Social influence in the adoption of digital consumer innovations for climate change

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Abstract

Digital consumer innovations offer low-carbon alternatives to mainstream consumption practices. We contribute new insights on the importance of social influence in the uptake of digital consumer innovations for climate change across mobility, food, homes, and energy domains.

Using nationally representative UK survey data (n=3007), we show that electronic word-of-mouth is the dominant mechanism of information exchange for strengthening adoption intentions. This finding is robust across 16 innovations from car clubs to 11th hour food apps. Other social influence mechanisms such as social norms and neighbourhood effects are as important only for highly visible innovations such as electric vehicles.

Using deep dive early adopter studies of ridesharing platforms, digital food hubs, and smart home technologies, we show that trust in digital platforms and place-based community networks are important characteristics affecting social influence. Social norms can help build trust, while word-of-mouth spreads positive information for locally salient innovations.

Policies stimulating innovation adoption tend to focus on purchase incentives. Opportunities to harness social influence processes remain unexploited. Our research emphasises the importance of digital skills and infrastructure for supporting these processes, social marketing for building positive norms, and community networks for enabling interpersonal exchange.

Keywords

low carbon; interpersonal communication; diffusion of innovations; information sources; electronic word-of-mouth

1 Introduction

To meet international climate change targets and minimise carbon emissions through reductions in energy demand and improved efficiency, policies enabling social transformations are urgently required (IPCC, 2018). According to the UK Committee on Climate Change, two thirds of measures necessary are social and behavioural, with the single most important category being low-carbon technology adoption (Stark et al., 2019). In recent years, digitalisation has enabled a surge of consumer innovations to emerge which challenge high-energy consumption norms and help tackle climate change by controlling, shifting, sharing, or reducing energy use (Wilson et al., 2020; Grubler et al., 2018). Examples include app-based shared mobility services with increased vehicle occupancy rates and smart home technologies for controlling heating, lighting, and appliances. In addition to emission reduction potential, numerous digital consumer innovations for climate change (digital consumer innovations hereafter) offer other benefits such as support for local economies (e.g., digital food hubs), relational networks (e.g., ride-sharing) and social capital (e.g., food sharing apps). There are, however, potential risks associated with such innovations. For example, reduced control of personal decision making

(Della Valle et al., 2021), the occurrence of rebound effects with a proliferation of energy use from digital devices and their associated infrastructure (Bonilla-Alicea et al., 2020), inequality of digital access (WBGU, 2019) and data security and privacy concerns (Acquisti et al., 2015; Wilson et al., 2017). Research is needed to focus on overcoming such risks, however our attention here is on the issue that many remain trapped in small market niches despite their carbon reduction potential (Wilson et al., 2019). With their low uptake rates and consequently limited impact on carbon reductions thus far, insights are needed regarding diffusion strategies and policies for rapid extensive adoption (TWI2050, 2020, 2019).

A wide range of factors influence the success or failure of an innovation. A large body of literature confirms Rogers' (2003) Diffusion of Innovations theory (DoI) which states that diffusion is fundamentally a social process (Sriwannawit and Sandström, 2015). In other words, the rate at which an innovation diffuses is shaped by the flow of information through social influences in a given environment (Valente, 2010). There are different forms of social influence: interpersonal exchanges within social networks, reading blogs and other online resources, seeing what neighbours are doing, as well as being aware of social norms. All have the potential to affect behaviours and adoption decisions (Axsen, 2016).

Previous research on social aspects of diffusion for low carbon innovations do not focus specifically on digital innovations and often consider a narrowly defined case e.g., alternative fuel vehicles (Pettifor et al., 2017), multiple innovations within a single domain e.g., energy (Hackbarth and Lobbe, 2020), or a particular type of social influence e.g., social norms (Horne and Kennedy, 2017).

The aim of this paper is to improve understanding of several social influence processes in the adoption of innovations across multiple domains. These innovations are both digital (or digitally enabled) and are potentially lower carbon alternatives to mainstream consumption practices. By understanding the role of social influences in diffusion for this important class of innovation, we aim to inform strategies and identify suitable policy mechanisms to overcome market stagnation and accelerate diffusion. We ask, 'What are the roles of different social influence mechanisms in the diffusion of digital consumer innovations for climate change?'.

Using DoI as a systematic framework, we extend the evidence base in three important ways: 1) we collect and analyse comparable data on a diverse range of innovations across four consumption domains: transport; food; homes and energy, allowing us to generalise findings despite contextual variation; 2) we conduct deep-dive studies on specific innovations which provide rich insights into unexplored social dimensions of diffusion processes; and 3) we focus on the intersection between digital technologies and low-carbon goods and services, providing crucial evidence for this newly emerging field.

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We first present the four social influence mechanisms identified from the literature as being key for diffusion (Pettifor et al., 2017) and hypothesise the impact a particular mechanism has on adoption processes. We then consider different innovation characteristics that may impact the influence these mechanisms have on adoption decisions. Next, we provide an outline of the novel methodology used to test our hypotheses, followed by the results. Our discussion section then provides robust cross-innovation insights to inform policy seeking to achieve a sustainable energy transition and accelerate low carbon digital innovations to the mass market.

2 Social influence

DoI describes communication from adopters to non-adopters as a vital mechanism for reducing risks and uncertainties, allowing the exchange of functional information on an innovation's attributes, as well as social information on group identity, status, and social difference (Rogers, 2003). We consider how four types of social influence mechanisms are associated with the adoption of digital consumer innovations.

2.1 Word-of-mouth

To help innovations spread from market niches to the mainstream, early adopters play a fundamental role by sharing trusted knowledge and information through word-of-mouth (WOM) to non-adopters within their social networks (Berger, 2016). WOM through verbal or written communication from those with first-hand experience provides reassurance, reduces perceived uncertainties and is a primary source of information for shaping attitudes, perceptions, and expectations of an innovation (Kimmel and Kitchen, 2014; Szmigin and Piacentini, 2015). Numerous consumer surveys, marketing research (see Danziger, 2017) and academic literature (Huete-Alcocer, 2017) provide evidence that WOM from friends and family is highly influential on purchasing behaviours. Research demonstrating the importance of WOM includes studies on encouraging the adoption of consumer innovations for climate change (Bale et al., 2013; Mcmichael and Shipworth, 2013; Southwell and Murphy, 2014; Axsen et al., 2013) and digital innovations (Dedehayir et al., 2017). In line with established diffusion theory, we hypothesise:

*H_1 **WOM** is positively associated with the adoption of digital consumer innovations*

2.2 Electronic word-of-mouth

Traditional methods of exchanging interpersonal information, such as face-to-face or over the phone, often consists of conversations amongst known peers. With the advent of the internet, users are increasingly accessing content via mobile phones and approximately 3.6 billion social network users exist globally (Statista, 2020a). Electronic WOM (eWOM hereafter) has enabled strangers from anywhere across the world to connect, produce, and share information quickly and easily (Abdallah et al., 2017; Powers et al., 2012; Wang 2017). Examples of eWOM include public posts on social media

platforms, blogs, review sites, and comment sections of e-commerce sites. By providing new ways of sharing information on products and services (Kimmel and Kitchen, 2014), eWOM has empowered consumers to shape opinions in digital spaces, which in turn influences opinions in the offline space (Smith, 2009; Voramontri and Klieb, 2019). There is increasing evidence that a large percentage of people rely upon online content generated by consumers to make purchasing decisions (Ahmed, 2015; Garvin, 2019). A necessary consideration in diffusion studies is that digital spaces are vulnerable to the diffusion not only of positive opinions and accurate information, but also misinformation and opinion polarization (Guess et al., 2019). Negative eWOM can therefore potentially have adverse effects on diffusion. We return to this in our discussion.

The importance of eWOM for information reaching the masses is clear. But what role does it have for digital consumer innovations? eWOM is already being harnessed to foster greater pro-environmental awareness, concern and action (Nabivi, 2020; Pearson et al., 2016; Vanko and Zaušková, 2019; Vu et al., 2021). Considering the growth of innovations requiring adopters to be connected to the internet to utilise their services, we hypothesise:

*H_2 **eWOM** is positively associated with the adoption of digital consumer innovations*

2.3 Social norms

Other forms of social influence act more subtly and often through social and visual cues (Bicchieri, 2016). Social norms are interpreted as: what people believe others do (descriptive norms); and what they think others approve or disapprove of (injunctive norms) (Cialdini et al., 1991). Such perceptions influence attitudes and behaviours as they help indicate what 'should' be done and what is considered normal in a particular context and situation (Schultz et al., 2008). Social norms develop through interactions in a given group or society and can change slowly or rapidly (Sanders and Hume, 2019).

Studies have been conducted which examine the role of social norms in the acceptance of sustainable innovations and behaviours. For the case of alternative fuel vehicles, acceptance has been found to increase with greater evidence that other people have adopted them e.g., seeing more vehicles on the road or the associated infrastructure such as charging points (Aini et al., 2013; Jansson et al., 2010; Schuitema et al., 2013). For behaviours such as recycling, low energy use and water conservation, Farrow et al. (2017) conducted a review and concluded that social norm interventions can be an effective tool for behaviour change.

We turn now to consider the relevancy of social norms in the digital world. Digital innovations in the form of an app or a digital platform are less apparent in the offline world. However, this does not make social norms less relevant, as they can still be created in the digital space through what is read, watched, and listened to online. An increasing amount of literature focuses on social norm formation online (Chia, 2020; Sirola et al., 2021). For example, Revilla (2020) found online discussion boards provide a medium for members of a community to share their thoughts on their peers' actions, transmitting

messages of social recognition or reprobation that can challenge common beliefs on current energy needs. We hypothesise:

H_3 ***Social norms*** *are positively associated with the adoption of digital consumer innovations*

2.4 Neighbourhood effects

Neighbourhood effects are interpreted as the influence of seeing what is done by peer groups defined by spatial proximity i.e., those who live nearby (Wolske et al., 2020). In energy research, studies predominantly focus on the importance of neighbourhood effects in the adoption of highly visible innovations such as solar panels (Curtius et al., 2018; Palm, 2017; Rai and Robinson, 2013) and electric vehicles (Axsen and Kurani, 2011). Axsen and Sovacool (2019) state that innovations which provide public benefits offer adopters the ability to social signal and communicate their identity and environmental values. However, such innovations can also act as an asset for displaying higher economic and symbolic capital (Bartiaux et al., 2016), bringing with it social division and visible inequalities.

Limited research has been conducted on other types of digital innovations which help tackle climate change (Wolske et al., 2020). In some cases, for instance home meal kit deliveries, a consequence of using the innovation is the digital replacement of physical social interaction (i.e., physically shopping at the supermarket). This has the potential to reduce the opportunity for visual cues, although one could argue that a delivery van acts as an adequate visual cue for neighbourhood effects. We investigate this concept and hypothesise:

H_4 ***Neighbourhood effects*** *are positively associated with the adoption of digital consumer innovations*

2.5 Innovation characteristics

Having established why we expect various social influence mechanisms to be important in adoption processes, we next consider why such mechanisms might differ in strength for certain innovations. Many of the digital consumer innovations we consider have specific characteristics which shape their use in social contexts, and thus have potential implications on how information spreads through society. We focus on three such characteristics that are common to a multitude of innovations and formulate hypotheses that they alter the association between social influence mechanisms and adoption[1].

The first characteristic is the '*requirement of trust'.* We established in Section 2.1 that trust is implicit and central within DoI as trusted information sources are important for effective WOM and information diffusion. As we focus on digital consumer innovations, one value proposition of digitalisation is the capacity to connect strangers offering and demanding services in real time. A challenge of this is the

[1] Alternative hypotheses emerged during the review process and are discussed in the Appendix

need for users to trust the offering from another unknown user through confidence in the digital platform (Geissinger et al., 2020; Möhlmann and Geissinger, 2018). The level of trust may be affected by, for example, privacy concerns (Joinson et al., 2010) or website quality (Yoon and Occeña., 2015). Multiple studies have found a lack of trust and perceived risks have been the main reasons for non-adoption of sharing economy platforms (see ter Huurne et al., 2017). We consider trust in the platform impacts upon social influence mechanisms. For example, if a friend recommends using P2P ride-sharing (WOM), but trust in the platform does not exist, the importance of the person's recommendation becomes stronger in the adoption process.

> *H_5 The positive association between **all social influences** and the adoption of digital consumer innovations is **strengthened** for innovations requiring **user trust***

The second characteristic, *'low salience',* refers to both an innovation's physical visibility as well as its social observability and prominence (Bordalo et al., 2013). For example, products inside the home such as smart heating are autonomous, used privately and designed to integrate - through adaptive learning and automation - into the background infrastructure of the home. This allows households to take a passive role in controlling their services (Hargreaves and Wilson, 2017). Consequently, they have low salience. This creates difficulties in establishing norms and utilising neighbourhood effects to spread information (Babutsidze and Chai, 2018; Welsch and Kühling, 2009). For innovations with low salience, interpersonal mechanisms (WOM and eWOM) are expected to play a more vital role in diffusion (Bollinger et al., 2019).

> *H_6 The positive association between **social norms/neighbourhood effects** and the adoption of digital consumer innovations is **weakened** for innovations with **low salience***
>
> *H_7 The positive association between **WOM/eWOM** and the adoption of digital consumer innovations is **strengthened** for innovations with **low salience***

The final characteristic we focus on is the aspect of an innovation being '*place-based'*. Numerous digital consumer innovations bring like-minded people together to form local networks, often with strong environmental values. For example, food hubs create geographically defined communities using an online platform to connect consumers with local food producers, reducing transport miles and connecting supply with demand to reduce waste (Kurnia et al., 2015; Richards and Hamilton, 2018). With digitalisation, personal social networks are no longer geographically restricted (Hampton and Wellman, 2001; Larsen et al., 2006) and innovations enable physical context and distance to become irrelevant. Nevertheless, some innovations still require local relational networks and social capital, namely those requiring a local physical exchange (Bauwens and Defourny, 2017; Hahnel et al., 2020). The importance of information diffusion through local channels such as WOM and other visible mechanisms are therefore expected to alter for the adoption of such locally defined digital innovations.

*H_8 The positive association between **WOM** and the adoption of digital consumer innovations **is strengthened** for **place-based** innovations*

*H_9 The positive association between **norms/neighbourhood effects** and the adoption of digital consumer innovations is **strengthened** for **place-based** innovations*

3. Method

To improve understanding of the social influence processes in the adoption of digital consumer innovations, our research elicited responses on a variety of consumer products and services. We used two approaches to collect both quantitative and qualitative empirical data: 1) a large nationally representative online survey (n=3007) and 2) deep dive innovation-specific studies. Figure 1 illustrates how the two methodologies investigate our hypotheses.

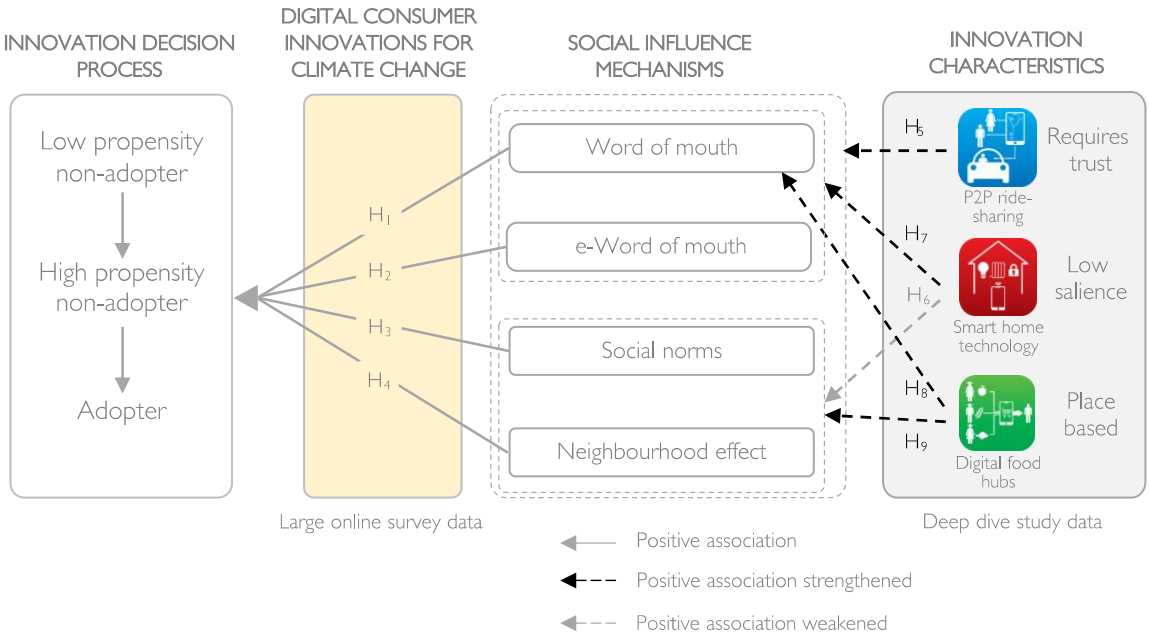

Figure 1. Research framework based on elements of DoI theory to investigate social influence mechanisms in the context of the adoption process of digital consumer innovations for climate change.

3.1 Large online survey

We conducted a large online survey which investigated a set of 16 consumer-facing innovations (Table 1) that are illustrative of the changing possibilities available to consumers as a result of digitalisation. Such possibilities include: substituting physical for digital; accessing services instead of owning goods; and integrating households into supply networks. The innovations selected are on the fringes of market shares and span across four domains which all require significant reductions in CO_2 emissions. These are mobility, food, homes, and energy. The 16 innovations consist of both products and services and cover a range of attribute appeal (Pettifor et al., 2020). All the innovations were pre-screened regarding their positive contribution to climate change (Wilson et al., 2020).

The survey was administered in the UK through a market research company (Dynata) between 2nd July – 3rd September 2019, with a sample of 3007 participants. Table 2 shows details regarding our sample's socio-demographics alongside UK nationally representative datasets. We used the weighted cases approach to conduct one-sample chi-square tests to assess our sample's representativeness. Statistical results confirm the sample is nationally representative in terms of gender ($\chi 2$ (df = 1) = .058, p = .810), age ($\chi 2$ (df = 5) = .938, p = .967) and household income ($\chi 2$ (df = 8) = 1.677, p = .989).

Survey participants first answered questions on their adoption experience of all 16 innovations and were then allocated as an adopter or non-adopter to answer standardised blocks of questions regarding one specific innovation. We considered priming and question order to mitigate hypothetical and social desirability bias. We did not frame the survey around climate change or the environment in the survey invitation or information consent and all climate and environment related questions were asked at the end of the survey after the innovation intention questions.

We used a quota sampling design to target 100 adopters and 100 non-adopters for each innovation. The survey took approximately 20 minutes to complete. Full details of the survey design, sampling method, pilot testing and quality checks performed are provided in the Supplementary Information.

The main block of survey questions in this paper focused on the relative influence of four mechanisms of information diffusion: WoM, eWoM, social norms and neighbourhood effects (question wording provided in Table 3). For each of the four social influence mechanisms, we used multi-item scales based on: 1) established precedents from the literature, with slight modifications to fit our research context (Francis et al. 2004; Parry et al., 2012); and 2) newly developed items to elicit responses to statements specific to this research.

Table 1 Number of non-adopter large online survey participants, along with the name, description, and an example for each of the innovations investigated (adapted from Wilson et al., 2021).

Domain	Innovation	Definition	Example[a]	# of high propensity	# of low propensity
Transport	Carsharing (car clubs in the UK)	A membership-based service offering short-term rental of vehicles	Zipcar	25	69
	Peer-to-peer (P2P) carsharing	Networks of car owners making their vehicles available to others for short-term rental	Turo	45	60
	P2P ride-sharing[b]	Networks connecting passengers and drivers for shared car journeys or commutes	Liftshare	40	51
	Shared ride-hailing or taxis	Cars or minivans with multiple passengers on similar routes, booked on short notice via apps	UberPool	41	42
	Mobility-as-a-service	App-based scheduling, booking, and payment platform for multiple transport modes	Whim	63	27
	Electric vehicles	Vehicles with electric motor propulsion and a battery that is recharged from external sources	Nissan Leaf	42	96
	E-bikes	Bicycles with an electric motor and battery for assisting with pedalling up to limited speeds	Gocycle	36	61
Food	Digital hubs for local food[b]	Buy food for delivery directly from multiple local producers	Open Food Network	61	10
	Meal kits (or meal boxes)	Home deliveries of fresh produce pre-portioned for cooking specific recipes	Hello Fresh	42	50
	11th hour apps	Food outlets advertise surplus fresh food at reduced prices	Too Good to Go	68	14
Home	Smart heating systems[b]	Monitoring, automation, adaptive learning, and control (via app) of heating	Nest	34	52
	Smart lighting[b]	Customization and control (via app) of lighting	Philips Hue	42	48
	Smart home appliances[b]	Automation and control (via app or by utilities) of white goods and other large appliances	Samsung Smart Fridge	35	56
Energy	Domestic electricity generation with storage	Electricity generated domestically stored in a battery system to maximize own consumption	Tesla Powerwall	37	10
	P2P electricity trading	Networks of households for trading surplus electricity generated domestically.	Brooklyn Microgrid	21	2
	Electric vehicle-to-grid	Allowing bidirectional flows of energy between the grid and batteries of electric vehicles	DriveElectric V2G	17	6
	Energy innovations[c]			73	18

[a] The example column draws mainly on current US and UK markets.
[b] Included in the deep dive studies
[c] Three energy innovations combined due to low respondent counts

Table 2. Sample representativeness. Source UK data: (ONS, 2018); (Understanding Society Wave 6, 2016)

	UK data	Large online survey respondents
Gender		
Female	50.7%	49.3%
Male	49.3%	50.4%
Other		0.3%
Age distribution		
18-24	12.3%	11.0%
25-34	19.2%	17.6%
35-44	17.9%	16.8%
45-54	19.8%	19.6%
55-64	16.7%	17.8%
65+	14.1%	17.2%
Gross household income		
below £15,000	15.8%	15.2%
£15,000 to £19999	10.7%	11.3%
£20,000 to £24,999	10.2%	10.0%
£25,000 to £29,999	8.4%	8.7%
£30,000 to £34,999	7.9%	9.0%
£35,000 to £39,999	6.5%	7.6%
£40,000 to £44,999	6.1%	6.7%
£45,000 to £54,999	9.8%	10.2%
£55,000 plus	24.6%	21.3%

Table 3. Question and response wording for survey components used for analysis.

Independent variable	**How much do you agree with the following statements about [innovation]? (1 = strongly disagree to 5 = strongly agree)**
WOM	... I hear good things about them from people I know
	... When I express interest in them, people around me often make suggestions or recommendations
eWOM	... I learn about positive aspects of them from user blogs and user web sites
	... I'm interested in consulting online sources to learn from people who use them
Social norms	... It's expected of me that I use them
	... People who are important to me would approve of me using them
Neighbourhood	... I see people using them
	... People who live near me seem to be using them

3.1.1 Analysis of social influence mechanisms

To test H_1 - H_4 and assess the importance of the different social influence mechanisms in adoption decision making, we conducted groupwise comparisons using Mann-Whitney U tests, with effect sizes between two groups of participants at different stages of the DoI decision process. Our independent variables were mean scores of multi-item scales for each of the four social influence mechanisms. Our dependent variable distinguished between high and low propensity non-adopters.

For propensity, we used responses to the question 'How likely are you to use [innovation] within the next year? (scale: [1] very unlikely - [100] very likely)'[2]. The overall distribution of respondents'

[2] A question originating from Kormos et al. (2019)

propensity is provided in the Supplementary Information. Overall, responses were skewed towards the lower end of the scale, with a median of 10. We ran two sets of analyses to test sensitivity: the first used the natural log of propensity as a continuous variable; and the second used a binary variable with the median as the cut-off point to create two groups: 'high propensity' and 'low propensity'. We found both methods produced similar results and model specifications. We chose to present the results of the binary method in this paper as it provided a dummy variable used in other analyses and aids clarity and ease of interpretation. Table 2 shows the number of 'adopters', 'high propensity non-adopters' and 'low propensity non-adopters' surveyed for each innovation. Results from the first method (using the continuous variable) are provided in the Supplementary Information.

We ran a binomial logistic regression to ascertain the effects of social influence mechanisms on adoption propensity, examining which hypotheses remain robust when other social influence variables are held constant. We controlled for age, gender, and household income. Linearity of the continuous independent variables (the four types of social influence) with respect to the logit of the dependent variable (propensity), were confirmed via the Box-Tidwell procedure for the binomial logistic regression.

To further investigate the robustness of H_1 - H_4, we clustered the 16 innovations by their attribute similarities and conducted groupwise comparisons (Mann-Whitney U tests, with effect sizes) and binomial logistic regressions as before, but for each cluster to see if the hypotheses held (see Supplementary Information for further details).

3.2 Innovation specific studies

In addition to the large online survey, we conducted deep dive innovation specific studies to examine different characteristics we reasoned could impact upon social influence mechanisms (H_5 – H_9). The three innovations, identified in Table 4, were chosen to represent different domains and characteristics: P2P ride-sharing (transport, requirement of trust – H_5); smart home technologies consisting of smart lighting, heating and appliances (home, low salience – H_6, H_7); digital food hubs (food, place-based - H_8, H_9). Additional data collection enabled: 1) further exploration of social influence dimensions; 2) collection of larger sample sizes of adopters; 3) qualitative insights to enhance interpretation and 4) validation of findings from the large online survey.

To collect over-representative samples of adopters, we partnered with gatekeeper organisations to invite users to participate ('Liftshare' for ride-sharing and 'Open Food Network' for digital food hubs). Additionally, we placed adverts on social media platforms (which recruited both adopters and non-adopters for all three innovations). Table 4 summarises the key aspects of the various data collection methods used. A pilot test was conducted for each method using a small sample size to verify appropriateness and interpretability of questions, as well as method duration (n=~15 for online surveys, and n=5 for both the focus groups and interviews).

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3.2.1 Analysis of innovation characteristics' effects on social influence and adoption

Our hypotheses relating to the effects of the three innovation characteristics (H_5 – H_9) were not directly tested through statistical analyses. We conducted exploratory analyses of our hypotheses through the multiple data collection methods outlined in Table 4. Details of questions asked, and analyses conducted for each of the innovation specific studies are provided in the Supplementary Information.

Table 4 Methodology summary of the innovation specific studies and their moderating attributes.

Innovation	Characteristic	Collection method	Collection period	Focus	Sample
P2P ride-sharing	**Requirement of trust**– user trust in the digital platform to organise ride sharing with a stranger	Online survey[a]	May – July 2019	Information sources, WOM, Trust	Non-representative convenience, n= 256 adopters, 223 non-adopters
		Online focus groups[b]	July – Sept 2020	Trust, social influences, social barriers	n= 5 focus groups with a total of 21 adopters
Smart home technologies	**Low salience –** use within home, out of sight	Online survey[a b]	May – July 2019	Information sources, communication behaviour, social networks, online use, social barriers	Non-representative convenience, n= 313 adopters, 360 non-adopters
Digital food hubs	**Place-based –** local community network of food producers and consumers	Online survey[a]	May – July 2019	Information sources, communication behaviour	Non-representative convenience, n= 196 adopters, 112 non-adopters
		Semi-structured interviews[b]	Dec 2020 – January 2021	Information sources, communication behaviour, social influences, social barriers,	n= 20 adopters

[a]Quantitative data collected

[b]Qualitative data collected

4. Results

4.1 Large online survey - importance of social influence mechanisms

Of the 1473 non-adopters, 1303 responded to the adoption propensity question (654 'low propensity' and 649 'high propensity'). Table 5 presents the Mann-Whitney U test results, with effect sizes. We find all social influence mechanisms to be significantly more important ($p<.01$) for respondents with high propensity to adopt compared to those with low propensity. All results have high effect sizes (>0.8), apart from neighbourhood effect which has a medium effect (>0.5). All four hypotheses (H_1 – H_4) regarding the positive association of a social influence mechanism and digital consumer innovation adoption are confirmed.

The binomial logistic regression model presented in Table 6 used the four social influence variables to predict adoption propensity, controlling for age, gender, and household income. The Exp(B) values show the odds ratios that measure how a specific variable increases or decreases the likelihood of being a high propensity non-adopter. Our model correctly classifies a high percentage of cases (80.8%). Across all 16 innovations, Table 6 shows that WOM, eWOM and social norms significantly contribute to the model, with eWOM having the largest odds ratio. These three social influence mechanisms are positively associated with an increased likelihood of high propensity adoption, with eWOM increasing likelihood the most.

Table 5. Mann-Whitney U tests with effect sizes to test H_1 – H_4

		Low propensity		High propensity					
H	**Social influence**	**n**	**Mean rank score**	**n**	**Mean rank score**	**U**	**z**	**p**	**effect size (cohen$_d$)**
1	WOM	585	420.36	610	768.36	282344.5	18.02	**.001***	1.167
2	eWOM	625	405.8	631	849.09	336377.5	22.13	**.001***	1.544
3	Social norms	614	433.64	630	806.56	309370	18.758	**.001***	1.214
4	Neighbourhood effect	629	496.28	630	763.51	282244	14.071	**.001***	0.79

* p<.01

Table 6. Binary logistic regression model predicting adoption propensity across all 16 innovations

	n=971	
Variables	**p-value**	**Exp(B)**
WOM	**.007***	1.446
eWOM	**.001***	3.228
Social norms	**.001***	1.706
Neighbourhood effect	.489	.915
Pseudo R^2	.54	
Correctly classifies % of cases	80.8%	

* p<.01

Note: We control for age, gender, and household income, none of which were significant. See Supplementary Information for full model and details.

Further exploring H_1 - H_4, our cluster analysis grouping the 16 innovations by their attribute similarities produced three clusters: 1) innovations with high trialability e.g., car clubs, 11th hour food apps; 2) high observability e.g., electric bikes, domestic electricity generation with storage; and 3) low trialability and complexity e.g., smart heating and lighting. Results from the Mann-Whitney U tests revealed similar results across the three clusters. All four influence mechanisms are significantly more important (p<.01) for non-adopters with high propensity compared to those with low propensity. However, to confirm whether findings still hold whilst controlling for other social influence effects, we created binomial logistic regression models for each innovation cluster. Of the four predictor variables, only eWOM was statistically significant for all three clusters (p<.01). WOM and social norms were also significant for innovations with high observability (p<.01) (Cluster 2's model). Highly observable innovations therefore benefit from more social influence mechanisms increasing the likelihood of high propensity and reinforcing the positive associations found in H_1 - H_4. For detailed statistical results of the innovation clusters see Supplementary Information.

4.2 Innovation specific studies – innovation characteristics

Evidence presented below is drawn from our three deep dive studies to explore the effects of specific innovation characteristics on the association between social influence mechanisms and adoption. Table 7 summarises the key findings.

4.2.1 P2P ride-sharing and requirement of trust

Results from our P2P ride-sharing study support H_5 regarding trust. Using survey data from adopters and non-adopters, we found both types of adopters (one-off journey users and commuters) to be significantly more trusting of the platform and other users than non-adopters (adopters = 10.91 ± 4.20, non-adopters = 12.93 ± 2.92, t=-4.210; p=.01, lower values indicate greater trust). To explore H_5 and the effect of '*trust'* on social influences and adoption, we used focus group data from a subsample of adopters. Two of the most striking findings were:

1) one-off journey users reported no social norms, no WOM and in fact some commented they actually hide their use as they believe family members would worry. One user who did admit their use to others said, *"my friends say I'm crazy for using it [ride-sharin*g]". For such adopters, the importance of eWOM in the form of ratings and other user feedback was crucial for developing trust in the platform.

2) commuters strongly expressed that ride-sharing with employees from the same company gave credibility, felt more trustworthy and therefore less '*dangerous*'. Institutional protocols were reported to provide reassurance, and several respondents stated that ride-sharing is the norm at work, *"everyone is aware that many people are doing it [ride-sharing]".*

4.2.2 Smart home technologies and low salience

Results from our smart home technology study support H_6 and H_7 regarding low salience. Findings from our online survey discovered adopters self-report as being opinion leaders, strongly agreeing with statements such as '*I often influence people's opinions about them [smart home technology]*'. Reflecting such findings, non-adopters were found to shape their opinions from interpersonal sources of information and adopters frequently stated that they were asked for advice – mainly about complexity, compatibility, and convenience. For example, one adopter wrote *"I've been asked…on ease of use and lifestyle compatibility".* The adopters essentially provide information on many of the attributes which for other innovations are often confirmed through observation. As smart home technologies are privately used, information diffusion appears to occur through WOM with known adopters, as well as eWOM, evidenced through comments from adopters such as *"I mostly provide advice via Facebook groups and forums".*

4.2.3 Digital food hubs and place-based

Results from our digital food hubs study support H_8 and H_9, that being place-based affects the association between social influences and adoption. Our online survey identified adopters to be opinion leaders (similar to smart home technology adopters), who first heard about the innovation mostly through talking with friends, family, or colleagues (WOM).

Findings from our semi-structured interviews with adopters from rural and city-based food hubs provide additional evidence that WOM plays a strong role in the adoption decision process. When asked if they recommended their digital food hub to others, one participant responded "*Yeah. My friend started using it [digital food hub], and I actually started using because my friend used it [digital food hub]".*

Moreover, many of the adopters interviewed had discovered their local food hub through WOM and had successfully encouraged others to adopt. Non-adopters who know someone participating in a digital food hub might be exposed to such recommendations. However, there is a risk that information remains trapped in echo chambers (groups consisting of only like-minded individuals), demonstrated by this adopter's quote "*quite a lot of people that I know … in our circle do already get a veg box [from the digital food hub] … so we'd be a bit preaching to the converted".*

Differences were found between the rural digital food hub which provides both a pick-up point and a delivery service and the city-based hub which provides only delivery. A strong pattern emerged that wider community WOM and local social norms were more prevalent for the rural hub. Several interviewees from the rural food hub stated they recommend their hub to village newcomers or passing visitors, whilst another adopter who moved to a new house explained they had started using the hub [rural hub] because they felt it's what people in the village did.

Table 7. Key findings from the deep dive innovation specific studies

			Key findings	
Hypothesis	**Context characteristic**	**Innovation**	**Social influence mechanisms strengthened**	**Social barriers to adoption**
H_5	Requirement of trust in digital platform	P2P ride-sharing	**eWOM** - review systems provide reassurance for one-off users. **Social norms** - workplace culture encourages additional colleagues to adopt.	Lack of societal norms exist in the wider community.
H_6, H_7	Low salience	Smart home technologies	**WOM** and **eWOM** from adopters to non-adopters helps diffuse information and increase salience.	Non-adopters lack exposure and social connection to adopters for first-hand knowledge.
H_8, H_9	Place-based	Digital food hubs	**WOM** most important for shaping opinions in communities. Adopters reported as opinion leaders persuading others to adopt.	WOM occurring in echo chambers. Limited exposure for wider community when interactions occur out of sight e.g., delivery.

5. Discussion

We build upon previous literature through our novel methodology and analysis of comparable data across innovations and domains, providing new broad insights into the overarching question 'What is the role of social influences in the diffusion of digital consumer innovations for climate change?'. Additionally, our deep dive innovation specific studies investigated the unexplored impact of three common characteristics of digital innovations on the association between social influence and adoption.

In line with DoI theory, we confirmed positive associations between each of the four social influence mechanisms and adoption propensity (accepting H_1-H_4). As our survey data is cross-sectional, we cannot infer causality. However, the positive associations found in our results are consistent with the explanation that information communicated through social mechanisms reduces the risks of adoption perceived by potential adopters and therefore increases propensity (Rogers, 2003).

Based on key findings from both our large online survey and innovation specific studies, we focus our discussion on policy strategies which enable and harness social influences to increase adoption of digital consumer innovations. The following sub-sections outline the practical implications of our results and the necessary considerations needed for diffusion strategies.

5.1 Importance of electronic word-of-mouth

eWOM was found to particularly strengthen adoption intentions, emphasising the role of digital communication strategies in diffusion processes. Approaches to improve digital skills and equitable access to digital infrastructure is needed not only to enable the use of such innovations, but also to enhance the success of information diffusion.

Nevertheless, it is important to consider the limitations and risks of eWOM which may encourage consumers to make unfavourable purchasing decisions. Examples include: misleading computer-generated content rather than human generated (Pew Research Center, 2018); overwhelming quantity of content leading to information overload (Schmitt et al., 2018); communication of biased knowledge within echo chambers; and algorithm-driven filter bubbles that selectively display information based on user preferences (Pariser, 2012). Additionally, due to a lack of editorial oversight, issues of information quality, misinformation, and online "trolling" can be common (Guess et al., 2019).

To overcome limitations when designing eWOM strategies, an important aspect to ensure consumer trust in content is high quality information (Zhao et al., 2020). Relevancy, understandability, sufficiency, and objectivity of content are key (Park et al., 2007), as well as being comprehensive and representative (Wu and Liu, 2017). To foster the provision of high-quality content, reviews and feedback forms could be structured to encourage users to provide logical and persuasive content, giving reasons based on specific facts about a product or service. Lorenz-Spreen et al. (2020) propose further interventions aimed primarily at empowering individuals to make informed and autonomous decisions in the online ecosystem. For example, contextualising the number of likes by expressing them against the absolute frequency of total readers of a given page or review could counteract false-consensus effects that a number presented without context may otherwise propagate.

A review by Pearson et al. (2016) draws together the emerging work around tweeting, posting, and sharing information online, showcasing some of the ways in which social media is already being applied to diverse sustainability issues. One strategy used in France has been a government created platform[3] with an eWOM campaign to raise awareness. This platform aims to bring together and signpost all available resources for reducing consumption, aiding the circular economy. Policy strategies should draw upon such work to develop effective strategies of trusted eWOM.

[3] https://longuevieauxobjets.gouv.fr/

5.2 Innovations with high observability

Innovations with high observability were found to have stronger associations between multiple social influence mechanisms and propensity to adopt (WOM, eWOM and social norms). Reflecting upon the digital consumer innovations perceived to be highly observable, both as an innovation and as a low carbon behaviour, all but one belongs to the transport or energy domain. This is unsurprising given travel often occurs in public and innovations involving energy generation and infrastructure are predominantly physical structures such as solar panels. Digital consumer innovations in the home are inherently hidden from public view and have low observability. On the contrary, food domain innovations can be used both in public and private depending on the context. 'Meal kits' were perceived by our respondents to have low observability, most likely due to their delivery and consumption occurring in the privacy of homes. Digital food hubs, on the other hand, involve community relational networks, with some having specific times and collection points for customers to pick up orders. Such hubs create physical places, increasing the innovation's observability or ease of knowing who the other users are.

DoI states that observability plays an important role in reducing perceived risks and uncertainty (Rogers, 2003). Given our results suggest numerous social influence mechanisms can be harnessed to increase adoption propensity of highly observable innovations, policy is recommended to both: 1) help increase the observability of innovations, and 2) better utilise a wide range of influences for those already highly observable.

There is a wealth of established strategies and mechanisms which stem from DoI and behavioural insights to increase observability and utilise social influences. Examples include: displaying the innovation in public to demonstrate its use already occurs and is acceptable; recruiting opinion leaders to seed information and encourage adoption; and providing incentives for spreading WOM through 'refer a friend' schemes (IEA, 2020; Li, 2016). These are all generic prescriptions which have previously aided products and services to diffuse rapidly (Berger, 2014). Another example involves building partnerships, illustrated by one of the UK's largest supermarkets partnering with an 11th hour food app 'Olio' to reduce food waste. This created a surge in media attention (e.g., BBC, 2020) and increased the innovation's observability. Policy should encourage more businesses to partner with such digital consumer innovations using taxation or incentive mechanisms.

5.3 Innovation characteristics and social influences

5.3.1 Trust – shifting social norms and removing mistrust

Our P2P ride-sharing study found a lack of social norms within broader society. The high uncertainty regarding potential dangers of P2P digital consumer innovations appear to create barriers towards acceptability and adoption by the mainstream, a finding from both our study and previous literature (ter Huurne et al., 2017). Our results re-emphasise the importance of eWOM, especially through review

systems for developing trust. Such eWOM enables the concerns surrounding personal safety to be overcome.

We also discovered a successful application of social influence mechanisms which encouraged adoption amongst commuters through integrating positive social norms into workplace culture. With workplaces being ideal social organisations to manifest positive norms (Appelbaum et al., 2007), institutional policies reported in our study are necessary on a much larger scale and can be encouraged through government policy. Such findings indicate that depending on the context of use, the requirement of trust interacts with different influence mechanisms, especially strengthening eWOM and social norms.

There is a requirement for policy mechanisms to provide reassurance and overcome issues of mistrust for the growing number of innovations that rely upon P2P networks. One of the dominant P2P ride sharing platforms in Europe, BlaBlaCar, conducted a user survey and found 75% of respondents identified the platform as being a trusted third party community regulator (Chronos and BlaBlaCar, 2012). Platform providers ensuring high standards and quality assurance schemes are in place will help increase trust and thus the reliability of eWOM. For example, BlaBlaCar have an ID and profile verification scheme along with a review system (www.blablacar.co.uk).

5.3.2 Low salience - increasing exposure

We found that information on digital consumer innovations with low salience spreads through WOM and eWOM, appearing to compensate for the lack of social norms and neighbourhood effects. This reliance on verbal and written exchange increases salience and exposure. Additional analysis presented in Vrain and Wilson (2021) supports such findings and emphasises that a lack of exposure (not knowing an adopter) results in WOM needing to occur outside adopter cliques.

Policy can help create supportive infrastructures to increase communication from adopters to non-adopters, thus enabling information to reach wider audiences. Koski (2010) found that for low salient policies, knowledge broker organisations play a key role in diffusion, acting as communication hubs. A similar approach would be seeding WOM through knowledge brokers for low salient innovations to aid diffusion and fulfil a saliency gap (Valente and Davis, 1999). Examples include policy and industry initiatives training smart heating system installers (e.g., Wiser, 2021) or supporting open home networks (real or virtual) to increase exposure to first-hand knowledge and experience (e.g., Bristol Green Doors, 2021).

5.3.3 Place-based – encouraging outreach

Our study on digital food hubs representing place-based innovations found WoM to be particularly important in the adoption decision process and that expectations of strong social norms were more pertinent in rural-based contexts. Strategies are needed which tackle barriers revolving around WOM occurring in echo chambers and limited exposure for the wider community when interactions occur out of sight e.g., delivery. One approach is community-based dialogs and trainings, showing that participants can be empowered to share their knowledge and understandings systematically with others,

facilitating social norms change (Cislaghi et al., 2019). Policies could also encourage outreach and provide financial support for collaborations to increase visibility (Driscoll and Lynton, 2012). For example, the two food hubs involved in our data collection were affiliated with charities, offering cooking skills, community beekeeping courses and supporting low-income households. Such collaborations aid the development of social norms and WOM in wider-community contexts. It seems having a pick-up point for adopters to collect their produce may help increase visibility and depict local norms. A stronger sense of pre-existing community spirit in a rural setting may also have led to the strengthening of both WOM and social norms for spreading information.

Reflecting upon the role of social influence in the diffusion of digital consumer innovations for climate change, our empirical data highlights that diffusion is impacted not only by the different types of social influence mechanisms but also by innovation characteristics altering the conditions and contexts in which the innovation is used. The requirement for consumer trust in a digital platform is heightened for innovations where a physical encounter occurs between users, further strengthening the role of eWOM. Low salience of an innovation increases the importance of WOM and the need for increasing awareness and exposure to help diffusion. Finally, the relevance of WOM and social norms in the adoption process is especially important for geographically restricted innovations which facilitate the physical exchange of goods or services. Recognition of such characteristics can help guide strategies to effectively harness social influence mechanisms for diffusion.

5.4 Limitations and further research

This paper focusses on the role of social influences, however, many other aspects from DoI research impact upon an innovation's rate of diffusion (Clausen and Fichter, 2019). A limitation of our research is the exclusion of such aspects as well as institutional and market factors. Further research would benefit from the development of a model that draws from DoI and other behavioural sciences, to better account for the individual and external dimensions affecting innovation diffusion. We also acknowledge that our large survey analyses compared non-adopters with different levels of propensity and not adoption. As the action-intention gap may bias results, we suggest future research to consider longitudinal studies to determine whether adoption occurs.

Due to the methodological limitation of our deep dive innovation specific studies being explorative, we recommend further research to formally test hypotheses on the effects of the three characteristics explored. We also recommend future work to expand investigations to other innovations with similar attributes to verify the robustness of our results.

5.4.1 Consequences of Covid-19

The Covid-19 pandemic has led to a series of confinements, urging people to stay home and limit contact with others (TWI2050, 2020). Consequences of such drastic transformations to everyday life have ranged from steering grocery shopping online (Latham, 2021; McKinsey & Company, 2020), to using video-conferencing to work and learn from home (Neate, 2020). Social networks have contracted,

with relationships experiencing a funnelling effect (Vrain et al., 2020), whilst time spent interacting online has rocketed (Statista, 2020b). We postulate that such changes have altered the ways in which information flows through social influences. For example, these changes could decrease exposure to peer effects and word-of-mouth, whilst increasing the dominance of eWOM. Further research is needed to determine the impacts of Covid-19 restrictions on social influence mechanisms and adoption processes of digital consumer innovations and what this means for diffusion strategies.

6. Conclusion

Digitalisation offers opportunities for both end-use and system energy efficiency, however, policy focussed on such enabling digital technologies is still limited (Gruber, 2019). Public policy has a critical role to play in steering digital consumer innovations towards delivering emission-reduction benefits (IEA, 2017), in addition to developing strategies to deliver effective and scalable behavioural interventions of adoption. A report from the UK's Citizens Advice (2020) on lessons for net zero, advises government strategies to 'take all opportunities to influence behaviour'.

Through focusing on a diverse set of digital consumer innovations for climate change, we find that social influences are important determinants of adoption propensity across different contexts and user groups, thus providing robust results with wide generalisability. Notably, we find that eWOM is of most importance across the board, highlighting the ever-increasing need for policy strategies aimed at improving digital skills as well as equitable access to digital infrastructure. This would not only aid the diffusion of information but also enable the adoption of digital innovations. We also discover the importance of innovation observability, recommending policies to harness this trait to aid diffusion through the numerous social influence mechanisms available. Findings from our deep dive investigations of context characteristics indicate that innovations requiring trust (e.g., P2P ride-sharing) need multiple strategies through social norm interventions and eWOM to build reassurance. Innovations with low salience (e.g., smart home technologies) would most benefit from strategies which increase non-adopters' exposure to adopters to aid the spread of WOM. Strategies supporting partnerships and outreach for place-based innovations (e.g., digital food hubs) would help reach wider networks of potential adopters.

To accelerate diffusion of digital consumer innovations for climate change and fast-track a low carbon energy transition, our findings provide useful insights for policy to harness social mechanisms.

Data Availability

The large online survey dataset, full survey instrument and methodology document relating to this article are provided at ReShare (part of the UK Data Archive), available at: https://reshare.ukdataservice.ac.uk/854723/.

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Appendix

During the article's review process, alternative hypotheses emerged for the investigation of the three innovation characteristics. We retained the original H_5 - H_9 which were developed a priori and then explored through our data collection and analysis. The alternative hypotheses are listed below to highlight potential future avenues for research in this field. These alternative hypotheses remove the direction of association, and if used would enable broader investigations of the innovation characteristics.

> *H_5* ***Trust*** *in a digital platform affects the association between social influence mechanisms and adoption of a digital consumer innovation*
>
> *H_6* ***Salience*** *affects the association between social influence mechanisms and adoption of a digital consumer innovation*
>
> *H_7 Being* ***place-based*** *affects the association between social influence mechanisms and adoption of a digital consumer innovation*

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