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Metric and Scale Effects in Willingness to Pay for Environmental Benefits

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What to study?

(1) Metric effect:

- Values of FC and CO_2 are equivalent in describing a car
  - Diesel: 1 L/100 km $\Leftrightarrow$ 26.5 g CO_2/km
  - Petrol: 1 L/100 km $\Leftrightarrow$ 23.2 g CO_2/km
- Do consumers value identical improvements in FC and CO_2 equally?

(2) Scale effect:

- How does the scale of CO_2 units influence consumers' perception?
  - Expanded scale vs. contracted scale
  - 10,000 g/100 km $\Leftrightarrow$ 100 g/km $\Leftrightarrow$ 0.100 kg/km

More contracted scale →

Why to study?

- Previous studies showed **how the framing of information affects consumers' decisions** (e.g., Tversky and Kahneman, 1981):

  (1) Metric effect: e.g., "MPG Illusion"

  (Larrick and Soll, 2008; Allcott, 2011; Schouten et al., 2014)

  - case 1: 5 km/l to 6 km/l saves 3.3 l/100 km
  - case 2: 15 km/l to 16 km/l saves 0.45 l/100 km
  - but perceived Δ in fuel savings are equal

  (2) Scale effect: (also "Unit effect", "numerosity bias")

  (e.g., Pandelaere et al., 2011; Camilleri and Larrick, 2014; Cadario et al., 2016)

  - e.g., \$20,000/100,000 miles perceived > \$20/100 miles

- Relevant for environmental policy

  (e.g., Teisl et al., 2008; Cohen and Vandenbergh, 2012; Heinzle, 2012; Newell and Siikamäki, 2014)

- Relevant for 'green' advertising

  (e.g., Xie and Kronrod, 2012; Chang et al., 2015)

This study

- investigates the **importance of metric and scale design as choice architecture tools** (close to Camilleri and Larrick, 2014; Aribarg et al., 2017)
- and contributes by ...
  - ... comparing WTP for identical improvements in FC versus CO_2
    - prior work: focus on one metric & difficulties to identify separately
  - ... exploring the scale and metric effects for diesel versus petrol cars
    - prior work: diesel buyers are more likely to look for the cheapest alternative (Olson, 2013)
- while controlling for observed and unobserved consumer heterogeneity

What to expect?

(H1) CO_2 value on expanded scale leads to higher WTP for a more environment-friendly car (replication)

- ▷ WTP(100 g CO_2/100 km) > WTP(1 g CO_2/km) > WTP(0.001 kg CO_2/km)

More contracted scale →

(H2) WTP for identical improvements is higher in terms of FC than CO_2 values (new)

- ▷ Diesel ΔWTP = WTP(1 l/100 km) - WTP (26.5 g/km) > 0
- ▷ Petrol ΔWTP = WTP(1 l/100 km) - WTP (23.2 g/km) > 0

(H3) The discrepancies b/w WTP(FC) and WTP(CO_2) vary by engine type (new)

- ▷ Diesel ΔWTP > Petrol ΔWTP

- Individual differences in WTP for FC and CO_2
(e.g., due to environmental attitudes; education; knowledge)

How to study?

Data Online survey; two choice-based conjoint experiments

- Scenario: car rental for a holiday trip
  - 10 days; 2000 km; fuel prices Details
- Within-subject variation: metric (FC & CO_2)
- Between-subject variation: CO_2 scale (g/100 km; g/km; kg/km)

Method (1) Model-free evidence

(2) MXL models, controlling for:

- environmental attitudes Details
- awareness of the FC-CO_2 correlation
- socio-demographic characteristics

Experimental design

- 4 designs (FC + CO_2 × 3 scales); random assignment Details
- 14 tasks per design
- 2 options + “no-choice” per task
- 2 × 4 × 4 attribute levels
- Allow for the interaction effect (Engine type × Metric) Details
- Design D-efficiency = 83.4

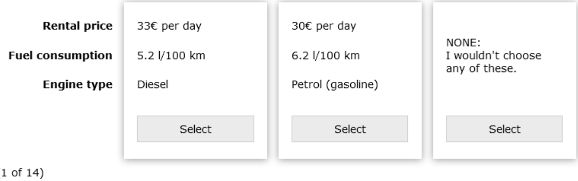
(1)	(2)	(3) Metric			
Engine	€/Day	FC	CO_2		
		l/100 km	g/100 km	g/km	kg/km
Diesel	23	3.2	8,500	85	0.085
Petrol	26	4.2	11,100	111	0.111
	30	5.2	13,800	138	0.138
	33	6.2	16,400	164	0.164

Details

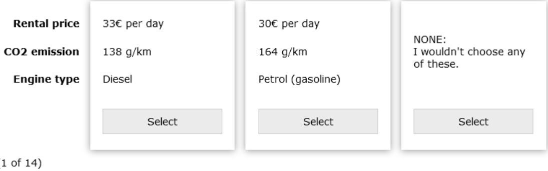
More contracted scale →

Experimental design

- FC-Design:



- CO_2-Design:



- Rental price (€/day): P1 > P2
- Total financial costs (€/trip) : TC1 < TC2
- Environmental costs (kg CO_2/trip): EnvC1 < EnvC2

Data description

Convenience sample	
N (used)	586
Country of residence	Germany: 96%; Western Europe: 100%
Period	July - November, 2017
Time spent, minutes	Mean: 15.69 (SD: 11.22)
Random design assignment	
First shown metric	(1) FC: 287 & (2) CO_2: 299
CO_2 Scale	(1) g/100 km: 194
	(2) g/km: 196
	(3) kg/km: 196
Respondents' characteristics (*)	
Age	Mean: 28.63 (SD: 10.00)
Male	47%
University degree (Yes)	57%
Own car (1+)	36%
Rental experience (Yes)	63%
Rental frequency	$\geq$ 1 over the past 2 years: 86%
Holidays/Tourism (Yes)	79%

(*): No statistically significant differences among designs

(1) Model-free evidence

(A) Respondents' perception of differences b/w pairs of attribute levels (as in Pandelaere et al., 2011; Aribarg et al., 2017)

⇒ Shift in mental representation Details

(B) How often was each attribute level chosen in each design (choice shares in %)?

Design \ Level	Level 1 (the lowest)	Level 2	Level 3	Level 4 (the highest)
FC (l/100 km)	36.99	23.14	18.89	**16.45**
CO_2 (g/100 km)	30.50	23.54	17.50	22.94
CO_2 (g/km)	30.15	23.13	17.43	24.53
CO_2 (kg/km)	26.86	20.89	19.36	**28.74**

Test for independence: $\chi^2 = 38.41$ ($p<0.001$)

⇒ The largest attribute level is more often chosen under the CO_2 design and more contracted CO_2 scale (kg/km)

(1) Model-free evidence

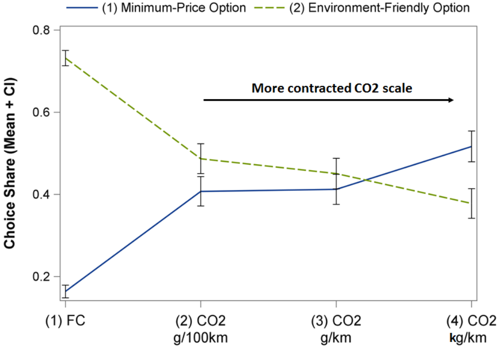
(C) How do choice shares of options from identical sets described by various metrics and scales change across designs? (e.g., Set 14)

Design \ Option	(1) Minimum-Price Option				(2) Environmentally Friendly Option			$\triangle$TC	$\triangle$EnvC
	Engine	€/Day	Metric		Engine	€/Day	Metric	€	CO_2 kg
FC (l/100 km)	Diesel	30	6.2	vs.	Diesel	33	4.2	14.00	106.00
CO_2 (g/km)	Diesel	30	164	vs.	Diesel	33	111	14.00	106.00
CO_2 (kg/km)	Diesel	30	0.164	vs.	Diesel	33	0.111	14.00	106.00
CO_2 (g/100 km)	Diesel	30	16,400	vs.	Diesel	33	11,100	14.00	106.00

$\Delta TC = TC_1 - TC_2 = (€/Day_1 - €/Day_2) \times Days - (FC_1 - FC_2) \times FP \times KM$
$\Delta EnvC = EnvC_1 - EnvC_2 = (CO2_1 - CO2_2) \times KM$

(1) Model-free evidence

(C) How do choice shares of options from identical sets described by various metrics and scales change across designs? (e.g., Set 14)



⇒ The more contracted the CO_2 scale, the smaller appeal of the environmentally friendly option

⇒ Under the more contracted CO_2 scale, focus rather on price

(2) Discrete Choice Model

$$U_{jn} = \alpha_{0n} \cdot \text{None}_{jn} + \alpha_{1n} \cdot \text{ET}_{jn} + \alpha_{2n} \cdot \text{Metric}_{jn} + \alpha_3 \cdot \left(\text{Metric}_{jn} \cdot \text{ET}_{jn}\right) + \beta_n \cdot P_{jn} + \epsilon_{jn}$$

$$\alpha_{2n} = \overline{\alpha}_2 + \sum_{k=1}^{K} \pi_k \cdot Z_{kn} + \sum_{m=1}^{4} \sigma_{2m}\eta_{2n},\ \eta_{2n} \sim N(0,1)$$

$$\theta_n = [\alpha_{0n}, \alpha_{1n}, \ln(\alpha_{2n}), \ln(\beta_n)]' \sim MVN(\overline{\theta}, \Sigma)$$

- $j \in J$ products; $n \in N$ respondents
- U_{jn}: utility
- None_{jn}: No-purchase option ($U_{0n} = \alpha_{0n} + \epsilon_{0n}$)
- P_{jn}: price per day
- ET_{jn}: engine type (diesel vs. petrol)
- Metric_{jn}: either FC or CO_2
- ϵ_{jn}: EV-error term
- $\theta_n = [\alpha_{0n}, ..., \ln(\beta_n)]'$: a vector of taste parameters
- Z_{kn}: individual-specific characteristics (mean-centered)

(3) Discrete Choice Model

$$U_{jn} = \alpha_{0n} \cdot \text{None}_{jn} + \alpha_{1n} \cdot \text{ET}_{jn} + \alpha_{2n} \cdot \text{Metric}_{jn} + \alpha_3 \cdot \left(\text{Metric}_{jn} \cdot \text{ET}_{jn}\right) + \beta_n \cdot P_{jn} + \epsilon_{jn}$$

$$\alpha_{2n} = \overline{\alpha}_2 + \sum_{k=1}^{K} \pi_k \cdot Z_{kn} + \sum_{m=1}^{4} \sigma_{2m}\eta_{2n}, \; \eta_{2n} \sim N(0,1)$$

$$\theta_n = [\alpha_{0n}, \alpha_{1n}, \ln(\alpha_{2n}), \ln(\beta_n)]' \sim MVN(\overline{\theta}, \Sigma)$$

- MXL estimation: Maximum Simulated Likelihood, 2000 Halton draws
- McFadden ρ^2 for MXL between 0.298 and 0.369 over designs
- Significant improvements over MNL
- Insignificant interaction term $\left(\text{Metric}_{jn} \cdot \text{ET}_{jnt}\right)$ in all designs
- Significant taste heterogeneity even after controlling for observed characteristics
- Focus on $\text{WTP(Metric)} = -(\alpha_{2n}/\beta_n)$

Willingness-to-pay

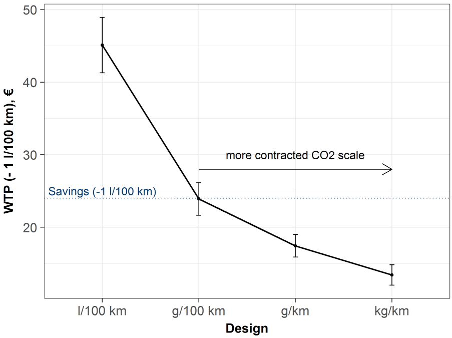
- € values for the whole trip (10 days; 2000 km) by design
- **Bold values**: computed from the estimates
- Non-bold values: implied by the values from other designs
- Median values with bootstrap SE in parentheses

Attribute \ Design	FC	CO_2		
		g/100 km	g/km	kg/km
FC (1 l/100 km)	**-45.11**	-23.90	-17.44	-13.42
	(3.83)	(2.24)	(1.54)	(1.40)
CO_2 (1 g/km)	-1.80	**-0.96**	**-0.70**	**-0.54**
	(0.15)	**(0.09)**	**(0.06)**	**(0.06)**

More contracted scale →

What do these WTP values mean?

- -1 l/100 km $\Rightarrow -20$ liters and -50 kg CO_2 over 10 days
- Savings in fuel and environmental costs: €24 (*)

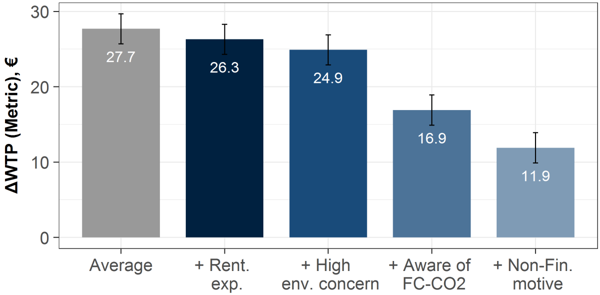


$\Rightarrow$ Under CO_2 in kg/km, value only 55% of the savings

(*) For both engines, on average

Individual differences in framing effects

- ΔWTP(Metric) = WTP(FC) - WTP(CO_2)



- Men, w/o rental experience, low environmental concerns, not aware of the FC-CO_2 link, fin. motive: €36
- Women, w. rental experience, high environmental concerns, aware of the FC-CO_2 link, non-fin. motive: €9

Discussion

- High importance of FC vs. low importance of CO_2
  (salience theory: Bordalo et al., 2013; Busse et al., 2015)
- FC: financial motive (personal) vs. CO_2: environmental protection (societal)
  (decision "signposts": Ungemach et al., 2017)
- Significant scale effect on the valuation of environmental benefits (CO_2 in kg/km: 55%)
- Framing effects even when the ecological option is also cost-minimizing

⇒ A wise choice architecture can nudge "non-green" consumers in a financially and environmentally optimal direction (but subconsciously)

⇒ Not only information provision, but also policies to enlarge knowledge and intrinsic motivation

Conclusion & future work

(H1): CO_2 value on expanded scale leads to higher WTP for a more environment-friendly car ☑

(H2): WTP for identical improvements is higher in terms of FC than CO_2 values ☑

(H3): Diesel ΔWTP > Petrol ΔWTP ✖

- Optimality: min TC vs. min EnvC "?"
- Underlying psychological mechanisms of the framing effects
- Δ for a representative sample "?"

Thank you for your attention

Questions? Comments?

Supplementary material

Experimental design: Scenario

- Car rental for a holiday trip
- 10 days, 2000 kilometers
- Diesel price is 1.10 €/liter, petrol price is 1.30 €/liter
- All rental fees are included in the price per day.
- CO_2 and FC reflect average on road values.
- Please assume that the offers are identical and acceptable to you in all other attributes not mentioned and include a comprehensive insurance coverage.

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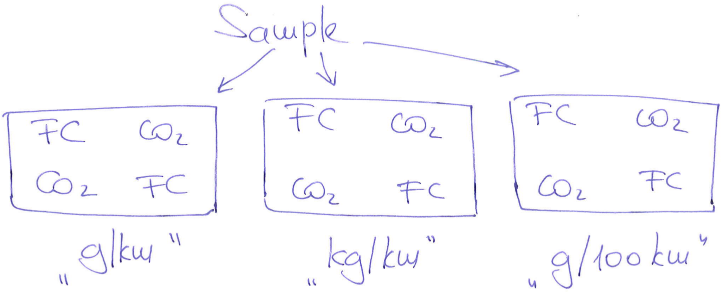

The following was randomized across participants:

- order of first presenting choice tasks of FC-design or CO_2-design
- position of attributes within choice tasks
- order of choice tasks

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Given and implied values for FC and CO_2

Given FC	Implied CO_2, g/km		Given CO_2	Implied FC, l/100 km	
l/100 km	Diesel	Petrol	g/km	Diesel	Petrol
3.2	85	74	85	3.2	3.7
4.2	111	97	111	4.2	4.8
5.2	138	121	138	5.2	5.9
6.2	164	144	164	6.2	7.1

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Test of the experimental designs

	FC-design				CO_2-design		
	Theoretical values	MNL estimates (nR = 400) Mean	SE		Theoretical values	MNL estimates (nR = 400) Mean	SE
mu	0.30	0.30	0.01	mu	0.30	0.30	0.01
no-choice	-45.00	-45.01	0.50	no-choice	-45.00	-45.00	0.50
Diesel	1.00	0.98	0.50	Diesel	1.00	1.05	0.51
FC	-2.60	-2.60	0.09	CO_2	-0.11	-0.11	0.00
FC×Diesel	0.40	0.41	0.11	CO_2×Diesel	0.03	0.03	0.00
log-likelihood		-4965.32	35.94	log-likelihood		-4789.39	40.49
Choice Shares	Option 1	Option 2	No-choice option	Choice Shares	Option 1	Option 2	No-choice option
	45.32	40.55	14.13		44.89	39.11	16.00

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Attitudes towards environment and car use

	Wording	Source
Affective		
1.	If things continue on their present course, we will soon experience a major ecological catastrophe.	UBA (2016)
2.	When I read newspaper reports or watch TV broadcasts on environmental problems, I get frustrated and angry.	UBA (2016)
3.	It worries me to think about the environmental conditions, under which our children and grandchildren would probably have to live.	UBA (2016)
Cognitive		
4.	There is a limit to the economic growth that our industrialized world has already crossed or will reach very soon.	UBA (2016)
5.	It is still the case that politicians are doing far too little for environmental protection.	UBA (2016)
6.	In my assessment, the so-called „ecological crisis" facing humankind has been greatly exaggerated by many environmentalists.	UBA (2016)
Conative		
7.	For the benefit of the environment, we should all be prepared to restrict our current standard of living.	UBA (2016)
8.	Science and technological progress will solve many environmental problems without a need to change our way of life.	UBA (2016)
9.	Measures to protect the environment should be enforced even if this results in lost jobs.	UBA (2016)

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Attitudes towards environment and car use

	Wording	Source
Perception of a car use		
10.	Even if public transportation was more efficient than it is, I would prefer to drive my own car.	Milfont and Duckitt (2010)
11.	People exaggerate the role of car traffic as the cause for climate change.	Peters et al. (2011)
Financial motive		
12.	For me, improvements in fuel consumption of a car are foremost linked to savings in my expenses.	Own
13.	I am willing to pay higher prices for products that are less polluting.	Own
Knowledge		
14.	Burning fossil fuels such as, for instance, gas and oil raises CO_2 levels in the atmosphere.	Kaiser et al. (1999)
15.	It is possible to improve the fuel consumption of a car, while keeping its CO_2 emission constant.	Own
16.	The burning of one liter of diesel does more harm to the environment and climate than the burning of one liter of petrol (gasoline).	Own

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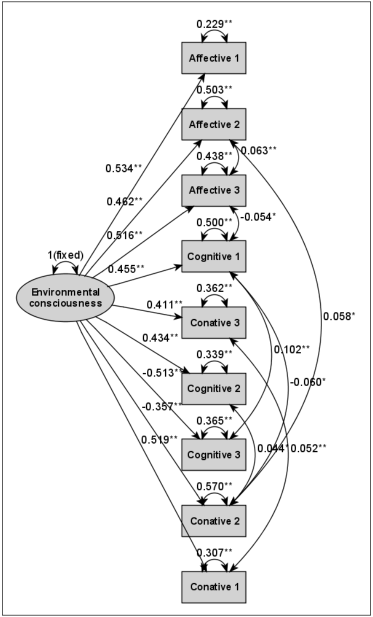
'General environmental consciousness'



N=586

1: Strongly disagree – 4: Strongly agree

Average Cronbach's α = 0.83

(bootstrap CI: 0.80-0.86)

$\chi^2(p)$=24.699 (0.213)

RMSEA=0.020

AGFI=0.980

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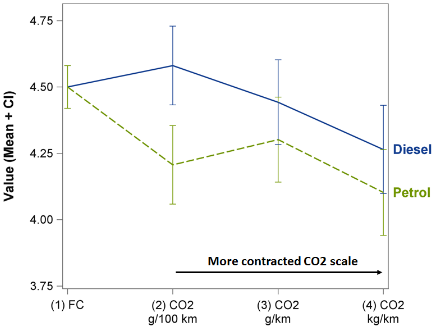
Self-stated perceived differences

*"In your perception, how much is a car with fuel consumption (CO_2 emissions) of [Option 1] **ecologically better** than a car with [Option 2]?"* (1: Not at all - 7: Extremely)

Design	Option 1	Option 2	Engine*
FC (l/100 km)	5.2	6.2	Diesel & Petrol
CO_2 (g/100 km)	13,780 12,064	16,430 14,384	Diesel Petrol
CO_2 (g/km)	138 121	164 144	Diesel Petrol
CO_2 (kg/km)	0.138 0.121	0.164 0.144	Diesel Petrol

*Respondents do not see information on engine type



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