Data and modelling for analyzing climate change policies

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University of Antwerp

Overview

- Introduction
- Data
- Distribution and determinants of household carbon footprints
- Carbon tax simulation
- Conclusion

Introduction

- “Rapid and far reaching” transitions

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- Climate and social inequality
  - unequal contribution to emissions
  - unequal exposure to consequences
  - unequal capacity to protect against climate risks
  - unequal incidence of costs and benefits of climate policy

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- Carbon taxation
  - Effective
  - Regressive effects

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  - *2) What determines the level of GHG emissions of households?*

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- Micro-level: households
  - Direct emissions
  - Indirect emissions

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- Consumption based emissions accounting
- Case: Belgium

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Basic concepts

- Emissions accounting
- Consumption-based vs production-based

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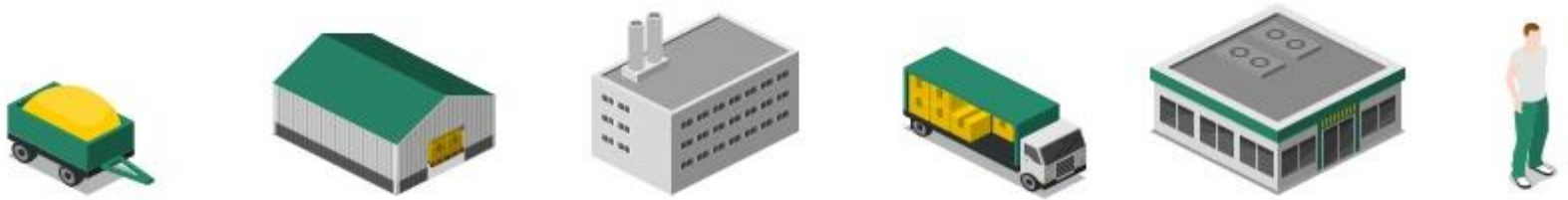
- Consumption-based vs production-based



Raw Materials → Supplier → Manufacturer → Distributor → Retailer → Consumer

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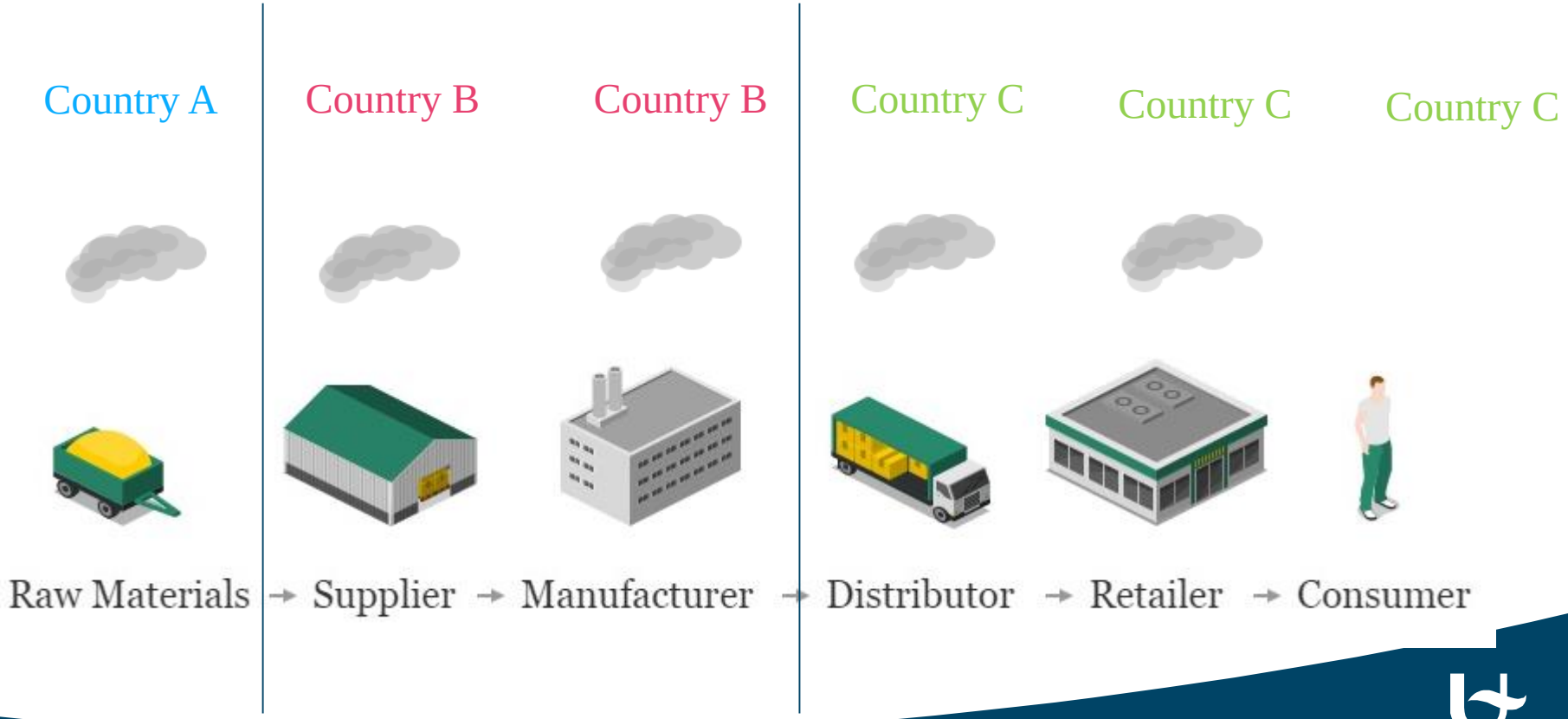

Emissions embedded in the supply chain

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Single-region environmentally extended input-output model

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Input-output model

- Maps interdependencies between economic sectors
- Intermediate vs final output
- Monetary flows

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- Domestic production technology assumption

PEACH2AIR database

Household consumption

GHG emissions

Frère et al., 2018

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- Belgian Household Budget Survey (2014)
- Expenditures on products and services purchased by households listed in the COICOP nomenclature

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- Durables: smoothing

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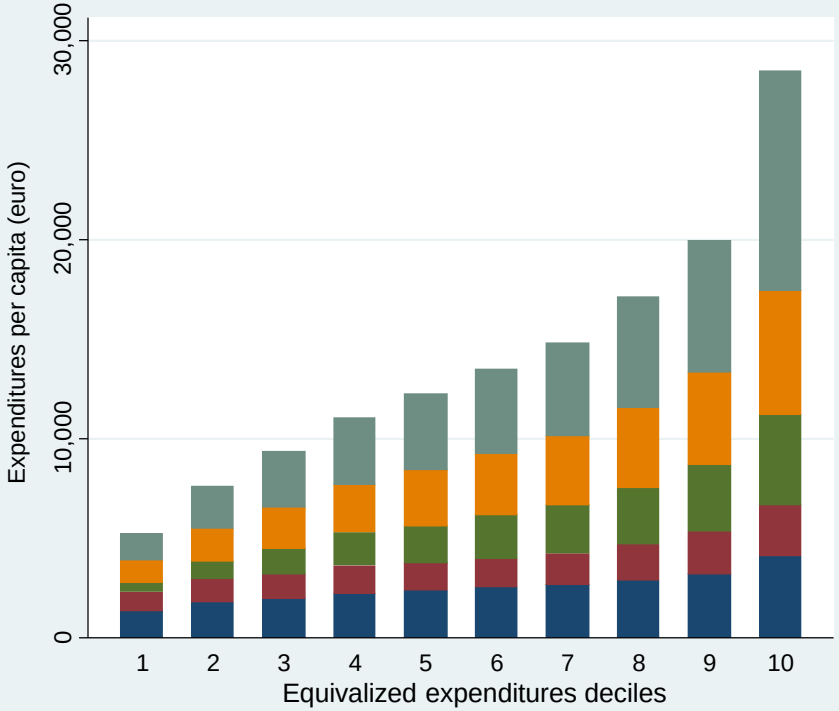
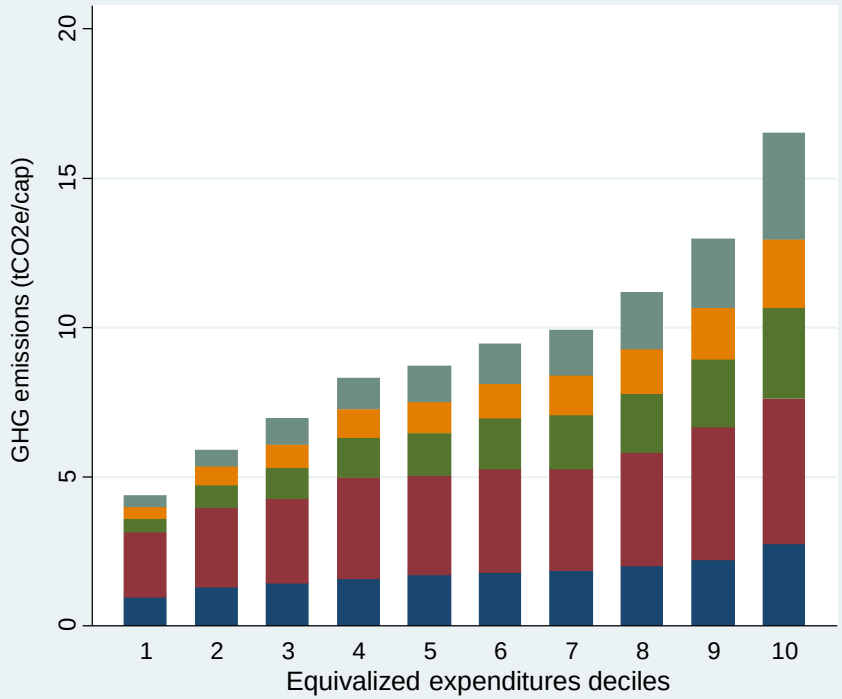
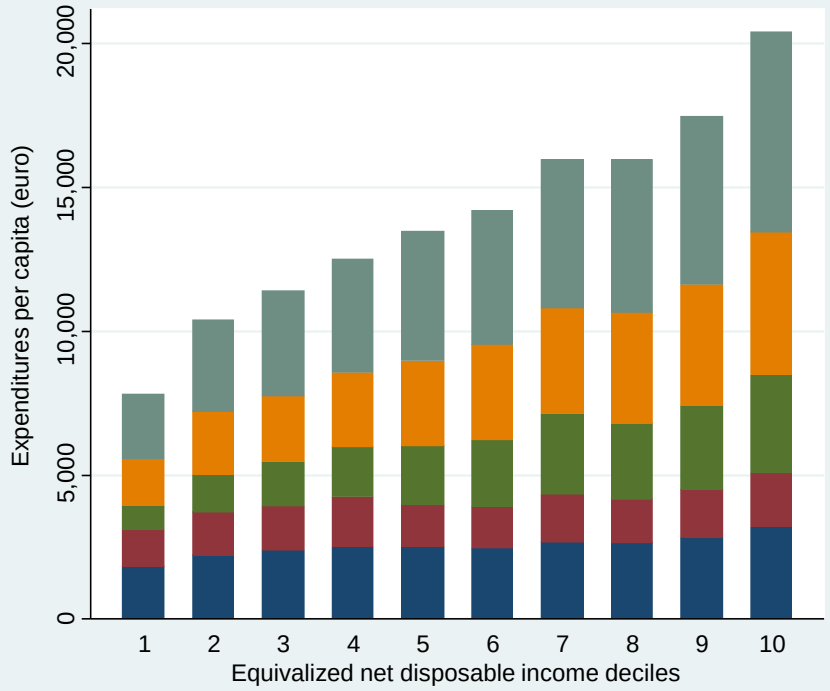
Distribution of expenditures and GHG emissions

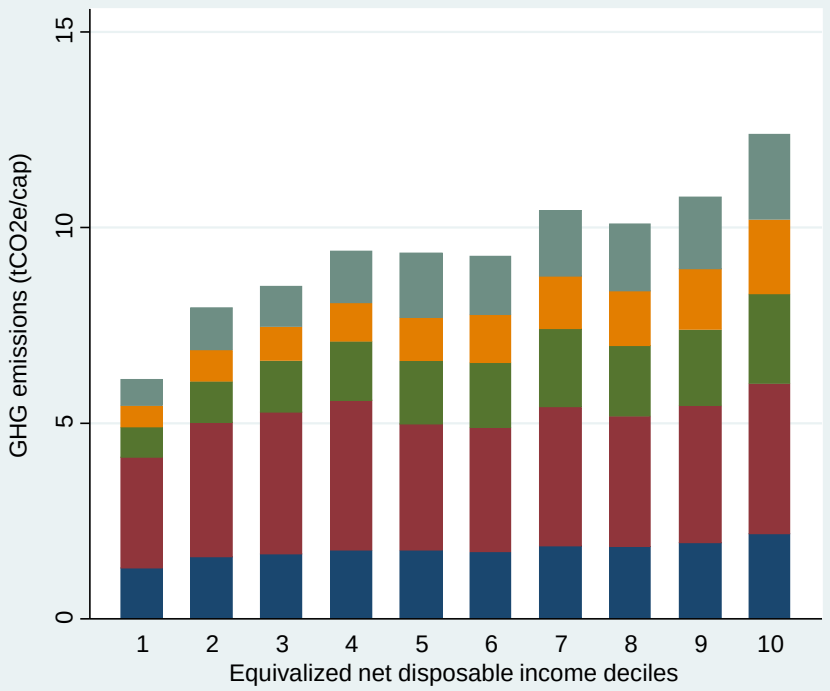




Food Energy&housing Transport Goods Services

Distribution of expenditures and GHG emissions





Food Energy&housing Transport Goods Services

Determinants

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Multiple regression analysis:

Determinants

Multiple regression analysis:

$$\ln(GHG) = \alpha + \beta \ln(inc) + \mathbf{X}\boldsymbol{\delta} + \boldsymbol{Z}\boldsymbol{\gamma} + u$$

Greenhouse gas emissions of households

Household income

Socio-economic variables:
- Number of adults
- Number of children
- Age
- Professional status
- Education
- Region

Housing-related variables:
- Number of rooms
- House type
- Tenure status

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
Ln(Income)	0.323***	0.235***	0.114***	0.589***	0.693***	0.582***
	(0.019)	(0.019)	(0.025)	(0.040)	(0.030)	(0.046)

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Number of adults						
1	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2	0.199***	0.437***	0.103***	0.360***	0.203***	0.175***
	(0.017)	(0.019)	(0.025)	(0.036)	(0.023)	(0.049)
3	0.264***	0.573***	0.149***	0.300***	0.126***	0.236***
	(0.023)	(0.027)	(0.032)	(0.065)	(0.030)	(0.062)
>=4	0.354***	0.738***	0.192***	0.284***	0.140***	0.387***
	(0.029)	(0.026)	(0.043)	(0.056)	(0.032)	(0.086)
Nr of children						
0	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
1	0.095***	0.123***	0.070**	-0.038	-0.018	0.269***
	(0.015)	(0.023)	(0.024)	(0.040)	(0.018)	(0.039)
2	0.122***	0.225***	-0.009	-0.088*	-0.066**	0.444***
	(0.015)	(0.022)	(0.025)	(0.039)	(0.020)	(0.050)
3	0.190***	0.316***	0.052	-0.105	-0.084*	0.636***
	(0.034)	(0.032)	(0.054)	(0.075)	(0.033)	(0.087)
>=4	0.292***	0.428***	0.122	0.093	0.051	0.730***
	(0.055)	(0.069)	(0.118)	(0.151)	(0.053)	(0.185)

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
Prof.stat.refpers.						
Working	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Unemployed	-0.085**	-0.084	0.018	-0.404***	-0.198***	-0.246***
	(0.030)	(0.045)	(0.048)	(0.072)	(0.040)	(0.069)
Student	-0.067	-0.120	-0.034	-0.360**	-0.104	0.090
	(0.098)	(0.096)	(0.187)	(0.136)	(0.115)	(0.178)
Housewife	-0.046	-0.127*	0.051	-0.235	-0.096	-0.199
	(0.064)	(0.061)	(0.133)	(0.204)	(0.061)	(0.179)
Incapacitated	-0.046	0.009	0.047	-0.406***	-0.067	-0.062
	(0.034)	(0.037)	(0.059)	(0.074)	(0.039)	(0.075)
Pension	-0.049*	-0.030	-0.007	-0.149**	0.003	-0.053
	(0.025)	(0.024)	(0.037)	(0.056)	(0.033)	(0.060)
Education						
Primary or less	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Lower secondary	0.025	-0.023	0.060	0.055	0.017	0.083
	(0.031)	(0.044)	(0.065)	(0.091)	(0.045)	(0.074)
Upper secondary	0.092**	0.044	0.074	0.262**	0.110**	0.301***
	(0.030)	(0.040)	(0.051)	(0.081)	(0.040)	(0.077)
Tertiary	0.173***	0.147***	0.092	0.323***	0.236***	0.515***
	(0.032)	(0.040)	(0.055)	(0.077)	(0.040)	(0.078)

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
Region						
BXL	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
VL	0.019	-0.034	-0.021	0.170*	0.035	0.080
	(0.028)	(0.025)	(0.038)	(0.073)	(0.022)	(0.061)
WA	0.100***	-0.016	0.200***	0.314***	0.017	-0.108
	(0.029)	(0.024)	(0.038)	(0.075)	(0.023)	(0.063)
Nr of rooms						
1	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2	0.185***	0.168*	0.119	0.184	0.126	0.348***
	(0.052)	(0.065)	(0.084)	(0.156)	(0.066)	(0.091)
3	0.248***	0.095	0.218*	0.342*	0.177*	0.462***
	(0.049)	(0.064)	(0.087)	(0.154)	(0.071)	(0.092)
4	0.323***	0.139*	0.330***	0.473**	0.186**	0.465***
	(0.047)	(0.068)	(0.083)	(0.153)	(0.071)	(0.092)
5	0.356***	0.196**	0.405***	0.473**	0.203**	0.466***
	(0.048)	(0.069)	(0.088)	(0.158)	(0.071)	(0.092)
>=6	0.398***	0.230***	0.471***	0.429**	0.236***	0.516***
	(0.049)	(0.067)	(0.088)	(0.165)	(0.069)	(0.097)

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
House type						
Detached	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Semi-detached	-0.083***	-0.008	-0.134***	-0.175***	-0.012	-0.010
	(0.012)	(0.016)	(0.021)	(0.030)	(0.020)	(0.030)
Apartment	-0.162***	-0.061*	-0.371***	-0.254***	-0.066*	0.137**
	(0.019)	(0.025)	(0.035)	(0.050)	(0.028)	(0.052)
Other	-0.015	-0.046	-0.118	-0.155	0.156	0.170
	(0.082)	(0.135)	(0.171)	(0.188)	(0.126)	(0.191)
Tenure status						
Owner	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Tenant	-0.109***	-0.050*	-0.060*	-0.242***	-0.113***	-0.315***
	(0.016)	(0.024)	(0.026)	(0.045)	(0.018)	(0.043)
Constant	-1.342***	-2.389***	-0.171	-6.080***	-7.021***	-6.931***
	(0.218)	(0.221)	(0.298)	(0.470)	(0.295)	(0.483)
Observations	6128	6128	6128	6128	6128	6128
R^2	0.803	0.584	0.305	0.528	0.731	0.580

Elasticity estimates

Paper	Country	Income elasticity	Expenditure elasticity
Ala-Mantila et al. (2014)	FI	0.607_{g} ($0.577_{g,o}$)	0.802_{g} ($0.790_{g,o}$)
Büchs & Schnepf (2013)	UK	$0.432_{c,o}$	
Duarte et al. (2012)	ES		$0.84_{c,o}$
Fremstad et al. (2018)	US		$0.728_{c,o}$
Girod & Haan, (2010)	CH		0.94_{c} (1.06_{c}^{1})
Isaksen & Narbel (2017)	NO		0.99_{c}
Kerkhof et al. (2009)	NL		0.84_{g}
Lenzen (1998)	AU	0.55_{g}	0.70_{g}
Levinson & O'Brien (2019)	US	0.393	
Steen-Olsen et al. (2016)	NO		1.14_{g}
Weber & Matthews (2008)	US	$0.35\text{-}0.52_{g,o}$	$0.6\text{-}0.7_{g,o}$
Wier et al. (2001)	DK	0.55_{c}	0.70_{c}
This paper	*BE*	*$0.22\text{-}0.56_{g,o}$*	*$0.76\text{-}0.95_{g,o}$*

Note: c: CO_2. g: GHG. o: other controls included in the regression (other than income/expenditures). 1: Without correction for scale economies

Elasticity estimates

Paper	Country	Food	Energy, housing	Transport	Goods	Services
Ala-Mantila et al. (2014) $_{g,e}$	FI	0.512	0.133		1.233	1.420
Büchs & Schnepf (2013) $_{c,i}$	UK		0.187	0.598		
Girod & Haan, (2010) $_{g,e}$	CH	0.08[1]	0.53	1.21	1.30	0.54[2], 1.26[3]
Isaksen & Narbel (2017)$_{c,e}$	NO	0.50	0.25[4]	1.01		
Steen-Olsen et al. (2016) $_{g,e}$	NO	0.98	1.02	1.48	1.26-1.29	0.57-1.05
This paper	*BE*	*0.235*	*0.114*	*0.589*	*0.693*	*0.582*

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- GHG emissions grow with increasing income
- ↑per capita expenditures; ↓emission intensity
- Because of different composition of expenditures
  - 'Food', and 'Energy and housing'
    - Highest share at the bottom
    - Relatively stable over the income distribution
  - 'Transport', 'Goods' and 'Services'
    - Highest share at the top
    - Strong growth over the income distribution

Conclusions – household carbon footprints

- Main determinants
  - income and household size

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- Other socio-demographic determinants
  - house type, number of rooms, education, professional status, region

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Policy implications

- Distributional effect of a policy measure will depend on
  - Domain of consumption which is targeted
  - Way of revenue recycling

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Carbon tax simulations

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- Scenarios
  - 10€/tCO_2 + lump sum redistribution
  - 50€/tCO_2 + lump sum redistribution
  - 100€/tCO_2 + lump sum redistribution

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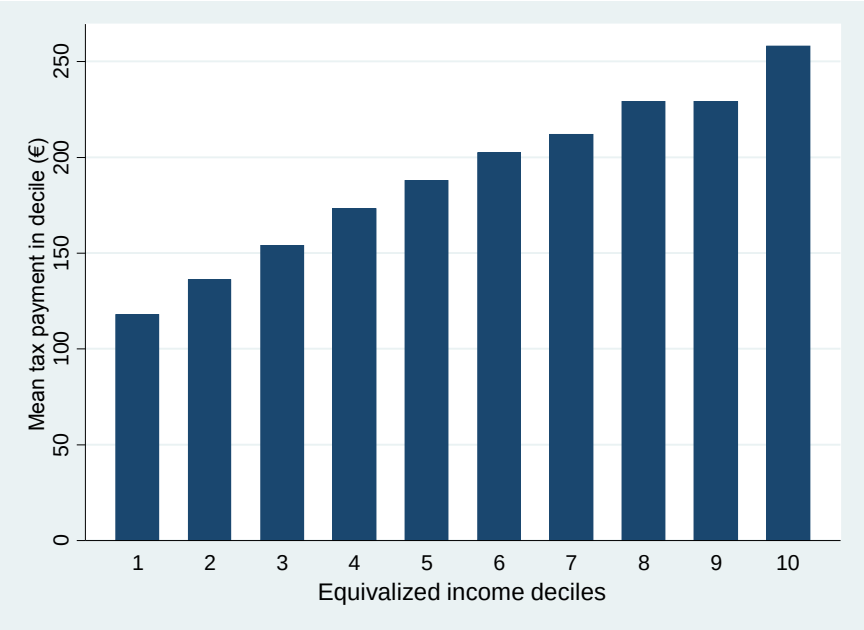
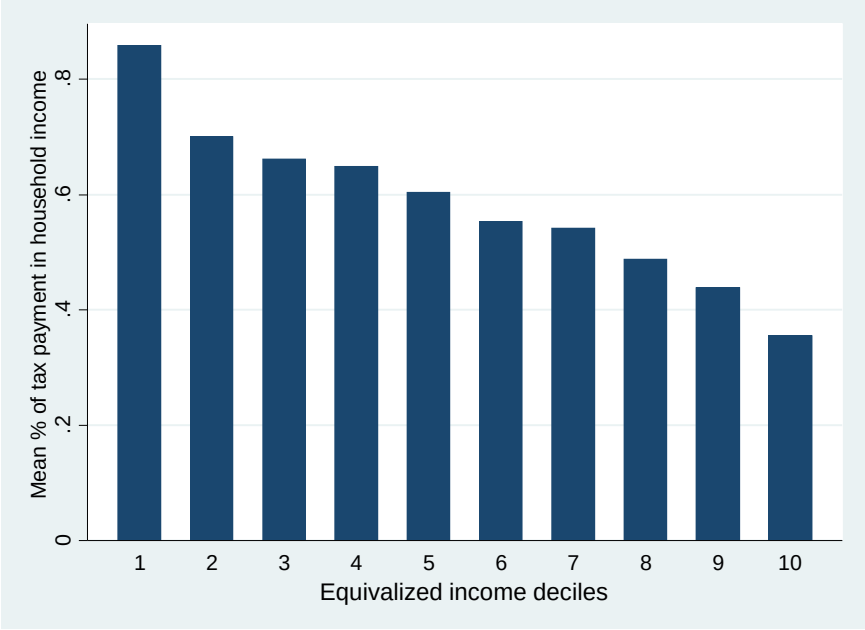
  - 100€/tCO_2 + lump sum redistribution

- Limitations
  - First order estimates – costs passed entirely to consumers, workers, capital owners bear no costs
  - No behavioral response of consumers and producers
  - Environmental co-benefits not examined

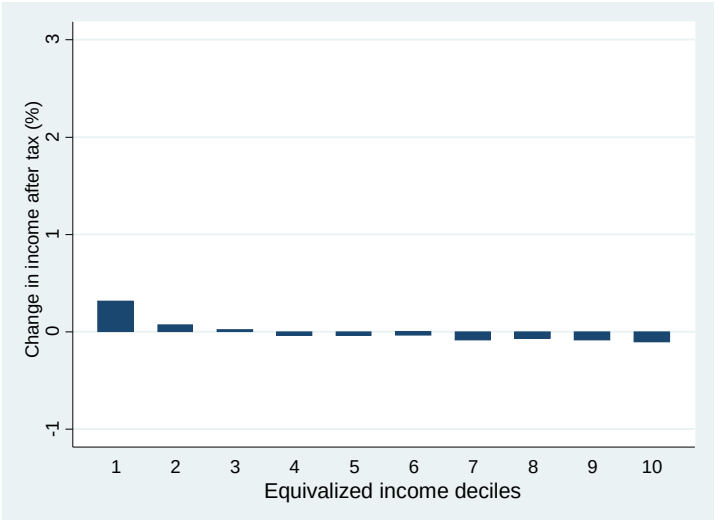
- Cf. Grainger and Kolstad, 2010; Kerkhof et al., 2008; Verde and Tol, 2009; Wier et al., 2005

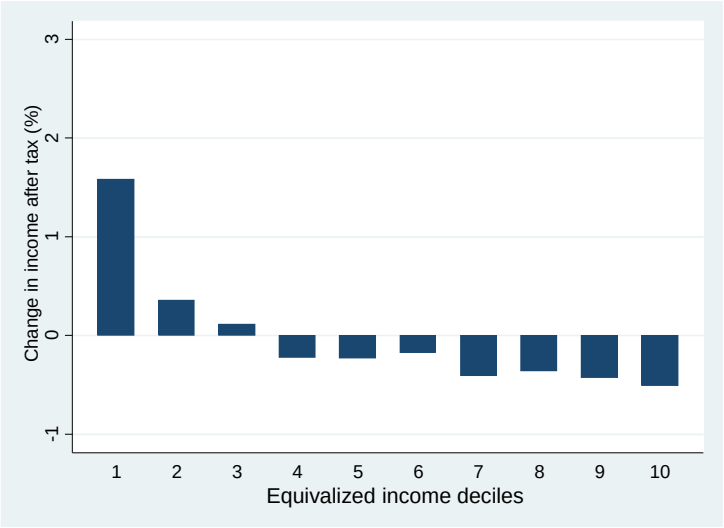
No revenue recycling - 10€/tCO_2



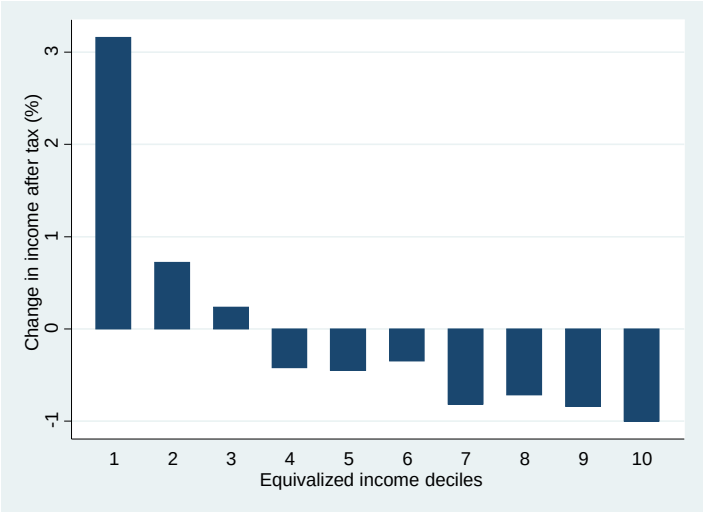


Revenue recycling





Tax rate	Lump sum transfer
10€/tCO_2	82€
50€/tCO_2	410€
100€/tCO_2	821€



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- Revenue recycling
  - Reduction of existing taxes (e.g. labor, income, VAT)
  - Increasing benefits (lump-sum redistribution, improve social security system, increase existing social transfers, increase social benefits to low income groups)

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- Who pays, what should be taxed, tax rate, timing, use of revenue, enforcement

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- Next steps
  - Extend database in EUROMOD with emissions
  - Link with CGE model
  - Household heterogeneity in bottom income deciles

Publications

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THANK YOU FOR YOUR ATTENTION!

University of Antwerp

Aggregate consumption categories

1-digit COICOP category	Aggregate category
01 Food and non-alcoholic beverages	'Food and drinks'
02 Alcoholic beverages, tobacco	'Food and drinks'
03 Clothing and footwear	'Goods'
04 Housing, water, electricity, gas and other fuels	'Energy and housing'
05 Furnishings, household equipment and routine maintenance of the house	'Goods' or 'Services'*
06 Health	'Goods' or 'Services'*
07 Transport	'Transport'
08 Communication	'Goods' or 'Services'*
09 Recreation and culture	'Goods' or 'Services'*
10 Education	'Services'
11 Restaurants and hotels	'Services'
12 Miscellaneous goods and services	'Goods' or 'Services'*

Indirect emissions from household consumption

- Industry-level direct production pollution coefficients are determined
  - Air Emissions Accounts + supply and use tables (63 industries)

- Industry coefficients are transformed into product coefficients, using the SUTPROD nomenclature (354 products)
  - Industry technology assumption: all products made by same industry produced with identical input mix
  - Product-level direct production pollution coefficients: weighted average of industries producing the product

Indirect emissions from household consumption

- The direct production pollution is determined
  - Domestic direct pollution from production: product-level direct production pollution coefficients multiplied by final demand for *domestic* products by Belgian households
  - Foreign direct pollution from production: product-level direct production pollution coefficients multiplied by final demand for *imported* products by Belgian households
- The indirect pollution from production is calculated
  - on the basis of the direct production pollution coefficients of the intermediate products used during a production process.
  - 1. domestic indirect production pollution
  - 2. foreign indirect production pollution for domestic final consumption products
  - 3. foreign indirect production pollution for imported final consumption products

Non-frequent expenses

- What?
  - Durable goods, maintenance services, holiday expenses
  - Identification: questions of the personal interview, COICOP classification
- Why?
  - Few purchases during the survey period
  - Large expenditures for few households
  - Majority of households possess and use these items
- How?
  - Smooth expenses among households
  - 14 clusters based on income and household size
  - Mean imputation

Non-frequent expenses

	Ownership known	Ownership not known
Number of items	12	141
Examples	Phone, TV, car, washing machine	Furniture, tools, small electronic products, holidays
Formula for calculation unit price of product *k*	$UP_{kc} = \sum_{i=1}^{n_c} p_{ik} \Big/ \sum_{i=1}^{n_c} q_{ik}$	N/A
Formula for smoothed expenditures on product *k*	$p_{ikSM} = UP_{kc} * q_{ik}$	$p_{ikSM} = \sum_{i=1}^{n_c} p_{ik} \Big/ n_c$

c: cluster, *i:* household, *k*: product, n_c: nr of households in cluster *c, p*: price, *q*: quantity

Imputation of fuel expenses

- Company cars: fuel expenses payed by employer and do not appear in HBS
- → Fuel expenses of company car owning households are underreported:

	Household with company car	Households without company car
Mean monthly fuel expenses	78.31 €	104.98 €
Percentage of households reporting zero fuel expenses (no private car)	64.8%	90.3%
Percentage of households reporting zero fuel expenses (with private car)	22.5%	12.8%

Imputation of fuel expenses

- Fuel mix: majority (87%) of company cars are diesel (Denys, Beckx, and Vanhulsel, 2016) → impute diesel
- Threshold based on fuel expenses of households without company car

Mean monthly fuel expenses (in euro):

Nr. of private cars	Number of company cars							
	zero		one		two		three	
	a	b	a	b	a	b	a	b
0	9	73	44	178	67	121	100	166
1	**88**	103	92	118	38	108	0	
2	**151**	163	105	129	33	33		
3	**188**	205	174	174				
4	**213**	219	146	146	139	139		
5	**140**	140						

Note: a: zero expenditures calculated in mean. b: zero expenditures excluded from calcul
of mean. Households that own any motorcycle and buy gasoline are

Dominance analysis

	Total	Food	Energy and housing	Transport	Goods	Services
income	28.3	24.4	10.1	29.2	43.3	32.2
adults	19.8	35.4	10.8	17.0	16.5	14.0
children	3.9	5.0	1.4	1.8	1.8	8.3
age	1.2	4.0	3.5	0.8	0.4	1.0
profstat	5.6	4.8	2.5	11.3	8.7	7.6
educ	6.3	4.8	1.7	7.8	9.6	12.7
region	2.0	0.5	12.1	3.0	0.9	2.8
roomnr	14.6	10.8	22.9	11.1	8.2	9.0
house_type	10.1	5.7	26.1	9.1	4.4	3.1
occupancy	8.2	4.6	9.0	8.9	6.1	9.1
R-squared	0.803	0.584	0.305	0.528	0.731	0.580

Note: Numbers indicate the percentage contribution of each variable to the overall fit measure (R-squared)