these indicators, so therefore they could not be included in the model. Moreover, the results are robust, and therefore it could be stated that the positive effect found on the issued devices is quite accurate.

For further research, instrumental validity could be checked and instrumental variables could be included in the difference-in-difference model used by Ansink et al. (2021), because results of the regressions of explanatory variables tested on issued devices showed significant effects. By including instrumental variables, the model used by Ansink et al. (2021) will get more accurate and will solve the endogeneity problems that may arise.

5.3 Conclusions

Research over the past decades has demonstrated that the use of different policies associated with water consumption positively affects water conservation. Policies such as technological devices, informational-based instruments, market-based instruments and regulations have shown complexity. Ansink et al. (2021) studied the effects of the provision of technological devices on water consumption in combination with an informational component. They find that the implementation of this policy shows a persistent long-run reduction in water use. However, some criteria the GD's might have used to distribute devices or the motivation of households to ask for devices were not included in their model. Therefore, this research aimed to capture the endogeneity problem and to identify how the type and number of devices were determined for the studied households. This was done by using different multiple regression models.

Overall, the results presented in chapter 4 indicate a positive, significant, but small effect of greenness on the kind and number of devices distributed, which means that greener households receive more devices. The policy of distributing water-efficient devices works better for these greener households. Therefore, the program's focus should then be more on motivating other households to become more environmentally conscious to save water.

Also, the devices the households already had in place, determined the kind and number of water-saving devices the households received. By including interaction terms, the outcome shows that for every level increase in greenness, households with a sustainable toilet and a sustainable shower head in place received significantly fewer devices than households that did not have these sustainable devices yet in place. This outcome corresponds to the assumption that households receive less devices because they already have sustainable devices in place.

Thereby, two variables were added to the model to run a placebo test. Since having a garden (yes or no) does not directly impact the devices being issued/installed, the effects were assumed to be close to zero. Also, the rateable value was added to the regression model because household higher income does usually consume more water. However, it does not necessarily impact the devices issued/installed. Both of the variables showed an effect close to zero, meaning that the assumptions were valid.

At last, the different GDs that visited the different households had a significant positive as well as negative effect on the number of devices distributed. Therefore, the number of devices being distributed, is strongly dependent on the type of GD that visited the household. Ansink et al. (2021) assumed the informational component of the program to be very effective. However, the significant negative effects of some of the GDs show that this is not the case for all GDs. Therefore, these specific GDs which had significant negative effects on the issued devices, must be better instructed in the future in order to motivate households to install and use technological devices so that these GDs reach the same positive effect as other GDs.

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Appendix A

	(1) isins	(2) isins	(3) isins	(4) isins	(5) isins	(6) isins
level_greenness	.02***	.094***	.231***	.214***	.157***	.152***
	(.008)	(.011)	(.031)	(.03)	(.025)	(.026)
Electric_	-.553***	-.545***		-.158***	-.373***	-.37***
	(.012)	(.065)		(.046)	(.038)	(.064)
power	.502***	-.822***		2.102***	1.272***	.715***
	(.037)	(.165)		(.149)	(.116)	(.17)
standard_mixer_	Base (0)	Base (0)				
sustainable_toilet	-.389***		.005	.091	.284***	.29***
	(.023)		(.118)	(.115)	(.091)	(.092)
Showertypecode# level_greenness						
Electric		.035*				0
		(.019)				(.015)
power		.584***				.15***
		(.053)				(.042)
standard_mixer_		Base (0)				Base (0)
Sustainable_toilet# level_greenness						
			-.125***	-.108***	-.157***	-.159***
			(.032)	(.031)	(.026)	(.026)
Showertypecodes# sustainable_toilet						
Electric_				-.332***	-.213***	-.215***
				(.049)	(.04)	(.04)
power				-1.088***	-.879***	-.819***
				(.156)	(.12)	(.115)
standard_mixer_				Base(0)		
Benjamin_james	Base (0)				Base (0)	
beverley_humphrey	-1.183***				-1.23***	-1.234***
	(.042)				(.046)	(.046)
christine_murphy	-.578***				-.578***	-.578***
	(.039)				(.039)	(.039)
daniel_miller	.171**				.172**	.173**
	(.078)				(.077)	(.077)
danny_lenain	-.044				-.034	-.034
	(.027)				(.027)	(.027)
dave_plunkett	.918***				.92***	.92***
	(.037)				(.037)	(.037)
domenico_bevilacqua	.366***				.355***	.348***
	(.037)				(.037)	(.037)
edward_fyfe	-.329***				-.334***	-.331***
	(.027)				(.025)	(.025)
emma_hollands	-1.107***				-1.093***	-1.094***
	(.026)				(.026)	(.026)
george_martin	-1.296***				-1.293***	-1.284***
	(.025)				(.025)	(.025)
ian_paterson	.053*				.063**	.06**
	(.03)				(.03)	(.03)
james_lee	-.389***				-.383***	-.382***
	(.031)				(.031)	(.031)
joe_osborne	-.542***				-.549***	-.547***
	(.032)				(.032)	(.032)

lawrence_beaufortjones	-.097***				-.092***	-.083***
	(.028)				(.028)	(.028)
lindsay_thomson	-.382***				-.38***	-.376***
	(.049)				(.048)	(.048)
neil_sephton	.63***				.632***	.628***
	(.061)				(.061)	(.061)
paul_lewis	.812***				.818***	.822***
	(.032)				(.032)	(.032)
richard_bingham	-.475***				-.466***	-.475***
	(.083)				(.079)	(.079)
ricky_omar	-1.128***				-1.132***	-1.132***
	(.03)				(.03)	(.03)
sophie_bell	-.742***				-.734***	-.734***
	(.037)				(.037)	(.037)
sophie_maidment	.089***				.102***	.106***
	(.031)				(.031)	(.031)
tariq_hawari	-.446***				-.46***	-.46***
	(.061)				(.062)	(.062)
thomas_ware	2.382***				2.376***	2.367***
	(.05)				(.051)	(.051)
tim_beecher	-.135***				-.137***	-.134***
	(.025)				(.025)	(.025)
tristan_owen	.148***				.152***	.153***
	(.028)				(.028)	(.028)
rv	.004***				.004***	.004***
	(0)				(0)	(0)
garden_litres	.004				.018	.017
	(.027)				(.027)	(.027)
_cons	2.125***	2.032***	1.827***	1.869***	1.517***	1.538***
	(.049)	(.04)	(.114)	(.11)	(.097)	(.1)
Observations	47748	47748	47748	47748	47748	47748
R-squared	.347	.055	.014	.064	.35	.35

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*