To what extent do people value sustainable-resourced materials?

A choice experiment with cars and mobile phones across six countries

Dimitris Potoglou[a*], Lorraine Whitmarsh[b], Colin Whittle[b], Ioannis Tsouros[c], Paul Haggar[b], Tobias Persson[d]

[a] School of Geography and Planning, Cardiff University, CF10 3WA, Cardiff, Wales, UK

- Dimitris Potoglou, e-mail address: potogloud@cardiff.ac.uk

[b]School of Psychology, Cardiff University, CF10 3AT, Cardiff, Wales, UK

- Lorraine Whitmarsh: WhitmarshLE@cardiff.ac.uk
- Colin Whittle: WhittleC1@cardiff.ac.uk
- Paul Haggar: HaggarPC@cardiff.ac.uk

[c] Department of Shipping Trade and Transport, University of the Aegean, 82132, Chios, Greece

- Ioannis Tsouros, e-mail address: jtsouros@aegean.gr

[d] Growth Policy Analysis, Torsgatan 11, Stockholm, Sweden

- Tobias Persson: tobias.persson@tillvaxtanalys.se

* *Corresponding author*:
Dr Dimitris Potoglou
School of Geography and Planning
Cardiff University
Glamorgan Building, Room: 2.79
King Edward VII Avenue
Cardiff CF10 3WA
Wales, UK
Phone: +44(0) 2920 8 76088
Email: potogloud@cardiff.ac.uk

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Abstract

The environmental impacts of material production, processing and consumption are profound and increasing. The aim of this study was to examine the extent at which consumers of diverse products – specifically, cars and mobile phones – valued the sustainability of materials resourced to make them. Using two choice experiments in Germany, India, Japan, Sweden, the UK and the US (total N = 6,033), we found that economic and functional attributes dominated product choice. Respondents placed relatively little or no value on ethically- or sustainably- sourced materials whereas non-conventional (organic) materials were important only in some countries. The overall low average scores of self-reported knowledge (4.8 for cars and 4.7 for mobile phones; score range 1-10) and salience about the sustainability of vehicles and phones (5.7 for cars and 4.9 for mobile phones) were partially consistent with this relatively limited influence of the sustainable materials on product preferences. Findings showed considerable cross-national differences in consumer knowledge, preferences and willingness to pay. For example, respondents from all countries except the US placed a significantly positive value on cars made of ethically-sourced-organic materials with marginal willingness to pay values ranging from a minimum of €1,951 in Germany up to a maximum of €4,524 in the UK. In the case of mobile phones, respondents placed both positive and negative values against alternative materials relative to conventional materials, which was the reference case. Also, there was disparity between self-reported sustainability knowledge/concerns and experimental product choices. Policymakers should consider further economic and/or education measures to facilitate consumer demand for products made of sustainable-materials.

Highlights

- Discrete choice experiments of cars and mobiles across six countries
- Evidence on the value of materials when choosing a car or a mobile phone
- Functional attributes (e.g. cost, refuelling infrastructure) drive choices, not materials
- Disparity between self-reported sustainability knowledge/concerns and experimental product choices
- Considerable cross-national differences in consumer knowledge, preferences and willingness to pay

Keywords

Material source, ethical production, sustainable sourced material, car choice, mobile choice, discrete choice experiment

Abbreviations

SPDCE: Stated Preference Discrete Choice Experiment
DCE: Discrete Choice Experiment
DCA: Discrete Choice Analysis
RUT: Random Utility Theory

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Declarations of interest
None

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1. Introduction

The environmental impacts of material production, processing and consumption are profound and increasing (Allwood et al., 2011). An estimated 25% of anthropogenic carbon dioxide (CO_2) emissions are due to energy use in materials production (the construction, manufacturing and mining of non-fuel materials) and emissions from industry are estimated to increase by around 0.5% per year to 2055 (IEA, 2017; Worrell et al., 2016). Materials production also generates environmental pollution and depletes scarce natural resources (Tukker and Jansen, 2006), whilst the extraction of metals finances armed conflicts and child working (Hofmann et al., 2018a; Young et al., 2010). Further, resource depletion is a critical issue for the supply of technological products, including renewable energy technology (Hofmann et al., 2018b; National Research Council, 2008). Commercialisation of sustainable materials and technologies is therefore critical for mitigating a range of environmental problems.

Despite the environmental impacts of material production, previous research indicates environmental considerations generally exert little salience in consumers' product choice (Luchs and Kumar, 2017), whereas economic, pragmatic and social factors are typically more influential. However, for certain products, where economic and environmental factors are aligned (e.g., vehicle fuel efficiency) or when sustainable products offer additional features (e.g., health benefits of organic food), consumers may be willing to pay more for these greener options (e.g. Haggar and Whitmarsh, 2017). This appears to vary cross-nationally; for example, one study found US consumers were more sensitive than Japanese consumers to fuel costs (Tanaka et al., 2014).

Consumers have a wide choice in terms of goods and this phenomenon has been quite distinct in two markets, cars and mobile phones. As new technologies appear on the market, consumer behaviour may change and attributes beyond price drive consumer choices for these goods. For example, there is now robust evidence from studies on the demand for cleaner cars showing that beyond price, running and maintenance costs, consumers are interested in the availability of fuel, performance and the environmental impacts of cars (e.g. Cordera et al., 2018; Potoglou and Kanaroglou, 2007). However, there are fewer studies of consumer interest in the ethical and/or environmental impacts of smartphones (e.g. Haucke, 2018). An area, which has received less attention overall, is how the sources of materials used to construct goods such as cars and mobile phones are affecting consumer choice. Although there is significant research on how much consumers are willing to pay for different attributes related to cleaner cars and mobile-phone technologies (e.g. Kim, 2018), much less is known about the value consumers place on materials and whether they would be inclined to purchase cars and mobile phones made of more environmentally sustainable or ethically resourced materials. Some initial insights are available from studies on individual perceptions of remanufactured products, particularly that quality/reliability concerns and prior knowledge about the environmental benefits of these products can vary considerably between individuals and cultures, leading to variations in willingness to pay for sustainable or ethically-sourced materials (Govindan et al., 2019; Hamzaoui-Essoussi and Linton, 2014).

Car and Mobile Phone Materials Manufacture Impacts

Currently, both cars and mobile phones are demanding in terms of materials and rare materials. The CO_2 emissions of car-materials manufacturing are considerable due to a reliance upon iron (64% of a car, by weight), aluminium (9.4%) and plastics (8.4%) (Ghassemieh, 2011; WSA, 2012); steel (and iron) manufacturing, alone, account for 25% of world CO_2 emissions from materials (plastics 5% and aluminium for 3%) (IEA, 2017; Worrell et al., 2016). Increasingly, plastics are substituted for steel in car designs, though plastics present additional recycling and toxicological challenges (Miller et al., 2014). By weight, mobile phones are also mostly composed of iron, aluminium and plastics (Mobile Phone Partnership

Initiative, 2009). Using scarce or critical materials in manufacturing is leading to a range of ethical and ecological problems (Eggert, 2011). The small quantities of scarce materials in smartphones (e.g. a smartphone contains only around 2g of rare earth metals; Bünzli, 2013; Cucchiella et al., 2015) belie their aggregate importance, with mobile phone and smartphone technology becoming ubiquitous (Ericsson, 2018). The integration of electronics within car designs (Restrepo et al., 2017) and the transition to electric vehicles. Gains and Nelson (2010) raise similar issues with respect to cars.

Sustainable Materials: Climate Neutrality, Ethical Production and Organic Materials
The term 'sustainable' is open to some interpretation (Robert et al., 2005); a common definition of sustainable development is that it is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"(WCED, 1987) (WCED, 1987) and sustainable production applies this principle to manufacturing (O'Brien, 1999) including the supply chain (Lebel and Lorek, 2008). Sustainability harmonizes three key elements: economic prosperity, human wellbeing and environmental conservation (Robert et al., 2005). Global climate change is of paramount importance in environmental conservation and sustainable development (IPCC, 2014a). 'Climate neutrality' in manufacturing is manufacturing at 'net-zero' greenhouse gas emissions: close to zero emissions or compensated for emissions by investing to remove greenhouse gases from the atmosphere (EC, 2018; IPCC, 2014b; Wyns et al., 2018). Extraction of natural resources has always a local environmental impact (Tuokuu et al., 2019). Sustainable production cannot be at the expense of human welfare (WCED, 1987) and ethical sourcing of materials entails paying fair prices for raw materials and labour (Lebel and Lorek, 2008), prioritising social benefits alongside profits when sourcing raw materials (Hutchins and Sutherland, 2008) and take action to avoid financing of warfare due to use of conflict minerals (Young et al., 2010). Innovative organic manufacturing materials offer new avenues for sustainable production of products such as cars and mobile phones (Georgios et al., 2016); organic materials are derived from living organisms and are not necessarily grown organically - i.e., without artificial chemicals (Rana and Paul, 2017). Likewise, the sustainability of organic materials depends upon the climate neutrality and ethics of the sourcing of the agricultural crops in question (Allwood et al., 2011). So, given that sustainability involves both human wellbeing and environmental conservation, materials that are both climate neutral and ethically sourced are sustainable materials, whether these are conventional or organic. It is therefore important to understand consumer preferences for these intangible properties in products.

Consumer Choice of Cars and Mobile Phones
Although there is currently a lack of evidence relating to the influence of materials on car and mobile-phone choices, there is good evidence that car choice reflects both demographic and situational factors and personality or lifestyle factors. For example, Choo and Mokhtarian (2004) found that 'large car' ownership was linked to larger incomes, but also to valuing personal status; likewise, 'small car' ownership was linked to high-density urban living, but also to being environmentally oriented. Whitmarsh and Xenias (2015) distinguish between preferences for *functional* attributes of cars (e.g. speed, fuel-efficiency, carrying capacity) and for *emotional* or *symbolic* attributes of cars (e.g. social approval, personal identity). Many studies show associations between car choice and practical attributes, including price, performance and fuel economy (e.g.Baltas and Saridakis, 2013; Kihm and Vance, 2016). The efficacy of these predictors is not in doubt. However, some studies have also found evidence for the influence of less tangible attributes: colour (Hafner et al., 2017), social comparison (Hoen and Geurs, 2011) and especially, branding (Baltas and Saridakis, 2013; Kihm and Vance, 2016) in car choice.

Preferences for alternative fuelled vehicles (AFVs) have also been considered with respect to symbolic or affective motives: pro-environmental identity, status seeking and being an early adopter of new technology (Rezvani et al., 2015). Concerning pro-environmental identity, Barbarossa et al. (2015) found that attitudes towards, and intention to buy, eco-friendly electric cars was associated with ‘green’ self-identity in Danish, Belgian and Italian consumers. Noppers et al. (2014) assessing explicit and implicit evaluations of electric vehicle (EV) attributes, found that environmental attributes and implicit symbolic/status evaluations better explained preferences for EVs than did evaluations of practical attributes. Indeed, the interplay of pro-environmental and status motives is unclear, with some experimental evidence that ‘green’ vehicles may be favoured as a display of status (one’s ‘green credentials’) (Griskevicius et al., 2010). Social norms and cultural values also appear to influence preferences for AFVs (Pettifor et al., 2017) highlighting the need for further cross-national studies.

Alongside pro-environmental identity and status motivations in making car choices, a factor of particular interest with regard to innovative car products is a desire to be innovative: to be an early adoptor of technologies, rather than following on behind (Rogers, 1983). Noppers et al. (2015) found that those who identified themselves as early adopters were more interested in, and more often intended to purchase, EVs compared to those identified as late adopters; early adopters also tended to value the symbolic/status aspects of these vehicles, compared to late adopters (they found no differences in preferences for environmental or instrumental attributes between early and late adopters, but environmental attribute preferences partly explained intentions to buy EVs). White and Sintov (2017) differentiated *environmentalist* and *social innovator* identities in preferences for EVs: they found both identities to be independently influential, though identifying as an environmentalist was somewhat more influential. Jansson and Bengtsson (2017) moved beyond hypothetical preferences by sampling, and comparing, motorists who had adopted AFVs to motorists who had not, whilst also assessing whether motorists identified as opinion leaders or opinion seekers, with respect to new technology (Rogers, 1983). Opinion leadership and pro-environmental norms were found to be independently associated with AFV ownership. Interestingly, these authors further distinguished between biofuel vehicles (a traditional AFV technology in Sweden) and EVs (the latest AFV technology in Sweden), finding that social norms and opinion *seeking* were associated with the adoption of biofuel vehicles, compared to electric vehicles.

There is less published evidence with respect to mobile phone choice and the factors that influence it, which perhaps reflects the pace at which these products have emerged and continue to evolve (e.g. from a telephone, ‘function phone’, to a touch-screen smartphone), compared to motor cars (Bento, 2016). There is some evidence that phone users prefer different brands for different purposes (Hsiao and Chen, 2015) and that consumers trade some functions off against others (Marley and Pihlens, 2012) with certain features (such as built-in higher-resolution cameras) being most important, with brand an important auxilliary choice criterion. Alongside evidence for consumer preferences for intuitive and efficient smartphone interfaces (Kim et al., 2015), there is some evidence that smartphone users also become brand loyal (Lin et al., 2015), partly because they prefer the brand and partly through inertia with respect to considering alternatives (Shi et al., 2018). There are some indications that the external design is also important, with social influence and culture also playing a role in which designs are prefered (Filieri and Lin, 2017). While these studies converge on mobile phones being chosen upon the strengths and weaknesses of their inherent attributes, there is less evidence concerning the motivational factors for choosing mobile phones with less tangible attributes; for example, social status, sustainability or innovativeness/originality (Haucke, 2018). Studies of perceptions of remanufactured/refurbished mobile phones indicate that we might expect many consumers to prefer conventional products as more familiar and (hence) more reliable, but with some consumers embracing their innovative and environmental/ethical qualities (Mugge et al., 2017; van Weelden et al., 2016).

The Present Study

The method known as Stated Preference Discrete Choice Experiments (SPDCE) or Discrete Choice Experiments (DCE), for short, has been widely applied across areas such as transport, environmental-resource management, and healthcare to derive estimates of the values individual consumers place on different products and services. The SPDCE method presents a number of advantages over the Contingent Valuation Method (CVM) (Hanley et al., 1998). The primary aim of this study is to examine the extent to which car and mobile phone consumers place any value on the materials resourced to make these products. In particular, we seek to understand whether sustainably and/or ethically resourced materials used to make cars or mobile phones play any role in consumer choices. A second aim is to examine how knowledge and concern about sustainability varies across diverse markets. Whereas previous research has explored consumer preferences for environmentally-friendly cars typically in terms of fuel type or powertrain (e.g. EVs: Rezvani et al., 2015), much less is known about willingness to pay for sustainable materials used to produce vehicles, or even how aware consumers are of the sustainability of materials used. Furthermore, very little research adopts a comparative design in which choice experiments are conducted for more than one product across multiple markets and cultures.

To address the research gap surrounding consumer preference for sustainable material use in cars and mobile phones, and to provide an exploration of these two substantively different products across cultures, the current study used a cross-cultural choice experiment focussing on cars and mobile phones. These products have also been selected because they include rare earth metals, graphite and steel, which have significant implications for climate change and other environmental problems. We also chose to compare cars and mobile phones because both goods reflect forefront technology development, but also very different types of purchases in terms of: (a) frequency of purchase – ranging on average from 20 months for mobile phones to 80 months (c.6.5 years) for cars (Counterpoint, 2018; IHS, 2018); and (b) price (ranging from tens to thousands of $/£ for mobile phones and cars, respectively). We are therefore able to determine how significant different factors, including sustainable materials, are in respect of contrasting products. In this context, we are also interested in whether there are cross-country/cultural differences in these valuations, hence, the geographic focus of our research is on six countries, representing major producers and/or consumers of products such as cars and mobile phones as well as greenhouse gas emissions (GHG, see Table 1), namely: (1) Germany, (2) India, (3) Japan, (4) Sweden, (5) UK and the (6) US. These countries are also interesting to compare because they reflect diverse cultural orientations, including individualism, with UK and US highly individualistic, Germany and Sweden moderately individualistic, and India and Japan less individualistic and more collectivist (Hofstede, 1980).

Table 1. Country population, gross domestic product and greenhouse gas emissions

	Germany	India	Japan	Sweden	UK	US
Population	82,928	1,352,617	126,529	10,183	66,489	327,167
Gross Domestic Product	3,997	2,726	4,971	551	2,825	20,494
GHG Emissions	719,883	2,238,377	1,214,048	43,421	419,820	5,254,279

Source: (The World Bank, 2019a, b, c)
Note: Population (2018) in thousands; GDP (2018) in billions current USD, GHG emissions (2014) in kt of CO2 equivalent.

2. Methods

2.1 Development of the survey questionnaire

Prior to the main survey, we obtained ethical approval for the research from Cardiff University's School of Psychology Ethics Committee. We then undertook a series of (N=10) qualitative consumer interviews with a UK convenience sample to explore awareness of material sustainability, factors shaping car and mobile phone purchasing, and understanding of key terminology (e.g., 'climate neutral') to be included in the choice experiment. Drawing on these interviews and a review of the literature on factors influencing car and mobile phone consumer purchasing (e.g. Haggar and Whitmarsh, 2017), we designed two discrete choice experiments and a survey. We then undertook cognitive interviews with a further UK convenience sample (N=10) to ensure terminology was understandable and that all the key variables were included in the choice experiment.

2.2 Stated choice experiments for cars and mobile phones

The survey comprised a car and a mobile phone choice experiment, which were designed to examine whether consumers placed any importance on – and to estimate their willingness to pay for - more sustainable materials and sources. Each experiment included five choice cards for car purchasing and a further five cards for mobile phone purchasing. For cars, participants selected from four choices (Petrol, Electric, Biofuel and Hybrid), and for phones, they chose from two unlabelled options (Mobile Phone A and Mobile Phone B). For both cars and mobile phones, the choices had eight attributes with different levels, which varied according to a D-efficient experimental design based on the multinomial logit model (MNL) and prior parameters equal to zero. The choice cards in both experiments were generated using the software Ngene and incorporated a blocking algorithm to reduce the 60 choice cards generated to a feasible number of cards (five per experiment into 12 blocks) for each participant (ChoiceMetrics, 2010).

Tables 2 and 3 present the attributes and levels introduced in the car and mobile experiments, respectively. It is worth highlighting that both experiments included the same number (eight) and as far as possible equivalent attributes (e.g. fuel availability for cars and battery life for phones), to enable comparison in decision-making across product types. To enhance the realism of the experiments, participants answered background questions relating to purchase intentions to buy a car and a mobile phone, including the money they would spend to purchase a car and subscribe to a monthly mobile phone contract. The amount of money they indicated they would spend for each product allowed us to then vary the products' prices in the choice experiment relative to that amount.

Materials, the attribute of main investigation in this study, corresponded to the type of materials cars and mobile phones were made from by using the terms 'Conventional' (i.e., steel, aluminium and plastic) and 'Organic' (wood fibre, soybeans and flax) (see Bajwa and Bhattacharjee, 2016 for a detailed discussion). Each of these could also then be "Climate neutral" or "Ethically sourced". Definitions of the terms 'climate neutral' and 'ethically sourced' were provided to participants as part of the introduction to the experiments. Climate neutral materials meant that efforts were made to avoid and reduce the release of greenhouse gas emissions such as CO2 during the extraction and processing of materials and the production of the product (Agarwal et al., 2019; Zhu et al., 2016). Ethically (responsible) sourced materials meant that the extraction of the materials (e.g. conflict-free metals) and the production process (e.g. soybeans) were conducted in a way which was fair, protected human rights and prevented negative social impacts (e.g. Giovannucci and Potts, 2016; Young, 2018). The implications of *not* being climate neutral or ethically sourced (i.e., the "Conventional" and "Organic" levels) were not explicitly explained to participants. However, the theoretical implication of a product whose materials are both climate neutral and ethically sourced is that it is made from sustainable materials, irrespective of whether it is a conventional or organic.

Even though potential substitution of metals and plastics (i.e., conventional materials) with materials such as wood fibre, soybeans and flax (i.e., organic materials) could cost less, may be recyclable, could improve performance or bring local environmental benefits, it would not guarantee that the supply chain or manufacturing would be carbon neutral or would have fewer ethical implications than conventional materials (Ramli et al., 2018). Therefore, 'Organic and climate neutral' and 'Organic and ethically sourced' levels were included alongside the

‘Conventional and climate neutral’ and ‘Conventional and ethically sourced’ as separate levels of the Materials attribute.

Table 2. Attributes and levels in the car choice experiment

Attribute	[Level] Description
Materials	[1]. Conventional materials (base level) [2]. Conventional materials, which are ethically sourced [3]. Conventional materials, which are climate neutral [4]. Organic materials [5]. Organic materials, which are ethically sourced [6]. Organic materials, which are climate neutral
Exterior design in terms of the car's shape, colour and style (Chan et al., 2015)	[1]. Conventional design (base level) [2]. Unique design
Annual running cost*	[1]. Average cost of a present-day petrol car for 10,000 kms [2]. 60% of a present-day petrol car [3]. 70% of a present-day petrol car [4]. 80% of a present-day petrol car [5]. 90% of a present-day petrol car
Availability of fuel at existing petrol stations (%)*	[1]. 40% of existing petrol stations [2]. 60% of existing petrol stations [3]. 80% of existing petrol stations [4]. 100% of existing petrol stations (base level)
Acceleration: 0 to 60 mph/100kph in seconds	[1]. 6 [2]. 8 [3]. 10 [4]. 12
Level of autonomous driving (SAE, 2016)	[1]. Zero automation (base level) [2]. Driver assistance [3]. Partial assistance [4]. Conditional automation [5]. High automation [6]. Full automation
Size	[1]. Small (base level) [2]. Mid-size [3]. Large
Price	[1]. Amount respondents would pay upfront (base level)** [2]. 20% higher than the base level [3]. 30% higher than the base level [4]. 40% higher than the base level

* Only applicable in the biofuel and electric car options (Sierzchula et al., 2014)
** Distribution values of base-level prices are shown in Table 7

Other attributes included both functional and symbolic/affective attributes found to be significant for car (e.g. Haggar and Whitmarsh, 2017; Potoglou and Kanaroglou, 2007, 2008), and mobile-phone (Marley and Pihlens, 2012) purchasing (see also, Luchs and Kumar, 2017). These attributes included price, running costs, functionality (e.g. car size, mobile-phone features), car acceleration and phone performance, and exterior design (Chan et al., 2015). The definitions of their levels involved adaptions based on previous studies (Cordera et al., 2019; Potoglou and Kanaroglou, 2008; Sierzchula et al., 2014) and subsequent cognitive testing of the experiments. With regard to the remaining functional attributes for mobile phones and their levels, definitions involved studying commercially available alternative products and

adaptations based on previous studies including Filieri and Lin (2017) (aesthetics/design), Kim et al. (2016) (design, price, performance) and Marley and Pihlens (2012) (camera).
Car-fuel availability has been introduced in previous choice experiments in varying ways including density of re-charging facilities, distance to nearest charging station or availability of charging stations at different locations (Liao et al., 2017). In this study, we adopted the concept of 'availability of charging infrastructure' to define the different levels of this attribute for electric and biofuel car-options. The definition of the fuel-availability attribute followed Sierzchula et al. (2014) who found that charging infrastructure provided the best explanation when examining the factors that influenced electric-vehicle adoption across 30 countries. Both experiments included aspects of innovative technologies such autonomous driving for cars and organic light-emitting diode (OLED) screens for mobiles. Definitions of the autonomous-driving levels were provided to respondents in the introduction to the car experiment and resembled the six (6) levels proposed by the Society of Automotive Engineers (SAE, 2016).

Table 3. Attributes and levels in the mobile phone choice experiment

Attribute	[Level] Description
Materials	[1]. Conventional materials (base level) [2]. Conventional materials, which are ethically sourced [3]. Conventional materials, which are climate neutral [4]. Organic materials [5]. Organic materials, which are ethically sourced [6]. Organic materials, which are climate neutral
Exterior design	[1]. Conventional design (base level) [2]. Unique design
Performance	[1]. Standard (1 GHz, 0.5 GB RAM) (base level) [2]. Fast (1.4 GHz, 1 GB RAM) [3]. Very Fast (2.39 GHz, 6 GB RAM)
Camera	[1]. Rear: 5 mega pixel (MP); Front: - ; Video: standard definition (SD) (base level) [2]. Rear: 8MP; Front: 1.2MP; Video: High Definition (HD) video [3]. Rear: 12MP; Front: 8MP; Video: Ultra HD (4K)
Display	[1]. 3.5" LCD Screen (165 pixels/inch) (base level) [2]. 4.7" LCD screen (326 pixels/inch) [3]. 5.8" OLED screen (458 pixels/inch)
Memory	[1]. 32GB [2]. 64GB [3]. 128GB [4]. 256GB
Battery	[1]. 5 hours (1-day stand-by time) [2]. 8 hours (2 days stand-by time) [3]. 10 hours (5 days stand-by time) [4]. 16 hours (10 days stand-by time) [5]. 21 hours (12 days stand-by time)
Price per month	[1]. Amount respondents would pay monthly including connection fees (base level)*** [2]. 10% higher than the base level [3]. 20% higher than the base level [4]. 30% higher than the base level [5]. 40% higher than the base level [6]. 50% higher than the base level

** Distribution values of base-level prices are shown in Table 7

Finally, participants were also instructed that, apart from the attributes shown on the choice cards, all other aspects of their purchase would be 'satisfactory to you'. For cars, that would include 'what colour they are, what the manufacturer/brand of the car is, and (if you are imagining second-hand cars during this task) what the mileage is.' For phones, they were told 'both mobile phone options will be available with your preferred operating system.' They were also given instructions on how to complete the discrete choice experiments, including definitions of the remaining terms used.

2.3 Knowledge and attitude measures

Following the choice experiment, sustainability knowledge and attitudinal (salience, priorities) questions were asked, along with demographic items (see, Table 4).

- *Sustainability knowledge*. Two questions elicited respondents' knowledge about sustainable materials in cars and mobile phones, respectively: 'How much do you know about the sustainability of the materials that [cars/mobile phones] are made from' with a 10-point response scale from 1 (Nothing at all) to 10 (A great deal).
- *Sustainability salience*. Two questions elicited the salience of sustainability in respondents' decision-making: 'Before today, how much thought had you given to the sustainability of your [car/mobile phone]?' with a 10-point response scale from 1 (Nothing at all) to 10 (A great deal).
- *Sustainability priorities*. Respondents were asked to rank nine sustainability considerations in terms of priority in decision-making through the item 'When purchasing a product, what information about its production do you think it is important to know about? Please rank the following impacts: Greenhouse gas emissions, Emissions of local pollutants/emissions, Health effects from production, Harm to local communities, Child labour, Corruption, Finance of armed conflicts, Gender equality, Fair wages/prices'.

2.4 Survey implementation

The choice experiments and survey were translated from English to Swedish, German, Hindi and Japanese, and the translations were checked by native speakers and revised as appropriate. The choice experiments were then embedded in the Qualtrics survey software, along with the survey items. Finally, after internal survey checks, we 'soft launched' the survey with 50 respondents in each of the six countries, to further check survey quality, prior to launching the main survey.

Participants were recruited via the Qualtrics online panel (https://www.qualtrics.com) and data were collected in October 2018. A quota sample of around 1000 consumers per country was recruited to provide a representative national sample matched on age (18 years or older), gender and region of each country based on census data. During the data collection, we assumed that respondents who completed the survey in less than seven minutes were more likely to provide insincere answers or not take the survey seriously. These responses were automatically discarded by Qualtrics and were replaced by new respondents. A total sample of 6,033 respondents across the six countries was achieved. Participant details are shown in Table 4.

2.5 Analytical approach

The analysis of the SPDCE data corresponding to participants' choices for cars and mobile phones was undertaken using Discrete Choice Analysis (DCA) based on Random Utility Theory (RUT) (McFadden, 1974). Under RUT, an individual n assigns a utility U for each car (or mobile phone) option i in choice card t, which is described as:

$$U_{int} = V_{int} + \varepsilon_{int} = \alpha_i + \beta * X'_{int} + \varepsilon_{int} \qquad [1]$$

where

V_{int} is a linear-in-parameters function of the vector of attributes X' describing the car (or mobile phone) alternatives observed by individual n in choice situation t;

β are parameters representing the weight individuals placed on the attributes of the alternatives and the association of individual characteristics with the utility of an alternative i, respectively. These parameters are to be estimated along with α_i, a constant term specified for J-1 alternatives;

ε_{int} is a random term, which incorporates unobserved or unobservable attributes, taste variation and measurement or specification errors (Ben-Akiva and Lerman, 1985).

Under the assumption that ε_{int} is Type I Extreme Value independently and identically distributed (IID) the probability of choosing alternative i takes a closed-form solution known as the MNL model (McFadden, 1974):

$$P_{int} = \frac{exp(\alpha_i+\beta*X'_{int})}{\sum_j(\alpha_{j-1}+\beta*X'_{jnt})} \quad [2]$$

The above specification treats the responses from each choice card t by the same individual n as independent observations thus not accounting for serial correlation induced in the model because of the repeated observations – i.e., the panel nature of the data, which may result in underestimation of the coefficient standard errors (Train, 2009).

One way to overcome this issue is to estimate a mixed logit (MXL) specification so that the parameter β – which in a MNL model is assumed to be constant – is now estimated as a random coefficient equal to (Hole, 2007; Revelt and Train, 1998):

$$\beta_n = \beta + \eta_n \quad [3]$$

where η_n represents the standard deviation around the mean of the coefficient β and captures the respondents' taste variation relative to the average taste in the sample (Revelt and Train, 1998). In this study, we specified the price and running cost coefficients to be fixed and the coefficients of attributes and the alternative specific constants α were allowed to vary as independently normally distributed. This specification provided a way to capture taste variation for different attributes across participants in the sample. Also, this specification allowed the estimation of standard errors that reflected the panel nature of the data (Lancsar et al., 2017) as each participant completed five choice cards for each of the car and phone experiments, respectively. The unconditional choice probability of the repeated choices does not have a closed form solution and is estimated by simulated Maximum Likelihood (see, Train, 2009). The models reported in the following sections were estimated using the `mixlogit` command in STATA 13 using 1000 Halton draws (Hole, 2007).

The marginal willingness to pay (MWTP) for different levels of materials and the other attributes is computed as the ratio of the marginal utility of an attribute X over the price coefficient and is also normally distributed as the coefficient of each attribute (Revelt and Train, 1998):

$$MWTP_{attribute} = -\frac{\beta_{attribute}}{\beta_{price}} \quad [4]$$

3. Results

3.1 Survey sample

As shown in Table 4, gender was approximately evenly split between males and females (with <1% identifying as other or preferring not to say). Consistent with census data, the Indian sample contained younger respondents than the other samples, while Japan had older respondents. Just over half of the respondents across all countries had children. Education and income varied across countries, with India and the US the most educated (52-54% had a university degree) and Germany, UK, Sweden and Japan less educated (60-71% did not have a university degree). It is worth highlighting that the Indian sample is far from providing a representative profile of the population in terms of education given the high proportion of respondents with a university degree or higher (vs. 46% of 25-64 year olds in the population have no primary education; OECD, 2017). Also, Indian respondents below the median income were underrepresented given the observed proportions in the sample.

Table 4. Survey sample characteristics (%)

	Number of respondents (%)					
	Germany	India	Japan	Sweden	UK	US
Gender						
Female	518 (51.2)	526 (47.6)	544 (53.5)	495 (50.0)	498 (54.3)	514 (51.4)
Male	494 (48.8)	579 (52.4)	471 (46.4)	494 (49.9)	418 (45.6)	484 (48.5)
Prefer not to say	-	1 (0.1)	1 (0.1)	1 (0.1)	1 (0.1)	1 (0.1)
Age (years)						
18 – 24	118 (11.6)	281 (25.4)	104 (10.2)	115 (11.6)	122 (13.3)	121 (12.1)
25 – 34	166 (16.4)	327 (29.6)	150 (14.7)	193 (19.5)	162 (17.6)	179 (17.9)
35 – 44	189 (18.7)	241 (21.8)	201 (19.8)	164 (16.6)	164 (17.9)	163 (16.3)
45 – 54	207 (20.5)	152 (13.7)	197 (19.4)	172 (17.4)	187 (20.4)	174 (17.4)
55 – 64	175 (17.3)	74 (6.7)	180 (17.7)	165 (16.6)	151 (16.5)	168 (16.8)
65+	157 (15.5)	31 (2.8)	184 (18.1)	181 (18.3)	131 (14.3)	194 (19.4)
Prefer not to say	-	-	1 (0.1)	-	-	-
Education qualifications						
Lower than university degree	714 (71.0)	494 (44.7)	602 (59.7)	644 (65.0)	607 (66.6)	483 (48.3)
University degree or higher	291 (29.0)	601 (54.3)	406 (40.2)	345 (34.9)	305 (33.4)	516 (51.7)
Prefer not to say	-	11 (1)	1 (0.1)	1 (0.1)	-	-
Have Children						
Yes	556 (55.0)	633 (57.2)	517 (51.9)	589 (59.5)	542 (59.1)	573 (57.4)
No	441 (43.6)	456 (41.2)	478 (47.9)	386 (39.0)	365 (39.8)	412 (41.2)
Prefer not to say	15 (1.4)	17 (1.6)	14 (1.4)	15 (1.5)	10 (1.0)	14 (1.4)
Annual Household Income						
Below median income	338 (33.4)	210 (19.0)	475 (46.7)	377 (38.1)	335 (36.5)	380 (38.4)
Median income or higher	665 (65.7)	896 (81.0)	537 (52.8)	606 (61.2)	541 (59.0)	616 (61.6)
Prefer not to say	9 (0.9)	-	5 (0.5)	7 (0.7)	41 (4.5)	3 (0.3)
Total	**1,012**	**1,106**	**1,009**	**990**	**917**	**999**

3.2 Choices for cars and mobile phones

Overall, participants were able to make comparisons across the car and phone choices, except an average of 3% across the six countries. Prior to the analysis of the stated choice data, we further screened out respondents based on the following criteria: (a) missing data[1], (b) respondents were not trading[2] - i.e., they consistently chose the same alternative across the five choice cards in each experiment (Hess et al., 2010). Non-trading behaviour was higher in the car experiment, but these were genuine responses for two reasons. Firstly, most non-traders (c. 90%) selected the petrol-car option over the alternative-fuelled or hybrid vehicles options. Secondly, there were significantly smaller proportions of non-traders in the unlabelled mobile-phone experiment (see, Footnote 2). If respondents were gaming or did not take the survey seriously, we would expect that non-trading patterns to be similarly high in both

[1] Car Experiment – mean: 3.5%; min: 1% in India; max.: 5.5% in Japan; Mobile experiment – mean: 1.7%; min: 0.1% in India; max: 6% in the US

[2] Car Experiment – mean 36.3%; min: 30.8% in the UK; max: 45% in Japan; Mobile experiment – mean: 11%; min. 6.8% in the UK; max. 17.2 in India

experiments. Despite excluding a large number of observations in both experiments, the characteristics of the respondents, except income, were not significantly different from the total sample; the only other exceptions were the under presentation of females in the mobile experiment in Japan (relative to the total sample) and the over presentation of those with university degree or higher in the US car experiment (for details on sample comparisons see, Supplementary File 1a). Further tests showed that there were no significant differences between the responses in the total sample and the subsequent samples in the car and choice experiments following screening, except the 'sustainability of car' question (see, Supplementary File 1b). The estimated coefficients of the MXL models for the car and phone experiments are shown in Tables 5 and 6, respectively[3].

3.2.1 Preferences for sustainably sourced materials

In most of the countries, respondents placed marginal or no value on ethically- or sustainably-sourced conventional and organic materials. This is evident from the non-significant coefficients of the different material levels in both the car and phone experiments.

In the car experiment (Table 5), the only exception was the UK where respondents were more likely to choose, in order of preference: (1) ethically-sourced-organic materials (coeff: 0.487; $p<0.001$), (2) ethically-sourced-conventional materials (coeff.: 0.396; $p<0.001$), (3) organic materials (coeff.: 0.332; $p<0.001$), (4) climate-neutral-conventional materials (coeff.: 0.249; $p<0.001$) and (5) climate-neutral-organic materials (coeff.: 0.247; $p<0.001$), relative to conventional materials (i.e., steel, aluminium and plastic), which was the reference level. Participants in India valued ethically-sourced-conventional materials and climate-neutral- and ethically-sourced-organic materials, though the latter were only significant at the 90% confidence level. On the other hand, Indian participants placed no value on climate-neutral-conventional materials and organic materials used in car manufacturing. Marginally significant effects at 90% confidence level were estimated for organic and ethically-sourced-organic materials in Sweden and climate-neutral-conventional materials in the US. It is worth noting that across the three European countries (Germany, Sweden, UK), respondents valued ethically-sourced-organic materials more than conventional car materials. The MXL model of the car experiment also revealed significant levels of taste heterogeneity in participants' preferences for ethically-sourced-conventional materials in Germany; climate-neutral-conventional and organic (at 90% confidence level) materials in Sweden and US; organic materials in India, climate-neutral-organic materials in Germany and Japan and ethically-sourced-organic materials in the UK.

In the mobile phone experiment (Table 6), participants across the six countries were indifferent between ethically-sourced-conventional materials and conventional materials, the reference level. On the other hand, all else being equal, participants in India, Sweden, US (marginally significant) and UK were more likely to choose a mobile phone made of climate-neutral-conventional materials. Also, participants in Sweden and the UK positively valued organic materials. Interestingly, respondents in Japan were more likely to choose a mobile phone made of conventional materials instead of a mobile phone made of organic materials or ethically-sourced or climate-neutral organic materials. The same pattern applies for climate neutral organic materials across Germany, India and the US. A possible explanation in this case is that respondents may find a little unrealistic that a mobile phone can be made of

[3] Each coefficient corresponds to the strength of preference (negative or positive) and in the case of qualitative attributes it is estimated relative to the reference level of an attribute (see, Tables 2 and 3). A significantly positive coefficient means that respondents were more likely to choose a car or a mobile phone when the attribute increased (e.g. fuel availability) or in the case of qualitative attributes (e.g. types of materials) they were more likely to choose the attribute attached to the positive coefficient instead of its reference level. On the other hand, a significantly negative coefficient would mean that participants were less likely to choose a car or phone option when the quantity of the attribute increased (e.g. for acceleration – the time to reach 60 mph or 100 kph) or in the case of a qualitative attribute, participants were more likely to choose the reference level than the attribute level with the negative coefficient.

alternative materials. A contrasting pattern was also found between Japan and Sweden participants; the former negatively valued ethically-sourced-organic materials whereas the latter were more likely to choose a mobile phone made of these materials relative to conventional materials.

Table 5. Mixed logit parameter estimates in the car choice models

Attribute	Germany	India	Japan	Sweden	UK	US
Price>>	-0.949***	-0.963***	-0.517***	-0.739***	-1.226***	-1.156***
Running Cost	-2.353***	-0.130**	-0.955***	-0.0932***	-2.653***	-2.712***
Autonomous Driving: Level 1	Reference					
Autonomous Driving: Levels 2-6	-0.019	0.094	0.411***	-0.188**	-0.319***	-0.166*
Conventional Materials^ (CMs)	Reference					
Ethically sourced CMs	0.113	0.260***	-0.143	-0.077	0.396***	0.094
Climate neutral CMs	-0.159	-0.010	-0.075	0.051	0.249**	0.168*
Organic materials (OMs)	0.162	0.097	-0.039	0.170*	0.332***	0.030
Ethically sourced OMs	0.185*	0.145*	-0.029	0.174*	0.487***	0.126
Climate neutral OMs	0.096	0.149*	-0.116	0.061	0.247**	0.133
Fuel Availability	0.019***	0.011***	0.014***	0.001***	0.018***	0.022***
Acceleration	-0.009	0.027**	-0.008	-0.032**	-0.014	-0.036***
Vehicle Size: Small	Reference					
Medium	0.440***	0.286***	0.073	0.234***	0.138*	0.409***
Large	0.168*	0.295***	-0.569***	0.202**	-0.006	0.246***
Design: Unique (vs. conventional)	-0.053	0.154***	-0.187***	0.0221	0.039	0.038
Alternative Specific Constants						
Electric	-0.592***	-0.192	-0.394*	-0.017	-0.512***	-0.564***
Hybrid	-0.808***	-0.331***	-0.0637	0.121	-0.546***	-0.372***
Biofuel	-1.128***	-0.457***	-1.354***	-0.295*	-0.862***	-0.675***
Standard deviation of parameters (normal distribution)						
Autonomous Driving: Levels 2-6	0.865***	0.243	0.771***	0.793***	0.531***	0.921***
Ethically sourced CMs	0.739***	0.027	0.297	0.003	0.009	-0.136
Climate neutral CMs	-0.371	-0.119	0.128	-0.532**	-0.556**	0.006
Organic materials (OMs)	0.114	-0.432*	0.005	0.048	-0.232	-0.035
Climate neutral OMs	0.590***	-0.064	0.539*	0.423*	-0.169	0.033
Ethically sourced OMs	0.397	0.204	0.306	-0.177	0.697***	-0.150
Fuel Availability	0.022***	0.012***	0.019***	0.015***	0.016***	-0.021***
Acceleration	0.0132	-0.012	0.046	-0.030	0.124***	0.112***
Medium	-0.050	0.198	-0.413*	0.470***	-0.293	-0.225
Large	0.871***	0.513***	0.884***	-0.591***	0.781***	0.886***
Design: Unique (vs. conventional)	-0.301*	0.328**	0.292	0.015	0.099	-0.048*
Electric	1.269***	0.748***	0.898***	1.284***	1.024***	1.189***
Hybrid	1.250***	1.034***	0.813***	1.153***	1.032***	0.969***
Biofuel	1.202***	0.926***	1.224***	0.935***	1.054***	1.040***
Number of observations (cases)	9,964	11,456	7,894	9,980	10,305	10,921
Log-likelihood at convergence	-3,194	-3,778	-2,430	-3,224	-3,269	-3,334

*** significant at 99% confidence level; ** significant at 95% confidence level; * significant at 90% confidence level
>> Price and running cost are scaled as follows: Germany, UK, US: price/10,000; running cost/1000 - Sweden: price / 100000; running cost/1000 – India: price / 1000000; running cost/10000; Japan price / 1000000 ; running cost/10000
^ Conventional = steel, aluminium and plastic. Organic = wood fibre, soy beans and flax.

Table 6. Mixed logit parameter estimates in the mobile choice models

Attribute	Germany	India	Japan	Sweden	UK	US
Price>>	-0.462***	-0.636*	-0.401***	-0.509***	-0.835***	-0.423***
Conventional Materials^ (CMs)	Reference					
Ethically sourced CMs	-0.107	-0.282	-0.237	0.097	-0.050	-0.202
Climate neutral CMs	0.150	0.314**	0.005	0.571***	0.309**	0.271*
Organic materials (OMs)	-0.251	0.123	-0.306*	0.534***	0.313*	-0.250
Ethically sourced OMs	0.033	0.179	-0.297**	0.275**	0.088	0.002
Climate neutral OMs	-0.266**	-0.248*	-0.412***	-0.116	-0.067	-0.347**
Camera – 5MP	Reference					
Camera – 8MP	0.045	0.275***	-0.041	0.174*	0.185*	0.064
Camera – 12MP	0.377***	0.929***	-0.023	0.315***	0.556***	0.596***
Memory	0.002***	0.003***	0.002***	0.007***	0.003***	0.005***
Display	0.361***	0.374***	0.241***	0.284***	0.357***	0.433***
Battery	0.072***	0.056***	0.118***	0.068***	0.064***	0.088***
Design: Unique (vs. conventional)	-0.152*	-0.116	-0.444***	-0.240***	-0.095	-0.423***
Standard (1 GHz, 0.5 GB RAM)	Reference					
Fast (1.4 GHz 1GB RAM)	0.858***	0.852***	0.693***	0.579***	0.826***	0.971***
Very Fast (2.39 GHz 6GB RAM)	0.929***	1.382***	0.685***	0.744***	0.953***	0.864***
Standard deviation of parameters (normal distribution)						
Ethically sourced CMs	1.555***	-1.343***	-1.446***	0.548	1.140**	1.971***
Climate neutral CMs	1.237***	-0.021	-0.794*	-0.533	0.963**	0.984*
Organic materials (OMs)	-0.734*	0.411	0.027	-0.653	1.026**	-0.294
Climate neutral OMs	-0.565	-0.186	0.423	0.787***	0.072	-0.649
Ethically sourced OMs	0.199	0.498	-0.585*	0.489*	0.024	-0.077
Camera – 8MP	0.031	-0.590**	-0.050	-0.303	0.713**	0.059
Camera – 12MP	-0.604***	1.227***	0.709***	0.758***	-0.658***	1.360***
Memory	0.006***	0.007***	0.005***	0.004***	0.005***	0.007***
Display	0.547***	0.609***	0.602***	0.457***	0.579***	0.664***
Battery	0.102***	0.113***	0.149***	0.081***	0.080***	0.118***
Design: Unique (vs. conventional)	0.851***	0.932***	0.632**	0.517**	0.439	0.895***
Fast (1.4 GHz 1GB RAM)	-0.033	0.277	0.079	-0.020	-0.008	0.218
Very Fast (2.39 GHz 6GB RAM)	-0.537**	-0.980***	0.950***	-0.522**	-0.007	0.795***
Number of observations (cases)	8,484	7,730	7,826	8,468	6,962	7,534
Log-likelihood at convergence	-2,610	-2,367	-2,356	-2,608	-2,063	-2,210

**** significant at 99% confidence level; ** significant at 95% confidence level; * significant at 90% confidence level*

>> Price is scaled as follows: Germany, UK, US: price/10 - Sweden: price / 100 – India: price / 10000; Japan price / 1000

^ Conventional = steel, aluminium and plastic. Organic = wood fibre, soy beans and flax.

As with the car choice data, the estimated MXL model for the mobile phone data accounts for taste heterogeneity of participants across the six countries. As shown in Table 6, there was significant taste variation: for ethically-sourced-conventional materials across Germany, India, Japan, US and the UK; for climate-neutral-conventional materials in Germany and the UK and marginally significant taste heterogeneity in Japan and the US. Preferences for mobile phones made of organic materials in Germany (marginally significant) and the US also exhibited taste heterogeneity. Similarly, Swedish preferences significantly varied for climate neutral organic materials and marginal variation in tastes were captured for ethically-sourced-organic materials in Japan and Sweden.

3.2.2 Preferences for car attributes

As shown in Table 5, all parameters of the remaining car attributes, except unique vehicle design, autonomous driving and acceleration were statistically significant at 99% confidence level. All else being equal, participants were more likely to choose less expensive cars, with lower running costs, and higher fuel availability the latter being applicable only to electric and biofuel car options.

With regard to the levels of autonomous driving, participants in Sweden, US (significant at 90% confidence level) and the UK were less likely to choose a car with any level of autonomous driving spanning driver assistance (Level 2) to full automation (Level 6, see Table 2). By contrast, Japanese consumers were more likely to choose cars with any autonomous driving between Levels 2 and 6 with no significant differences in the coefficients across these levels. Finally, participants in Germany and India placed no significant value on the potential autonomous-driving capacity of a car compared to 'no automation', the reference level.[4]

We found mixed evidence with regard to acceleration. The negative coefficient of acceleration implied that participants in US and Sweden (95% confidence level) were more likely to choose cars that would accelerate from 0 to 60 mph (100kph) in shorter times (range: 6 to 12 seconds). By contrast, participants in Germany, Japan and the UK did not place any significant value on the acceleration of the car options. Interestingly, the significant (at 95% confidence level) and positive coefficient indicated that participants in India were more likely to choose slower cars – which could be due to poor quality of the road network and consequent safety concerns.

With regard to size, with the exception of the UK and Japan, there was a significant preference for medium and large cars relative to small cars, the reference level. In Germany and the US, participants placed a higher value on medium than large cars. Participants in India and Sweden were indifferent between medium and large cars as the estimated coefficients were not significantly different from each other. Finally, UK participants, all else being equal, were more likely (significant at 90% confidence level) to choose a medium car relative to a small car but they were indifferent between small and large cars.

Only Indian consumers placed a significantly positive value on the unique design of a car relative to conventional design. On the other hand, participants in Japan were more likely to choose a car with conventional design (the reference level) relative to a car with unique design.

The values of the alternative specific constants implied that among a set of four cars with identical features, consumers across Germany, US and the UK were more likely to choose a petrol car over an electric, a hybrid and a biofuel car. The values of the estimated alternative specific constants indicated no significant difference in the order of preference across electric, hybrid and biofuel in those countries. Participants in Sweden were indifferent across the four car technologies, should those have had the same features. Also, all else being equal, participants in India valued a petrol and electric car the same whereas participants in Japan valued a petrol and a hybrid car the same.

The standard deviations for the majority of the estimated parameters were statistically significant, which suggests that there was significant taste heterogeneity in the data for these attributes. The exceptions were: autonomous driving in India; acceleration in Germany, India, Japan and Sweden; medium sized cars in Germany, India, US and the UK; and unique design in Japan, Sweden and UK.

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[4] Earlier specifications showed no significant difference across coefficients estimated for each autonomous driving level across all countries, hence we report a single coefficient for all levels in Table 5.

3.2.3 Preferences for mobile phone attributes

Table 6 shows MXL model coefficients for different mobile phone attributes. Across all countries, participants expressed economically rational preferences and thus were more likely to choose cheaper mobile phones with higher memory, larger display, better performance and long-lasting battery. The standard deviations of all the above attributes, except price, which was fixed, were statistically significant indicating significant taste heterogeneity in preferences across all countries.

With regard to camera resolution, respondents across all countries, except Japan, were more likely to choose a mobile phone with a 12MP rear camera, an 8MP front camera and ultra-high definition video recording function relative to a mobile phone with 5MP rear camera, no front camera and standard video recording, the reference level. Participants in Germany and the US placed no added value on a mobile phone having an 8MP rear camera, 1.2MP front camera and high definition video relative to the reference level. The standard deviation for a 12MP rear-camera phone was statistically significant across all countries implying significant taste heterogeneity in preferences. The standard deviation of the parameter distribution for an 8MP rear-camera phone was only significant from India and the UK.

Finally, respondents were less likely to choose a mobile phone with a unique design (vs. conventional design) across Germany (significant at 90% confidence level), Japan, Sweden and the US. Also, taste heterogeneity with regard to the unique design attribute was detected in all countries except the UK.

3.2.4 Willingness to pay for sustainable- and ethically- resourced materials

In all cases where model coefficients in Table 5 were statistically significant, willingness to pay for sustainable material vehicles ranged from €1,203 in the US, for climate-neutral conventional materials up to a maximum €4,524 in the UK, for ethically-sourced-organic materials (see, Table 7). After the US, Germany showed the next lowest WTP for sustainable materials, specifically €1,951 for ethically-sourced-organic materials (OMs). In Sweden, WTP for OM cars was €2,214 or €2,256 if also ethically-sourced; while in India, participants were WTP €3,239 for ethically-sourced-conventional material (CM) cars, €1,856 for climate neutral OMs and €1,803 for ethically sourced OMs. In the UK, WTP for sustainable cars ranged from €2,319 for climate-neutral CMs and €2,297 for climate-neutral OMs to €3,091 for OMs, €3,687 ethically-sourced CMs, and €4,524 for ethically-sourced OMs. In those cases where the coefficient for sustainable materials were not statistically significant, it was not possible to estimate a marginal willingness to pay (Hensher et al., 2005). Table 7 also provides the descriptive statistics of the price respondents would pay to purchase a car or for a mobile phone contract across the six countries.

Swedish participants expressed the highest WTP for sustainable mobile phones – specifically, €11 for climate-neutral CMs, €10 for OMs and €5 for ethically-sourced OMs. UK participants were also WTP more for sustainable phones: €4 for climate-neutral CMs and €4 for OMs. Japanese participants placed negative valuations on some levels of alternative materials; for example, they were only willing to accept organic phones if there was a price reduction of €6-€8. Similarly, German respondents would only accept a climate-neutral OM for a €6 discount. There are more mixed findings from the US and India, where both would be WTP €6 extra for a climate-neutral CM phone, but they would require a discount of €5 (India) or €7 (US) to accept a climate-neutral OM phone.

Table 8 shows the WTP for other car and phone attributes. Notably, many of these were lower than WTP for sustainable materials, although WTP for size was higher in some countries. In contrast, WTP for other mobile phone attributes was higher than for materials, in most cases; for example, WTP in India for very high-performance phones the WTP was €26 (compared to €6 for climate-neutral CMs).

Table 7. Marginal willingness to pay (and accept) for car and mobile-phone materials

	Car materials					*Mobile phone materials*					
	Germany	India	Sweden	UK	US	Germany	India	Japan	Sweden	UK	US
Ethically sourced CMs		3239 (689:5789)		3687 (1514:5860)		-	-	-	-	-	-
Climate neutral CMs				2319 (288:4350)	*1203* *(-86:2493)*	-	*6* *(-3:15)*		11 (5:16)	*4(0:8)*	*6* *(-1:12)*
Organic Materials (OMs)			*2214* *(-312:4741)*	3091 (963:5219)		-	-	-6 (-13:1)	10 (5:15)	*4* *(0:9)*	-
Climate neutral OMs		*1856* *(-343:4055)*		2297 (432:4163)		*-6* *(-11:0)*	*-5* *(-12:2)*	-8 (-14:-3)		-	-7 (-13:-1)
Ethically sourced OMs	*1951* *(-73:3974)*	*1803* *(-412:4019)*	*2256* *(-186:4699)*	4524 (2201:6848)		-	-	-6 (-11:0)	5 (1:9)	-	-
Mean stated price respondents would pay	18,094	12,328	16,168	13,891	21,565	29	30	39	30	39	43
Standard deviation	13,588	5,832	11,359	11,514	10,774	25	28	24	19	24	35
Min	1,500	3,250	1,692	1,110	2,250	10	20	12	9	9	9
Max	60,000	26,000	52,640	66,600	54,000	150	110	125	113	167	180

All values are in Euros (exchange rate as of: 01/02/2019); confidence intervals in brackets
Italicised WTP values were computed for statistically significant parameters at the 90% confidence level
Japan is not listed in the car materials experiment as none of the material coefficients were significant

Table 8. Marginal willingness to pay (and accept) for car and mobile phone attributes

Experiment	Attribute	Germany	India	Japan	Sweden	UK	US
Car	Fuel Availability	202 (108:296)	138 (49:227)	209 (45:374)	127 (40:214)	165 (87:244)	154 (100:209)
	Design	-	1920 (400:3440)	-	-	-	-
	Acceleration	-	337 (17:657)	-	-419 (-787:-50)	-	-259 (-460:-59)
	Size: Medium	4635 (2550:6720)	3570 (1267:5872)		3036 (648:5425)	*1283* *(-239:2805)*	2935 (1709:4161)
	Size: Large	*1773* *(-86:3632)*	3683 (1434:5932)	-8803 (-13805:-3800)	2629 (391:4867)		1763 (554:2971)
	Autonomous Driving (Levels 2-6)	-	-	6360 (2059:10661)	-2444 (-4902:14)	-2965 (-4810:-1120)	*-1194* *(-2480:91)*
Mobile phone	Camera – 8MP	1 (-3:5)	5 (-1:12)	-	*3* *(0:7)*	*3* *(-1:6)*	
	Camera – 12MP	8 (4:12)	18 (-2:37)	-	6 (3:9)	8 (5:10)	12 (7:17)
	Memory	0.054 (0.027:0.08)	0.055 (-0.008:0.118)	0.045 (0.023:0.067)	0.031 (0.014:0.048)	0.037 (0.023:0.052)	0.103 (0.068:0.137)
	Display	8 (4:11)	7 (-1:15)	5 (2:7)	5 (3:7)	5 (3:7)	9 (6:12)
	Battery	2 (1:2)	1 (0:2)	2 (2:3)	1 (1:2)	1 (1:1)	2 (1:2)
	Design	*-3* *(-7:0)*	-2 (-6:2)	-9 (-13:-5)	-5 (-7:-2)		-9 (-13:-4)
	Performance: Fast (1.4 GHz 1GB RAM)	19 (11:26)	16 (-2:34)	14 (9:19)	11 (7:15)	11 (8:15)	20 (13:27)
	Performance: Very Fast (2.39 GHz 6GB RAM)	20 (12:28)	26 (-3:55)	14 (8:20)	14 (9:19)	13 (9:17)	18 (11:24)

All values are in Euros (exchange rate as of: 01/02/2019); confidence intervals in brackets
Italicised WTP values were computed for statistically significant parameters 90% confidence level

3.3 Sustainability knowledge and attitudes

Consumers tended to have limited to moderate knowledge about the materials that either cars or phones were made from (Figure 1). Mean knowledge for mobile phones was 4.7 and for cars 4.8 across all countries (on 1 to 10 scale). Similarly, the salience of sustainability in consumers' decision-making was not high: overall mean thought given to the sustainability of mobile phones was 4.9 and 5.7 for cars (again on 1-10 scale). Highest knowledge about sustainability was observed in India (6.9 for cars and 7.1 for mobiles) and lowest in Japan (4.1 for cars) and the US (3.7 for mobiles). Consistent with this, Indian consumers reported having given most thought to sustainability of mobiles (7.6) and cars (7.4), while Japanese and UK consumers reported the least thought for cars (4.9) and UK consumers the least for mobiles (4.6).

Respondents were also asked about the relative importance of different sustainability attributes in their product decision-making. As shown in Figure 2, the top ranked (most important) items were 'health effects from production' and 'fair wages' in India, Japan and the US; 'fair wages and child labour' in Sweden and the UK; and 'fair wages' and 'child labour' in Germany. There are some differences across cultures, with child labour ranked much less important in Japan and more important in Sweden than elsewhere; fair wages/prices were ranked higher in Japan than elsewhere. In terms of environmental criteria, local pollution was ranked somewhat higher than greenhouse gases (GHGs). Both were ranked slightly more important in India and Japan, and (for GHGs) lowest in the US.

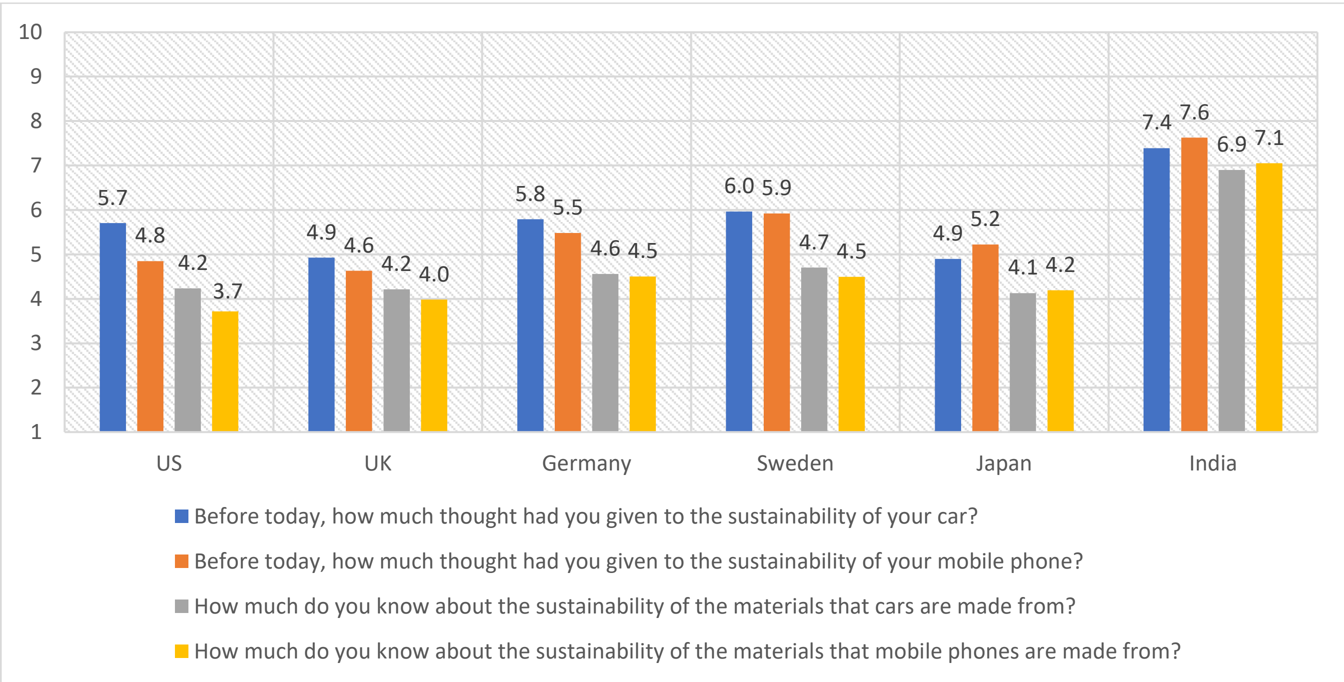

Figure 1. Salience and knowledge of sustainability in relation to car/phones

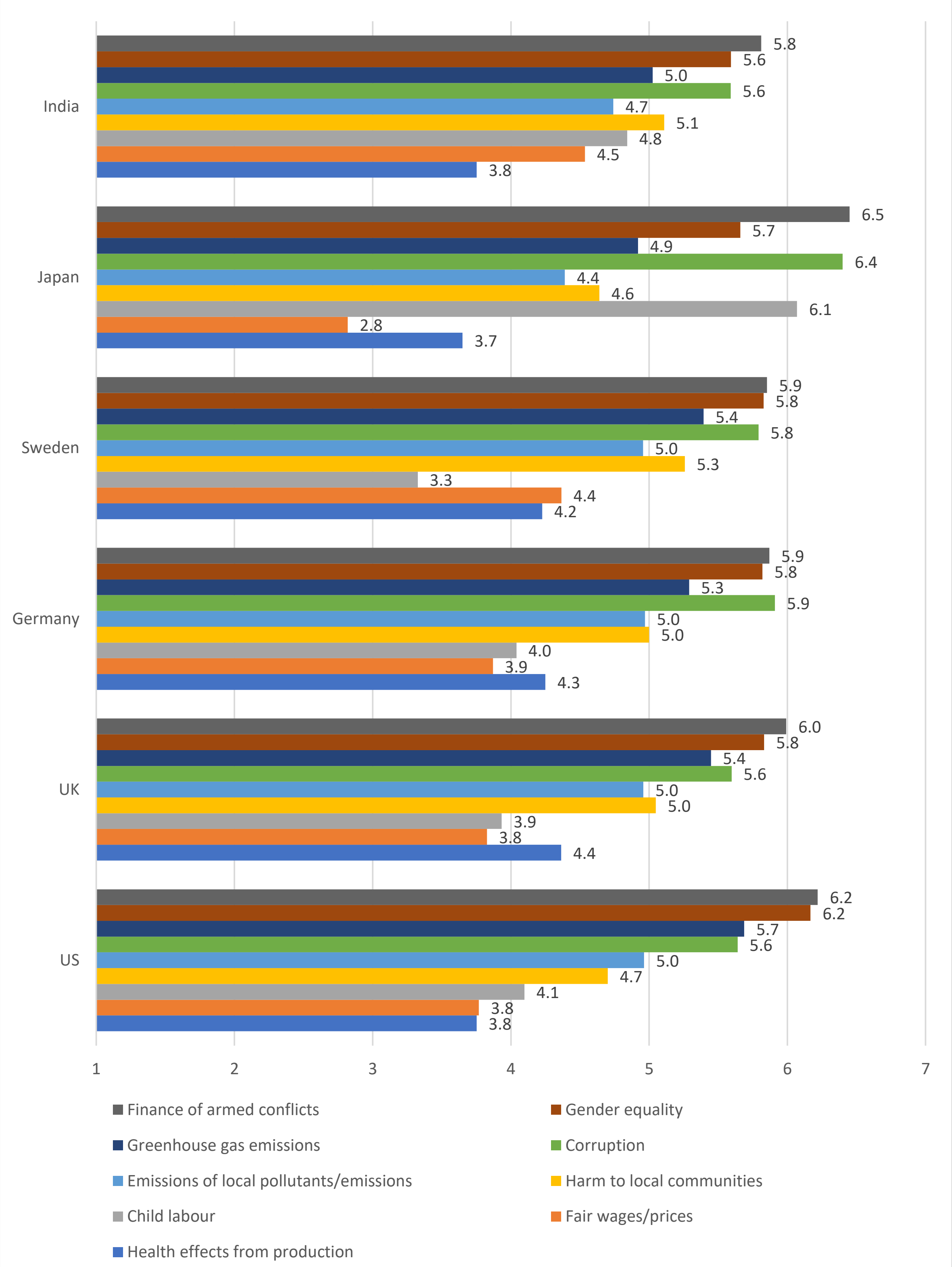

Figure 2. Ranking of different sustainability criteria when purchasing (1=most important)

4. Discussion & Conclusion

The aim of this study was two-fold: to examine the extent to which consumers of diverse products – specifically cars and mobile phones – place any value on the materials resourced to make these products; and to explore knowledge of and attitudes to sustainability in relation to these products across diverse markets. While previous research has shown environmental attributes (e.g. alternatives fuel vehicles) can command a price premium, very little research has explored consumer interest in or preference for material provenance or sustainability. We conducted choice experiments for these products in six culturally-diverse markets – US, UK, Germany, Sweden, Japan and India – representing an important advance in cross-cultural studies of consumer preferences. A summary of our findings in the car and phone choice experiments is shown in Appendix B (see, Tables B1 and B2). Table B3 in Appendix B also provides a qualitative overview of the significant effects the materials had on respondents' car and mobile-phone choices.

Overall, we found respondents had limited knowledge of or interest in product sustainability and, consistent with this, their choices were not strongly associated with ethically- or climate-neutral conventional or organic materials. Indeed, in many countries, we found no significant preference for sustainable materials cars and even a significant preference for less sustainable (e.g. conventional) phones. Rather, and consistent with the literature (e.g., Whitmarsh and Xenias, 2015), economic and practical attributes including price, running cost, and functionality (e.g. fuel availability; mobile phone features) were more salient in respondents' product choices than symbolic or ethical considerations including material sustainability.

There was, however, considerable heterogeneity in respondent preferences across these countries. Specifically, we found that UK participants were more likely to choose all types of sustainable material for cars over conventional ones, with ethically-sourced materials to be the most preferred. UK respondents, more specifically, were willing to pay €4,360 extra for a car made from ethically-sourced-organic materials. To a lesser extent, participants in other countries preferred cars made of certain sustainable material. In particular, European car consumers valued ethically-sourced-organic materials more than conventional materials. For mobile phones, preferences were more mixed across countries. Swedish and UK respondents valued organic phones over conventional material ones; while in other countries, conventional materials were typically preferred. In terms of policy implications, in Germany, Japan, India and the US, it may be necessary to inform and reassure customers that such products are not inferior goods and have positive environmental and ethical advantages (Govindan et al., 2019). More generally, this cross-national variation in consumer preferences is consistent with the prior research that has been conducted on alternative-fuel vehicles (e.g. Pettifor et al., 2017). These national differences may reflect the varying importance of these products in different markets, and/or different cultural values for sustainability, technology or materialism (Hofstede, 1980).

An interesting finding in this study was that respondents' preference patterns for different materials relative to the reference category – i.e., conventional materials, were mixed and varied between car and mobile phones. For instance, there was a broad trend across countries (except Japan and the US) for the ethically-sourced-organic materials to have the strongest influence on the choice of cars (relative to the other material levels). However, this trend was not found for mobile phones, with only Swedish consumers being positive about ethically-sourced-organic materials. For mobile phones the broad trend across the countries (except Germany and Japan) was in favour of climate-neutral-conventional materials, whilst climate neutral-organic materials were negatively associated with choices (except in the UK and Sweden). As such, preferences for different materials and their sustainability credentials was likely to be product dependent as well as varies between and within countries. An avenue of future research would be to explore the underlying reasons why consumers place different (or no) values on sustainable materials for different products. For instance, differences in preference patterns between cars and mobile phones may be explained by the profiles of consumers who buy these different types of product and the marked differences in price scales relative to disposable incomes. Future work will further investigate patterns according to socio-demographic characteristics and participants' responses to salience and knowledge of sustainability.

There was also heterogeneity in knowledge and attitudes in respect of sustainability across countries: while generally, sustainability awareness and concern was low/moderate, Indian consumers (followed by Swedes and Germans) claimed to know most about sustainability of cars and phones and to have considered sustainability in their decision-making about these products. Japanese, UK and US consumers expressed the lowest knowledge and issue salience. Specific sustainability concerns also varied across countries: although health and economic (e.g., fair wages/prices) criteria tended to be more important than environmental (e.g., GHGs) or certain social (armed conflict, gender equality) aspects, child labour was much less important in Japan and more important in Sweden, while fair wages/prices ranked higher in Japan, and GHGs were less important in the US than elsewhere. These survey findings were partly in keeping with the choice experiment results, which indicated low salience of sustainability concerns in product choice, though somewhat higher for cars than phones. On the other hand, the low self-reported awareness and interest in sustainability in the UK seems at odds with the much higher willingness to pay for sustainable material products in the UK than elsewhere. One possible explanation may be that consumers do not readily associate 'sustainability' with material provenance and impacts, whereas other associations (e.g., health effects from production, as suggested by Figure 2), may be more salient. Hence our experimental focus on materials did not map onto the sustainability concerns of (some) consumers.

Our study had several strengths including the comparison across both products and countries and the application of a robust experimental method (DCE) to better understand product choices, albeit in an experimental context. One limitation of this method is that it still only approximates actual behaviour in a real-world consumption context, and so its ecological validity is limited. Future work should triangulate and build on these findings with research using observation and retail consumption data. Another aspect of this work to be investigated further in the future would be whether different dimensions of materials (e.g. type, source, environmental impacts) could be represented by different attributes instead of a single attribute as in this study. Along these lines, further work should also go beyond material sustainability to explore the extent at which more diverse sustainability concerns (e.g., health impacts, fair trade) would influence consumers' product choices.

The choice experiment undertaken here did not provide sustainability information; for example, about the social or ecological impacts of rare metal mining, supply chain workforce conditions or pay, or greenhouse gas emissions associated with production of mobile phones and cars. Therefore, the choices made in the choice experiment were based on consumers' existing knowledge about sustainability, which the survey found to be modest at best. This raises the question of whether product choices would be different if relevant sustainability information were to be provided (and if so, which format or framing might be most effective). Most likely, this is the case since the results show that consumers' preferences for climate-neutral materials in mobile phones were mixed within and across countries. For example, in most countries including Germany, India, Japan and the US respondents were not in favour of climate-neutral-organic materials, whereas respondents in India, Sweden, UK and the US were more likely to purchase a phone made of climate-neutral-conventional materials. The use of materials in mobile phones is more associated with social and local environmental concerns. For cars, it would be expected that carbon-neutral materials would increase in importance. This could be a fruitful avenue for future work.

Overall, our research found that: (a) instrumental motives dominated product choice, and tangible attributes were more important than less visible ones (e.g., material provenance); (b) sustainable materials were more important for some product choices (e.g., cars), than others (e.g. phones), and similarly salience of sustainability was higher for cars than phones; (c) there were considerable cross-national differences in consumer knowledge, preferences and WTP; and (d) there was some discrepancy between consumers' sustainability preferences and their choices. The policy implications of these findings are that prices should reflect products' sustainability (i.e., internalising social and environmental externalities); sustainable products should include some additional functionality or features that will attract consumers; and/or education programmes should raise awareness of material provenance and sustainability issues, and therefore simulate consumer demand for more sustainably-manufactured products. The greater importance of sustainable materials for car choice over phone choice may reflect the higher investment and longer lifespan of cars, and therefore greater consumer attention to symbolic/ethical features than for products like phones that will more quickly be replaced. There may therefore be particular benefit in raising awareness of sustainable materials in relation to higher-cost goods, for which consumers are likely to be more deliberative in their decision-making. Our findings also showed that certain types of markets are more interested in products made from sustainable materials, specifically, UK and Swedish markets. Marketing sustainable products to these countries as early adopters may then help reduce prices and raise wider awareness of these products, facilitating subsequent consumer adoption elsewhere.

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Appendix A. Summary of findings in the car and phone choice experiments

Table A1. Summary of preferences in the car choice experiment

	Germany	India	Japan	Sweden	UK	US
Preferences for car materials	• Would prefer ethically-sourced-organic materials over conventional materials, the reference category* • No significant difference across all the other material categories	• More likely to choose ethically-sourced-conventional materials, ethically-sourced-organic materials* and climate-neutral-organic materials* over conventional materials • No significant difference in preferences across climate-neutral-organic materials, organic and conventional materials	• No significant preference for any type of material category when compared with conventional materials	• Would prefer organic materials* and ethically-sourced-organic materials* over conventional materials • No significant different across the climate-neutral (conventional or organic) categories and conventional materials	• Would prefer any material type (conventional or organic), which is ethically-sourced or climate-neutral over conventional materials • Ethically-sourced-organic materials were valued higher than climate-neutral (conventional or organic) materials	• More likely to choose cars made of climate-neutral conventional materials over conventional materials • No significant different across the other material options when compared with conventional materials, the reference category
Preferences for other car attributes	• Would prefer medium and large cars • More likely to choose Petrol over Electric, Hybrid and Biofuel^^ • No difference in preferences across any level of autonomous driving, acceleration and design	• Would prefer medium and large cars • More likely to choose Petrol and Electric over Hybrid and Biofuel cars^^ • No difference in preferences across any level of autonomous driving • Would prefer faster cars with unique design	• Less likely to choose large cars • More likely to choose Petrol and Hybrid over Electric and Biofuel cars^^ • More likely to choose a car with some level of autonomous driving • Would prefer conventional design • No difference across any level of acceleration	• More likely to choose medium and large cars • Less likely (marginally) to choose Biofuel cars • Disinclined to choose a car with any level of autonomous driving	• More likely to choose medium cars • Would prefer Petrol over Electric, Hybrid and Biofuel^^ • Disinclined to choose a car with any level of autonomous driving • Indifferent to car design and acceleration	• More likely to choose medium and large cars • Would prefer Petrol over Hybrid, Electric and Biofuel^^ • Disinclined to choose a car with any level of autonomous driving* • Indifferent to car design • Would prefer faster cars
All countries: All else being equal, respondents would prefer cheaper car with lower running costs and higher fuel availability						

* significant at 90% confidence level; ^^ all else being equal, the order of preference follows the order each car technology is mentioned in the table

Table A2. Summary of preferences in the mobile-phone choice experiment

	Germany	India	Japan	Sweden	UK	US
Preferences for phone materials	• Less likely choose phoned made of climate-neutral-organic materials over conventional materials, reference level • No significant difference across the other material categories and conventional materials	• More likely to choose phones made of climate-neutral-conventional materials over conventional materials • Less likely choose phones made of climate-neutral organic materials over conventional materials, reference level • No significant differences across the other material-type categories and conventional materials	• Less likely to choose phones made of any organic materials including climate-neutral or ethically sourced • No significantly different preferences across conventional materials (ethically sourced or climate neutral)	• Would prefer climate-neutral-conventional materials, organic or ethically-sourced-organic materials • No significantly different preferences across ethically-sourced-conventional materials or climate-neutral organic materials	• More likely to choose a phone made of climate-neutral-conventional materials and organic materials • No significant difference across other material levels and conventional materials	• Would prefer climate-neutral-conventional materials • Less likely to choose phones made of climate-neutral organic materials • No significantly difference across ethically-sourced-conventional materials, climate-neutral and ethically-sourced-organic materials over conventional materials
Preferences for other phone attributes	• More likely to choose a phone with conventional design	• No difference between conventional and unique phone designs	• More likely to choose a phone with conventional design	• More likely to choose a phone with conventional design	• No difference between conventional and unique phone designs	• More likely to choose a phone with conventional design
	• Would prefer a 12MP camera over 8MP or 5MP	• Would prefer a 12MP or an 8MP camera over 5MP				
	All countries: All else being equal, respondents would prefer cheaper phones, with more memory, larger display and higher performance relative to the base levels					

Table A3. The effects of material levels on car and mobile choice (vs. reference level: Conventional Materials)

	Germany		**India**		**Japan**		**Sweden**		**UK**		**US**	
Level	Car	Phone	Car	Phone	Car	Phone	Car	Phone	Car	Phone	Car	Phone
Ethically Sourced CM			+						+			
Climate Neutral CM				+				+	+	+	+	+
Organic						-	+	+	+	+		
Ethically Sourced OM	+		+			-	+	+	+			
Climate Neutral OM		-	+	-		-			+			-