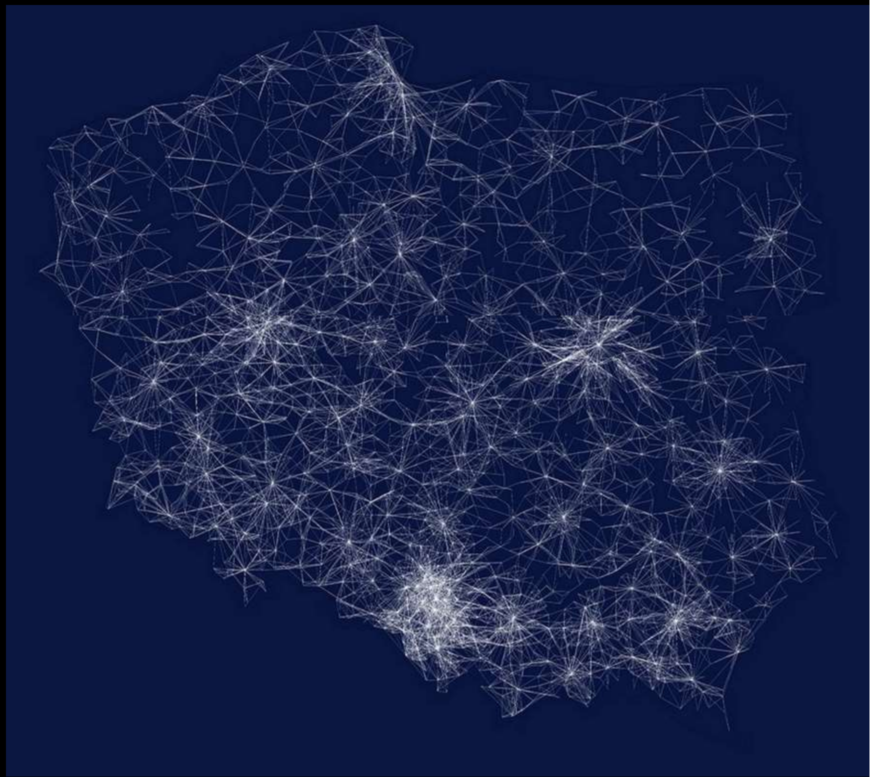
Soft factors, spatial structure and carbon dioxide emission from car-related commuting in Poland



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Outline

- Factors affecting commuting behavior/patterns
- Setting the scene
- Aims, data and research design
- Results
- Conclusions

Factors affecting commuting patterns

Commuting patterns depend on *hard* and *soft* factors (Lin et al. 2015)

- ***Hard* factors**:
- urban form
- urban structure

- ***Soft* factors**:
- residential environment
- individual/household characteristics

Factors affecting commuting patterns

Urban structure:

- Restructuring urban regions in the late 20th c. – from monocentric to polycentric (multinodal) urban systems
- Multinodal systems may reduce the length and duration of worker's commute (Gordon et al. 1991; Zhao et al. 2011)
- But not all studies confirm this hypothesis (Cervero and Wu 1998; Schwanen et al. 2003; Veneri 2010)

Factors affecting commuting patterns

Urban form:

- Population/employment density is the most common indicator
- High employment/population density generally reduces commuting distance/time (Ewing and Cervero 2001, 2010)
- Low density generally leads to poor access to public transport network (Muniz and Lopez 2019) and, thus, to car commuting (Guerra et al. 2018)

Factors affecting commuting patterns

Individual/household characteristics and residential environment:

- History, institutional and cultural factors, and economic-related characteristics of a city/region matter
- Socio-demographic factors - age, income, education, gender and household type (household related responsibilities), employment status, and individual preferences - may be more significant than the factors of urban spatial patterns (Hanson 1982)

Setting the scence

Urban structure after socialism:

- *Under-urbanization* under socialism – a substantial increase in the number of commuters from rural to urban areas (Szelenyi 1996)
- Deconcentration has been the main trend in urban and regional dynamics after 1990 (Stanilov and Sykora 2014)
- Polycentric urban development is not the only trend in the evolution of urban regions (Bartosiewicz and Marcińczak 2022).

Setting the scence

2.3.4 Passenger Cars

	billion pkm							%
	1990	1995	2000	2005	2010	2014	2015	CHANGE '14/'15
EU-28		*3 904.4*	*4 300.9*	*4 508.4*	*4 625.0*	*4 615.1*	*4 719.4*	2.3
BE	89.5	96.4	102.5	102.8	109.4	108.2	107.1	-1.0
BG		*25.0*	*26.9*	*35.1*	*46.9*	*54.0*	*56.8*	*5.4*
CZ		54.5	63.9	68.6	63.6	66.3	69.7	5.2
DK	47.2	48.4	50.6	49.8	51.7	54.2	56.5	4.3
DE	683.1	815.3	831.3	856.9	887.0	916.4	928.3	1.3
EE		*5.1*	*6.7*	9.9	*10.1*	*11.9*	*12.3*	*4.0*
IE	*28.5*	*31.6*	*34.6*	*44.4*	*48.1*	*47.2*	*51.9*	*10.0*
EL	*35.0*	*44.0*	*63.0*	*85.0*	*99.6*	*96.9*	*98.3*	*1.5*
ES	174.4	250.4	302.6	337.8	341.6	308.7	317.6	2.9
FR	592.5	641.2	687.7	704.6	695.9	706.9	724.1	2.4
HR		*12.5*	*20.0*	*24.0*	*25.7*	26.1	26.4	1.3
IT	522.6	614.7	713.9	677.0	698.4	642.9	679.4	5.7
CY		*3.4*	*3.9*	*4.8*	*5.9*	*6.1*	*6.2*	*2.4*
LV		*7.5*	*11.5*	12.1	12.3	12.6	13.5	7.3
LT		*16.0*	*26.0*	34.8	32.6	24.3	24.9	2.2
LU	*4.0*	*4.7*	*5.6*	*6.3*	*6.5*	*7.1*	*7.3*	*2.6*
HU	47.0	45.4	46.2	49.4	52.6	52.7	54.6	3.6
MT		*1.7*	*1.8*	*2.0*	*2.2*	*2.4*	*2.5*	*3.8*
NL	137.3	131.4	141.1	148.8	144.2	145.0	139.3	-3.9
AT	55.7	62.2	66.7	70.6	73.5	76.6	78.3	2.3
PL		110.7	130.1	152.3	188.8	197.0	200.6	1.8
PT	*40.0*	*52.5*	*71.0*	*85.0*	*83.7*	*83.3*	*84.5*	*1.4*
RO		*40.0*	*51.0*	*61.0*	*75.5*	*85.2*	*89.9*	*5.5*
SI	13.3	16.3	20.3	22.5	25.6	*25.6*	*26.0*	*1.4*
SK		18.0	23.9	25.8	26.9	27.3	27.5	1.0
FI	51.2	50.0	55.7	61.9	64.7	65.5	66.3	1.2
SE	85.9	87.6	103.7	108.0	108.0	110.3	111.9	1.4
UK	588.0	617.9	638.6	667.2	644.0	654.4	657.6	0.5

Road 2.6.2

PASSENGER CARS

STOCK OF REGISTERED VEHICLES

	1000							%
	1990	1995	2000	2005	2010	2014	2015	CHANGE '14/'15
EU-28	*160 106*	179 690	200 245	221 211	240 070	249 790	254 235	1.8
BE	3 864	4 273	4 678	4 919	5 276	5 573	5 662	1.6
BG	1 317	1 648	1 993	2 538	2 602	3 014	3 162	4.9
CZ	2 410	3 043	3 439	3 959	4 496	4 833	5 115	5.8
DK	1 590	1 679	1 854	1 965	2 164	2 330	2 391	2.6
DE	36 772	40 499	39 059	40 660	42 302	44 403	45 071	1.5
EE	241	383	464	494	553	653	677	3.6
IE	801	998	1 333	1 684	1 899	1 966	2 007	2.1
EL	1 736	2 205	3 195	4 303	5 217	5 108	5 160	1.0
ES	11 996	14 212	17 449	20 250	22 147	22 030	22 356	1.5
FR	23 550	25 100	28 060	30 100	31 300	31 800	32 000	0.6
HR	*580*	711	1 125	1 385	1 515	1 474	1 500	1.7
IT	27 416	30 301	32 584	34 667	36 751	37 081	37 351	0.7
CY	179	220	268	355	463	478	488	1.9
LV	283	332	557	742	637	658	679	3.2
LT	493	718	1 172	1 455	1 692	1 206	1 244	3.2
LU	183	229	273	307	337	373	381	2.2
HU	1 944	2 245	2 365	2 889	2 984	3 108	3 197	2.9
MT	*120*	181	189	213	241	267	275	3.3
NL	5 509	5 633	6 539	7 092	7 736	7 979	8 101	1.5
AT	2 991	3 594	4 097	4 157	4 441	4 695	4 748	1.1
PL	5 261	7 517	9 991	12 339	17 240	20 004	20 723	3.6
PT	1 849	2 560	3 443	4 200	4 480	4 496	4 538	0.9
RO	1 292	2 197	2 778	3 364	4 320	4 908	5 155	5.0
SI	587	711	866	960	1 062	1 068	1 079	1.0
SK	880	1 016	1 274	1 304	1 669	1 949	2 035	4.4
FI	1 939	1 901	2 135	2 430	2 877	3 195	3 258	2.0
SE	3 601	3 631	3 999	4 154	4 335	4 586	4 669	1.8
UK	20 722	21 951	25 067	28 326	29 334	30 557	31 214	2.1

Setting the scence

3.2.1 **Total Greenhouse Gas (GHG) Emissions (*)**

MILLION TONNES CO_2 EQUIVALENT

	1990	1995	2000	2005	2010	2014	2015
EU-28	5716.4	5381.4	5270.8	5345.2	4909.5	4423.7	4451.8
BE	148.8	157.3	154.2	148.7	136.6	118.1	121.6
BG	104.4	75.3	59.6	64.3	60.8	58.0	62.0
CZ	198.5	157.6	150.0	148.6	140.6	127.5	128.8
DK	72.1	80.1	73.1	68.9	65.6	53.5	51.0
DE	1263.0	1135.7	1062.2	1014.9	966.0	928.8	926.5
EE	40.5	20.3	17.4	19.3	21.3	21.2	18.1
IE	57.2	60.9	70.9	72.5	64.0	60.0	62.4
EL	105.6	111.8	128.9	138.9	120.9	102.2	98.6
ES	293.4	335.2	395.8	451.6	369.6	338.3	350.4
FR	555.8	554.6	566.4	569.1	527.7	470.0	474.6
HR	31.7	22.6	25.5	29.6	27.6	23.4	23.9
IT	524.1	536.8	560.9	588.3	514.1	432.5	442.8
CY	6.4	7.9	9.2	10.2	10.4	9.2	9.2
LV	26.4	12.8	10.4	11.5	12.6	11.5	11.6
LT	48.4	22.4	19.7	23.2	20.9	20.1	20.3
LU	13.1	10.6	10.6	14.3	13.5	12.0	11.7
HU	94.4	76.0	74.2	76.6	66.1	58.4	61.6
MT	2.6	2.9	3.0	3.3	3.3	3.3	2.6
NL	226.1	239.2	229.7	225.4	224.5	198.5	206.7
AT	79.7	81.2	82.2	94.6	87.1	78.4	81.0
PL	468.5	439.7	391.4	399.8	408.4	384.7	387.7
PT	61.1	71.7	84.5	88.6	72.1	67.4	72.1
RO	247.1	181.7	140.6	146.8	121.4	116.0	117.8
SI	18.6	18.8	19.2	20.6	19.7	16.7	16.9
SK	74.5	54.5	49.9	51.5	46.7	40.8	41.4
FI	72.3	72.7	71.1	70.9	77.3	61.1	57.5
SE	73.0	75.2	70.7	68.8	66.7	56.1	55.9
UK	809.1	765.8	739.8	724.5	643.9	555.8	536.9

GHG Emissions from Transport 3.2.2

MILLION TONNES CO_2 EQUIVALENT

INCLUDING INTERNATIONAL BUNKERS (*)

	1990	1995	2000	2005	2010	2014	2015
EU-28	961.4	1034.4	1168.6	1263.3	1222.3	1165.2	1182.9
BE	36.5	38.6	45.6	55.2	55.3	46.5	48.7
BG	7.5	6.2	6.0	8.8	8.8	9.3	10.2
CZ	7.8	9.9	12.5	18.1	18.0	17.8	18.6
DK	15.5	19.0	18.7	18.2	17.6	17.1	17.3
DE	183.0	198.3	208.0	191.5	186.7	191.4	192.4
EE	3.1	1.9	2.1	2.7	3.0	3.4	3.3
IE	6.3	7.8	13.1	16.0	14.3	14.0	14.9
EL	25.4	31.1	33.3	34.0	34.1	25.6	25.9
ES	76.4	87.6	116.4	140.6	131.4	119.6	122.3
FR	137.6	149.0	163.4	165.5	157.9	154.3	155.7
HR	4.5	3.7	4.8	5.9	6.3	6.0	6.3
IT	111.2	124.5	136.2	143.8	131.2	122.3	121.4
CY	2.1	2.6	3.3	3.9	3.8	3.3	3.4
LV	4.8	2.7	2.3	4.2	4.5	4.1	4.3
LT	6.5	3.7	3.6	4.8	5.0	5.1	5.6
LU	3.0	3.9	5.8	8.5	7.8	7.4	7.1
HU	9.4	8.0	9.8	12.8	12.4	11.7	12.8
MT	1.3	2.4	3.2	2.9	5.5	5.0	6.1
NL	68.1	73.3	85.8	97.3	90.8	83.7	82.1
AT	14.9	17.3	20.6	27.0	24.7	24.2	24.8
PL	22.4	24.3	29.5	37.3	50.3	46.6	49.1
PT	13.0	16.3	22.9	23.5	23.1	21.0	21.5
RO	13.2	9.2	10.3	13.0	14.8	16.5	17.2
SI	2.8	3.9	3.9	4.6	5.4	5.6	5.6
SK	7.0	5.6	5.7	7.7	7.5	6.6	6.9
FI	15.0	13.3	15.3	15.9	15.0	13.3	14.0
SE	23.0	24.7	26.6	29.8	29.4	26.4	26.5
UK	140.1	145.9	160.1	170.4	157.8	157.4	158.7

Aims, data and research design

Aims:

- to investigate the impact of urban form and spatial structure on the direct CO2 emission from car commuting in Poland
- to explore the relationship between individual worker characteristics and CO2 emission

Data:

- Travel Behaviour Sruvey (2015) (10042 cases)
- Central Statistical Office (CSO) (2015)

Aims, data and research design

Research desgin:

- Robust estimates require controlling for the problem of self-selection (the place of residence or transport mode) (Cao et al. 2009, Schwanen et al. 2002)

- We estimate separate models for urban and rural areas
- We control for endogeneity in models predicting CO2 emission from car commuting

Aims, data and research design

Methods:

- The annual equivalent CO_2 emission of car trips made by the individual *i* is:

- $CO2eq_i = EqP_z * Dtw_i * Nowt_i$

EqP_z – emission of equivalency factor per the type of fuel (z) per passenger and per kilometer (grams of CO2eq km-passenger)

Dtw_i – distance of a round work trip made by commuter *i*

$Nowt_i$ – number of trips per year made by commuter *i*

Aims, data and research design

Methods:

- Linear models (OLS)
- Sample selection models (the Heckman model)
- Robusr sample selection model (Zhelonkin et al. 2016)

Results: urban areas

Selection equation (dependent variable: commuting by car)		
	Probit	Robust SSM
constant	-1.3160**	-1.2524***
Age	0.04269***	0.0455***
Age ^{2}	-0.0005***	-0.0005***
Sex (ref: female)	0.5817***	0,6024***
Private car ownership (ref: no car)	1.2910***	1.2827***
Chiild(ren) in household (ref: no children)	0.1525***	0.1434***
Education level (ref: higher education)		
Secondary education	-0.2351***	-0.2533***
Vocational education	-0.4291***	-0.4525***
Primary education	-0.2785***	-0.3013***
Employment type (ref: self-employed)	-06250***	-0.6808***
Population density in municipality	-0.0001***	-0.0001***
Density of main roads in municipality		
Accessability index (municipality)		
Circularity index of urban region	1.4550**	1.3972**
Gini index (employment in urban region)	-1.3790***	-1.3396***
Rank-size indicator (employment in urban region)		
Logarithm of area (urban region)	0.1278**	0.1264**

Results: urban areas

Outcome equation (dependent variable: logCO2em)				
	OLS	Heckman	ML	Robust SSM
constant	11.86***	11.97***	11.99***	11.73***
Age	0.0170'	0.014'	0.0144'	0.0203*
Age ^{2}	-0.0002*	-0.0002*	-0.0002*	-0.0003**
Sex (ref: female)	0.357***	0.3350***	0.3319***	0.3549***
Education level (ref: higher education)				
Secondary education	-0.1313***	-0.1237***	-0.1228***	-0.1275***
Vocational education	-0.0967*	-0.0803'	-0.0780'	-0.1082*
Primary education				-0.1081*
Population density in municipality	-0.0001***	-0.0001***	-0.0001***	-0.0001***
Density of main roads in municipality	-0.0599***	-0.0594***	-0.0594***	-0.0698***
Accessability index (municipality)				
Circularity index of urban region				
Gini index (employment in urban region)	1.1380***	1.1870***	1.1940***	1.2387***
Rank-size indicator (employment in urban region)	-0.0792*	-0.0814*	-0.0817*	-0.0949**
Logarithm of area (urban region)				
IMR		-0.0791		-0.0382
Rho		-0.0841	-0.0956	
R^2	0.0587	0.0589		

Results: rural areas

Selection equation (dependent variable: commuting by car)		
	Probit	Robust SSM
constant	-0.8214’	-0.7189’
Age		
Age ^{2}		
Sex (ref: female)	0.4542***	0.5682***
Private car ownership (ref: no car)	1.1729***	1.5302***
Chiild(ren) in household (ref: no children)	0.1228*	0.1347’
Education level (ref: higher education)		
Secondary education	-0.6237***	-0.8000***
Vocational education	-0.8364***	-1.0185***
Primary education	-0.7475***	-0.8872***
Employment type (ref: self-employed)		
Population density in municipality		0.0011*
Density of main roads in municipality	-0.3238***	-0.5553***
Accessability index (municipality)		
Circularity index of urban region		
Gini index (employment in urban region)	-1.3621**	-1.6295**
Rank-size indicator (employment in urban region)		
Logarithm of area (urban region)	0.1634’	0.1674’

Results: rural areas

Outcome equation (dependent variable: logCO2em)				
	OLS	Heckman	ML	Robust SSM
constant	13.2366***	13.57***	13.95***	13.55***
Age				
Age ^{2}				
Sex (ref: female)	0.331***	0.2465***	0.1248*	0.2201***
Education level (ref: higher education)				
Secondary education	-0.1129'			
Vocational education	-0.2082**			
Primary education	-0.1962*			
Population density in municipality				-0.0004'
Density of main roads in municipality				
Accessability index (municipality)	0.0117'	0.0121'	0.0132'	0.0109'
Circularity index of urban region				
Gini index (employment in urban region)	1.2551***	1.4850***	1.8112***	1.6481***
Rank-size indicator (employment in urban region)				
Logarithm of area (urban region)	-0.1459*	-0.1688**	-0.1952**	-0.1705**
IMR		-0.4109**		-0.4243**
Rho			-0.8803***	
R^2	0.0477	0.0523		

Conclusions

- Urban systems (intra-urban structure) and individual characteristics significantly affect commuting patterns in Poland
- CO_2 emissions are lower in polycentric regions
- Higher concentration of employment brings about higher emissions
- Higher density indeed appears to reduce CO_2 emissions from car commuting

Conclusions

- Demographic characteristics and socioeconomic status are important explanatory factors; however, urban strucuture and form appear to have a stronger effect on CO2 emissions

- Not surprisingly, residents of rural areas rely more on the car

- Controlling for sample selection is important

Thank you