

SUPPLEMENTARY MATERIAL

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Methods M1. Example R code for weights calculation for PM_{2.5} with a cut-off of 15.

```
## STEP 1: Definition of indicator for pollutant's level (above/below cut off)
# PM2.5
data$pm25.u15<-1
data[data$PM25FULLt<15,]$pm25.u15<-0
data$pm25.u15<-as.factor(data$pm25.u15)

## STEP 2: Null model - run a logistic regression for pollutant's level
indicator with no independent variables and take the predictions
# PM2.5 < 15 ug/m3
pm25logit.u15<-glm(pm25.u15~1,data=data,family="binomial")
pm25predprob.u15<-predict(pm25logit.u15,type="response")

## STEP 3: PS model - run a logistic regression for pollutant's level
indicator with independent variables the covariates of main model and take the
predictions.
# PM2.5 < 15 ug/m3
pm25logit.u15wcov<-glm(pm25.u15~age_b+year+as.factor(sex)+as.factor(smoking)+
smoke_cig+smoke_dur + further covariates ,data=data,family="binomial")
pm25predprob.u15wcov<-predict(pm25logit.u15wcov,type="response")

## STEP 4: Calculate weights as the ratio of predictions from null model vs
predictions from PS model
# PM2.5.
data$Wpm25.u15[data$pm25.u15==0]<-(1-pm25predprob.u15[data$pm25.u15==0])/(1-
pm25predprob.u15wcov[data$pm25.u15==0])
data$Wpm25.u15[data$pm25.u15==1]<-
pm25predprob.u15[data$pm25.u15==1]/pm25predprob.u15wcov[data$pm25.u15==1]
```

Table S1. Characteristics of the ELAPSE pooled cohort and subcohorts.

	Participants (%)	Person years follow-up	Natural deaths	Women (%)	Mean (SD) age at baseline (years)	Current smokers (%)	Mean (SD) No. of cigarettes/day ^a	Mean (SD) years of smoking ^a	Overweight or obese (%)	Married or living with partner (%)	Not employed ^b (%)	Mean (SD) small-area income, *1000 €
Pooled cohort	325,367 (85.4)	6,339,553	47,131 (14.5)	66	48.7 (13.4)	24.2	15.2 (8.9)	25.5 (13.1)	43.3	71.7	30	20.1 (5.8)
Subcohorts												
Stockholm county, Sweden												
CEANS-SDPP	7,727 (98.6)	122,606	337 (4.4)	61.2	47.1 (4.9)	26.4	13.5 (7.4)	27.9 (8.6)	51.5	83.5	9.2	24.3 (4.2)
CEANS-SIXTY	3,969 (95.0)	61,328	593 (14.9)	52.1	60.0 (0.0)	21.1	13.4 (7.6)	36.3 (9.9)	64.1	73.9	32.3	24.7 (6.9)
CEANS-SALT	6,176 (91.9)	64,140	891 (14.4)	55.3	57.8 (10.6)	21.2	12.7 (8.0)	37.9 (9.3)	39.8	67.7	35.6	25.3 (6.6)
CEANS-SNACK	2,830 (87.1)	20,970	960 (33.9)	62.4	72.9 (10.4)	14.3	11.7 (8.2)	43.3 (13.6)	53	45.9	76.8	28.7 (2.2)
Denmark (Copenhagen and Aarhus)												
DCH	53,647 (95.3)	974,868	10,644 (19.8)	52.4	56.7 (4.4)	36.3	16.4 (9.0)	36.3 (7.7)	56.1	71.5	21.7	20.2 (3.4)
Denmark (nationwide)												
DNC-1993	17,043 (86.7)	318,351	4,003 (23.5)	100	56.2 (8.4)	37.5	13.9 (8.2)	31.6 (9.9)	28.1	67.6	30	19.2 (2.6)
DNC-1999	8,128 (92.7)	117,390	313 (3.9)	100	47.9 (4.2)	28.6	13.3 (7.3)	27.1 (7.1)	30	75.8	5.3	19.0 (2.4)
Netherlands (four cities)												
EPIC-NL-Morgen	18,302 (88.4)	308,257	1,180 (6.4)	55	42.9 (11.2)	34.7	15.7 (8.6)	24.8 (10.6)	49.1	65.1	31.3	12.2 (1.6)
EPIC-NL-Prospect	14,570 (90.0)	239,372	1,997 (13.7)	100	57.7 (6.1)	22.9	13.7 (8.7)	36.8 (7.6)	54.8	76.7	49.2	13.1 (1.4)
Germany (Ruhr area)												
HNR	4,733 (98.4)	56,857	694 (14.7)	50.3	59.7 (7.8)	23.5	18.6 (12.0)	34.5 (9.4)	73.5	74.8	60	25.2 (8.2)
France (nationwide)												
E3N	39,006 (72.9)	650,664	2,260 (5.8)	100	53.0 (6.8)	13	11.4 (9.2)	28.6 (7.6)	20.7	83.3	32.3	11.2 (3.0)
Germany (Augsburg area)												
KORA-S3	2,572 (56.3)	40,080	391 (15.2)	50.9	49.4 (13.9)	20.2	16.5 (9.5)	25.2 (12.1)	67	80.1	44.7	36.7 (4.4)
KORA-S4	2,281 (53.6)	29,528	215 (9.4)	51.4	49.3 (13.8)	22.9	15.7 (9.5)	24.3 (11.6)	68.5	79.2	40.6	38.0 (7.3)
Austria (Vorarlberg region)												
VHM&PP	144,383 (84.8)	3,335,141	22,653 (15.7)	56.2	42.1 (15.0)	20	15.6 (8.9)	13.4 (8.3)	42.4	68.9	30.2	22.9 (1.7)

SD: standard deviation. ^a For current smokers; ^b Includes unemployed, home workers and retired subjects.

Table S2. Characteristics of the administrative cohorts.

	Norwegian	Danish	English	Dutch	Belgian	Swiss	Roman
N participants total	2,516,192	3,323,612	1,491,124	10,532,360	6,491,801	4,293,521	1,263,712
N participants with complete data	2,309,001	3,083,227	1,368,740	10,376,406	5,474,548	4,188,175	1,263,712
Individual level covariates							
Age, mean (SD)	53.9 (15.9)	53.0 (15.1)	58.9 (12.8)	53.6 (15.1)	52.6 (15.2)	52.7 (15.2)	55.1 (15.4)
Women (%)	50.9	51.7	52.5	51.3	49.4	52.0	54.5
Smoking status (% current smokers)	-	-	36.0	-	-	-	-
BMI, mean (SD)	-	-	27.5 (5.6)	-	-	-	-
Country origin (% local)	-	94.5	-	82.8	96.9	83.1	-
Household income	Quartiles	Deciles	-	Deciles	-	-	-
Marital status - Single	17.8	-	-	18.9	12.3	14.0	15.3
Married	59.3	-	-	63.1	68.3	69.3	66.3
Divorced	12.3	-	-	10.1	9.9	8.7	7.0
Widowed	10.6	-	-	8.0	9.5	8.1	11.4
Education - Low	31.2	-	-	-	23.8	24.5	24.9
Medium	45.8	-	-	-	51.9	52.7	58.8
High	23.0	-	-	-	24.3	22.7	16.2
Occupational status	65.8	64.7	-	-	53.3	61.4	45.8
Employed/self-employed							
Unemployed	1.2	2.7	-	-	5.1	2.2	5.0
Homemaker	0	32.6	-	-	8.5	14.6	21.0
Retired	33.0	-	-	-	33.2	21.8	23.5
Mother tongue	-	-	-	-	-	65.1	-
German + Rhaeto-Romansch							
French	-	-	-	-	-	19.6	-
Italian	-	-	-	-	-	7.4	-
Other	-	-	-	-	-	8.0	-
Area-level covariates ^a							
Neighborhood income	Linear	Linear	-	Linear	Linear	-	Deciles
Neighborhood low education	Linear	Linear	-	-	Linear	Linear	Linear
Neighborhood high education	-	-	-	-	-	Linear	Linear
Neighborhood unemployment rate	Linear	Linear	-	Linear	Linear	Linear	Linear
Neighborhood non-Western ethnic	-	-	-	Linear	Linear	-	-
Neighborhood score (% lowest)	-	-	Deciles	Linear	-	Linear	Quintiles
Regional income	Linear	Linear	-	Linear	Linear	-	-
Regional low education	Linear	Linear	-	-	Linear	Linear	-
Regional high education	-	-	-	-	-	Linear	-
Regional unemployment rate	Linear	Linear	-	Linear	Linear	Linear	-
Region non-Western ethnic	-	-	-	Linear	Linear	-	-
Region score (% lowest)	-	-	-	Linear	-	Linear	-

^a Because all cohorts have different representations, we add whether and how a variable was available and adjusted for in the main model 3.

Table S3: Cohort description by air pollutants (PM_{2.5} and NO₂) and selected cut-off values. Cohorts with less than 5% of data above or below the respective cut-off values (number of persons below (pooled); 273,727 (Belgian); 154,161 (Danish); 518,820 (Dutch); 68,437 (English); 115,450 (Norwegian); 63,186 (Roman); 209,409 (Swiss)) were not considered for the respective analyses and are indicated with "-". For the pooled cohort, only subcohorts with more than 5% of data above or below the respective cut-off values were included.

Cut-off value	Cohort	Characteristic	PM _{2.5}				NO ₂			
			15 µg/m ³		12 µg/m ³		40 µg/m ³ ^a		20 µg/m ³	
			above	below	above	below	above	below	above	below
Pooled ^b	Number of persons	136,746	130,314	192,229	30,972	66,990	96,681	199,267	88,495	
	Person-year at risk	2,868,935	2,597,088	4,110,300	635,451	1,133,393	1,621,947	3,954,764	1,780,304	
	Number of cases	19,465	21,014	32,883	4,730	9,630	13,211	32,013	11,247	
Norwegian	Number of persons	-	-	131,491	2,177,510	-	-	596,923	1,712,078	
	Person-year at risk	-	-	1,806,412	30,725,009	-	-	8,318,697	24,212,724	
	Number of cases	-	-	33,141	491,451	-	-	141,717	382,875	
Danish	Number of persons	220,346	2,862,881	1,807,189	1,276,038	-	-	1,326,775	1,756,452	
	Person-year at risk	2,919,571	39,666,893	24,584,389	18,002,075	-	-	17,903,091	24,683,373	
	Number of cases	55,895	658,734	448,358	266,271	-	-	333,883	380,746	
English	Number of persons	97,254	1,271,486	1,102,363	266,377	-	-	1,191,212	177,528	
	Person-year at risk	646,381	8,437,912	7,317,916	1,766,378	-	-	7,907,054	1,177,239	
	Number of cases	10,079	135,909	117,048	28,940	-	-	126,693	19,295	
Dutch	Number of persons	8,496,943	1,879,463	-	-	1,149,065	9,227,341	9,763,916	612,490	
	Person-year at risk	40,964,703	9,069,855	-	-	5,475,281	44,559,276	47,058,364	2,976,194	
	Number of cases	479,662	111,170	-	-	71,392	519,440	560,706	30,126	
Belgian	Number of persons	-	-	-	-	594,221	4,880,327	-	-	
	Person-year at risk	-	-	-	-	5,796,694	48,778,529	-	-	
	Number of cases	-	-	-	-	87,782	619,364	-	-	
Swiss	Number of persons	3,059,474	1,128,701	3,922,922	265,253	-	-	2,856,967	1,331,208	
	Person-year at risk	38,881,535	14,462,761	49,960,988	3,383,307	-	-	36,203,657	17,140,639	
	Number of cases	483,187	178,347	617,514	44,020	-	-	458,689	202,845	
Roman	Number of persons	-	-	-	-	125,842	1,137,870	-	-	
	Person-year at risk	-	-	-	-	1,485,169	13,815,231	-	-	
	Number of cases	-	-	-	-	27,359	208,184	-	-	

^a Cut-off value was set to NO₂ = 30 µg/m³ for the Pooled cohort

^b Subcohorts for cut-off values PM_{2.5} = 15 µg/m³ (DCH, DNC-1993, DNC-1999, E3N, KORA-S3, KORA-S4, VHM_PP), PM_{2.5} = 12 µg/m³ (DCH, DNC-1993, DNC-1999, VHM_PP), NO₂ = 30 µg/m³ (CEANS-SALT, CEANS-SIXTY, CEANS-SNACK, DCH, DNC-1993, DNC-1999, E3N, EPIC_NL-Morgen, EPIC_NL-Prospect), NO₂ = 20 µg/m³ (CEANS-SALT, CEANS-SDPP, CEANS-SIXTY, CEANS-SNACK, DCH, DNC-1993, DNC-1999, E3N, KORA-S3, KORA-S4, VHM_PP)

Table S4: Hazard ratios (and 95% confidence intervals) of the association between PM_{2.5} above versus below the specified cut-off values 12 and 10 µg/m³ and natural-cause mortality in the Norwegian cohort.

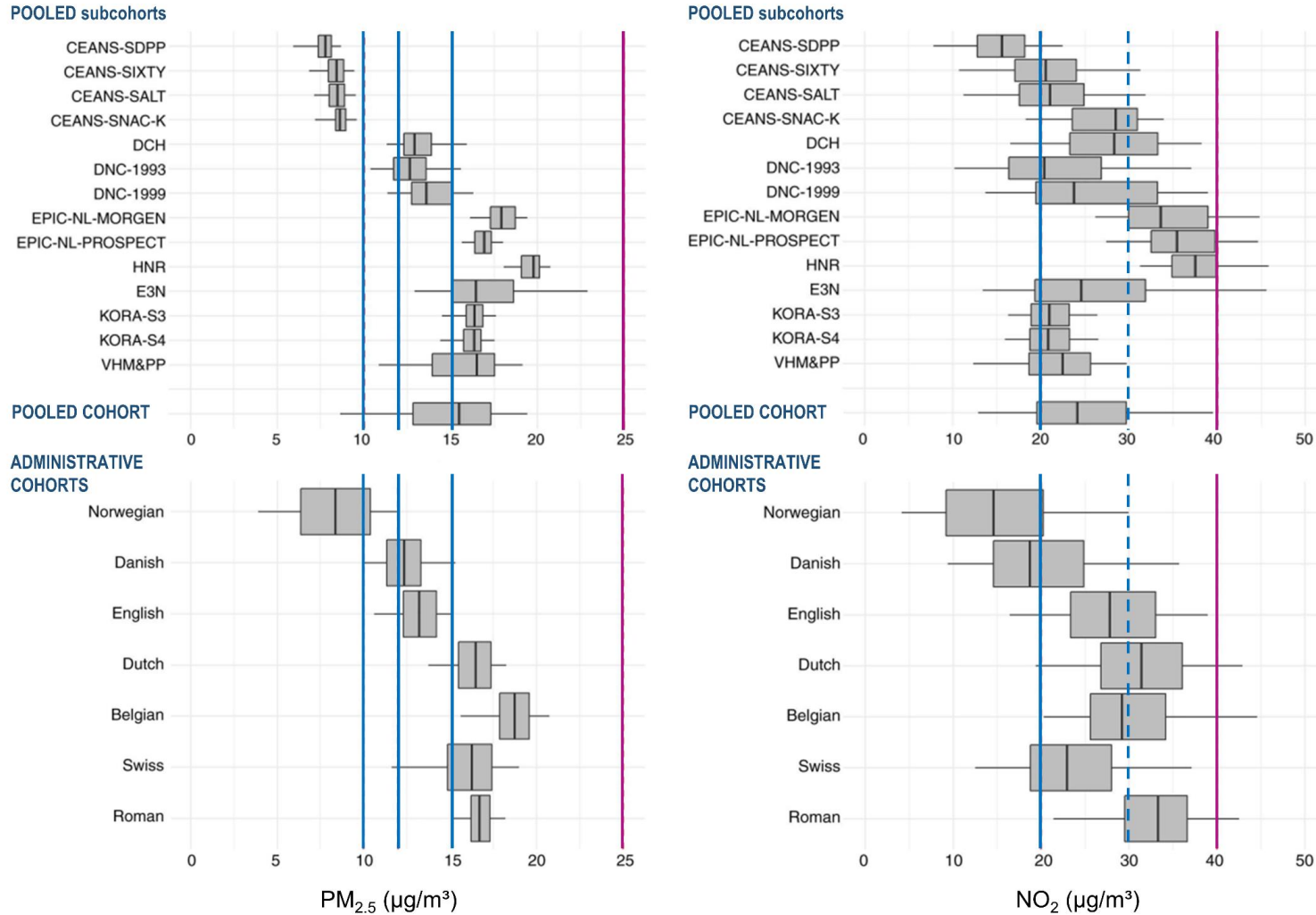
Model	PM _{2.5}	
	12 µg/m ³	10 µg/m ³
Number of persons above/below	131,491 / 2,177,510	666,357 / 1,642,644
Person-year at risk above/below	1,806,412 / 30,725,009	9,332,079 / 23,199,342
Number of cases above/below	33,141 / 491,451	153,846 / 370,746
% above / below cut-off	6 / 94	29 / 71
Traditional Cox ^a	1.03 (1.01, 1.04)	1.04 (1.03, 1.05)
Main Causal ^b	1.09 (1.07, 1.12)	1.03 (1.03, 1.04)
Sensi Causal ^c	1.07 (1.06, 1.08)	1.03 (1.02, 1.04)

^a Main model as in Stafoggia et al 2022 but sex as factor and continuous pollutants replaced with binary pollutants as factors.

^b Main causal model included only the pollutant as factors weighted by IPW truncated at the 1st and 99th quantiles.

^c Sensitivity causal model included the pollutant as factors weighted by IPW truncated at the 5th and 95th quantiles.

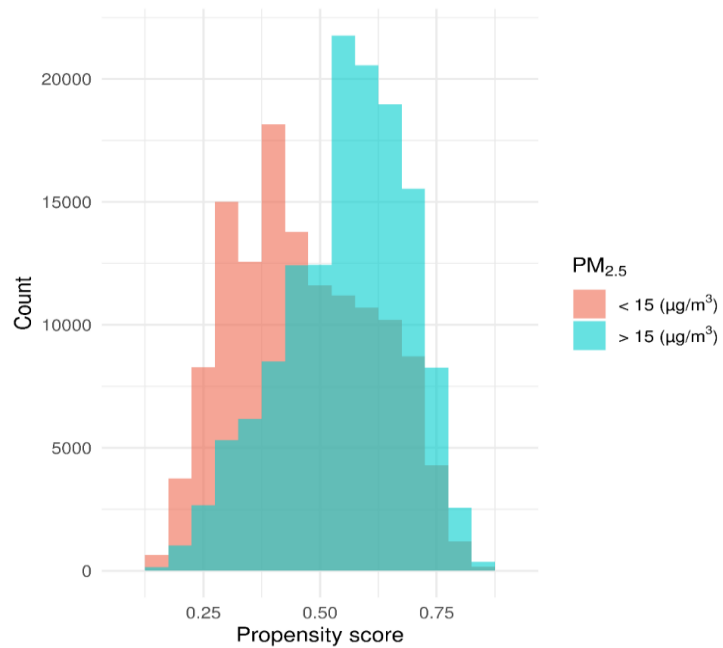
Figure S1: Distribution of modeled PM_{2.5} (left) and NO₂ (right) concentrations at participants' residential baseline addresses



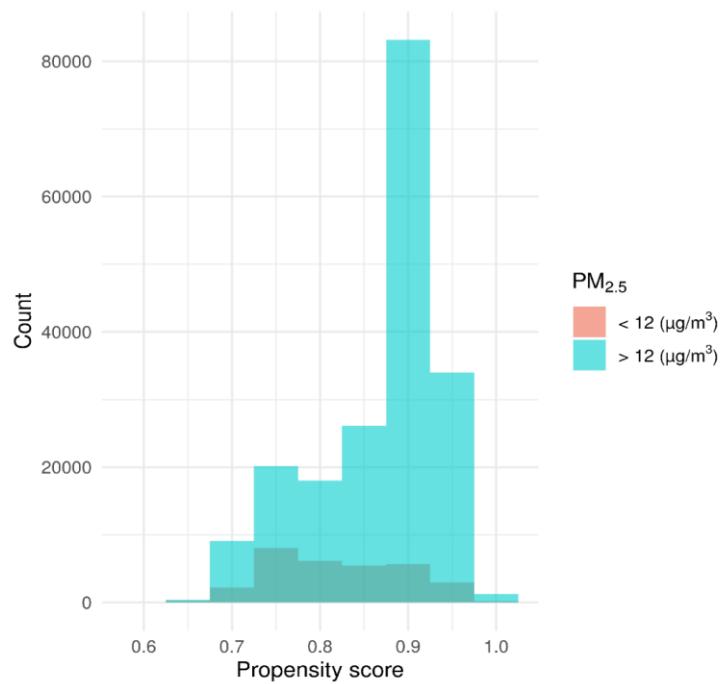
PM_{2.5}: fine particulate matter. NO₂: nitrogen dioxide. Blue lines indicate a priori selected cut-off levels for dichotomized exposures, the dashed line an additional cut-off level for the Pooled cohort as less than 5 % of data were above or below the originally selected cut-offs, purple lines indicate current EU limits. The boundary of the box closest to zero indicates the 25th percentile; the boundary furthest from zero indicates the 75th percentile; the bold line in the middle of the box indicates the 50th percentile (median); whiskers indicate 5th and 95th percentiles.

Figure S2: Propensity score distribution for PM_{2.5} by cohort

A Pooled cohort

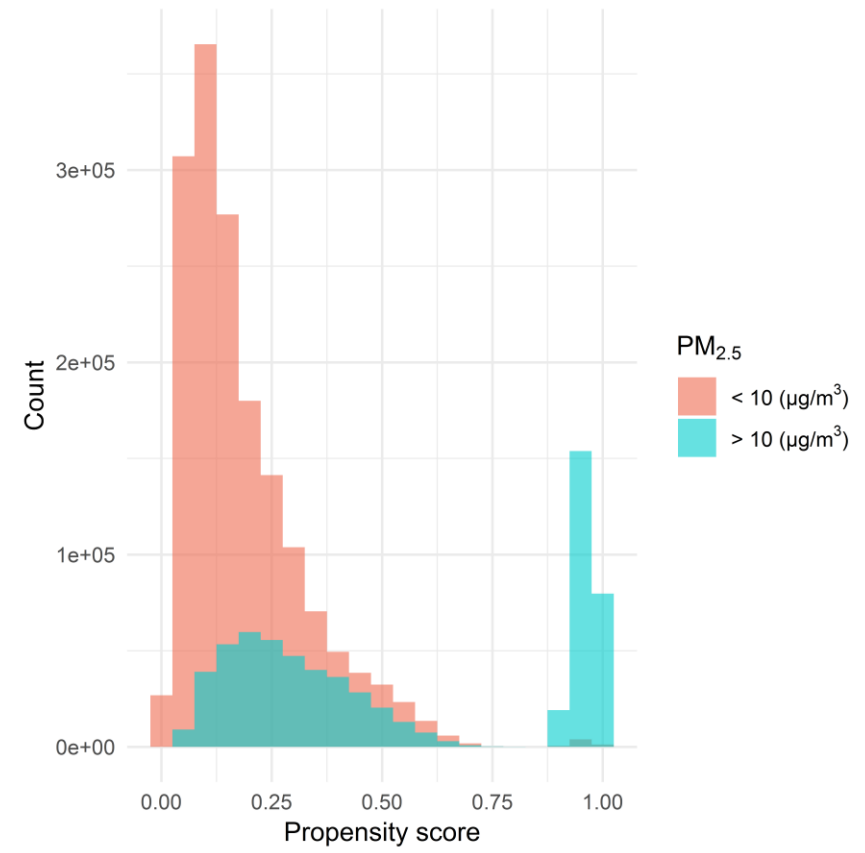
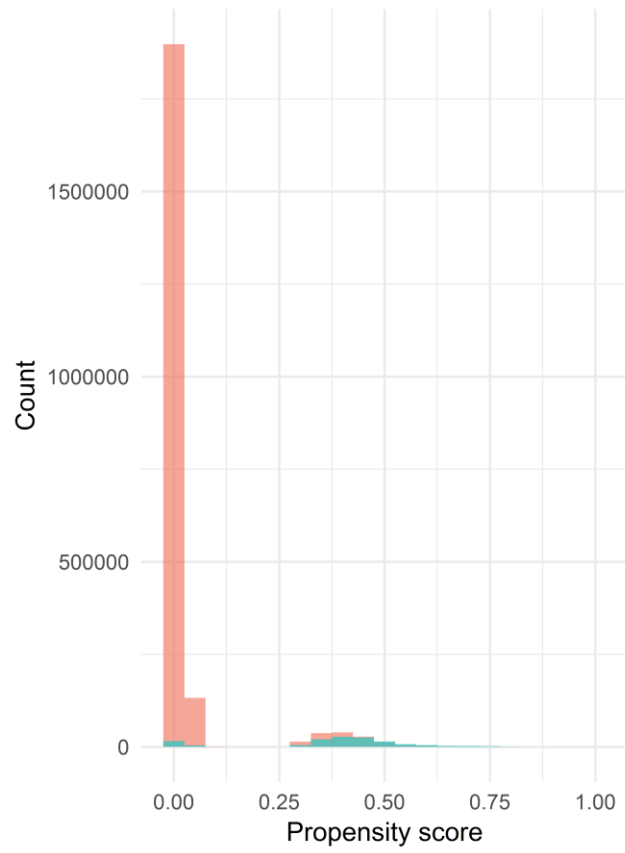


(Sub) Cohorts included: DCH, DNC-1993, DNC-1999, E3N, KORA-S3, KORA-S4, VHM_PP

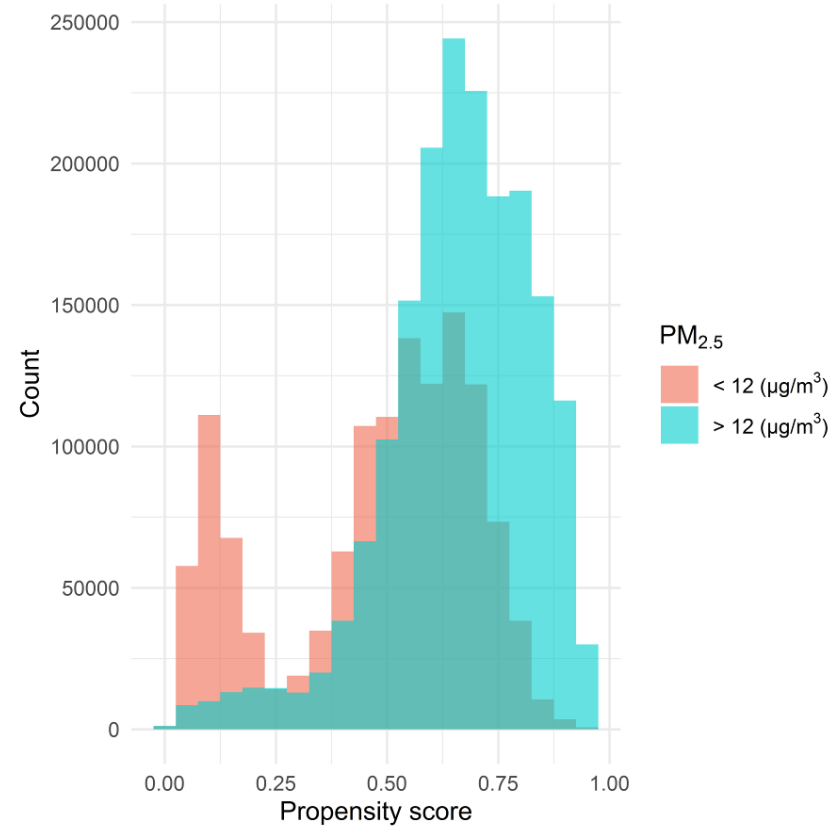
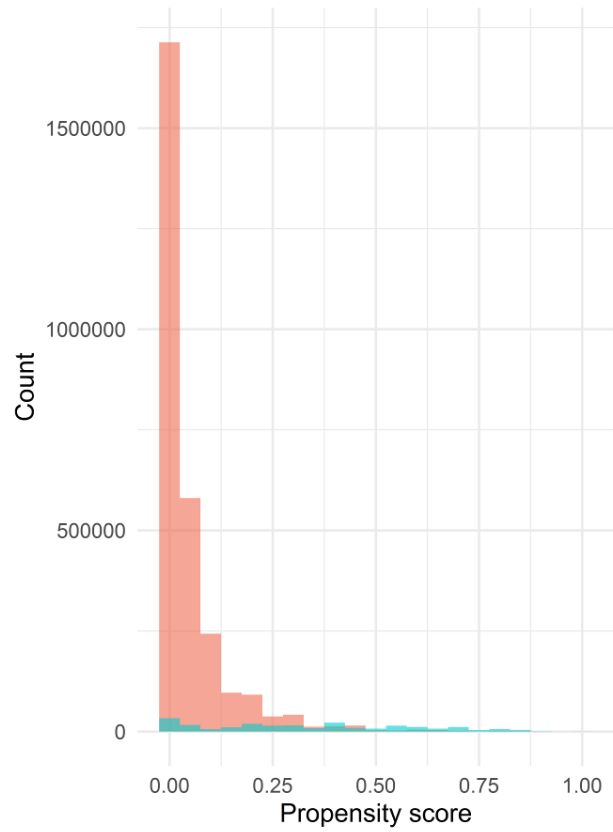


(Sub) Cohorts included: DCH, DNC-1993, DNC-1999, VHM_PP

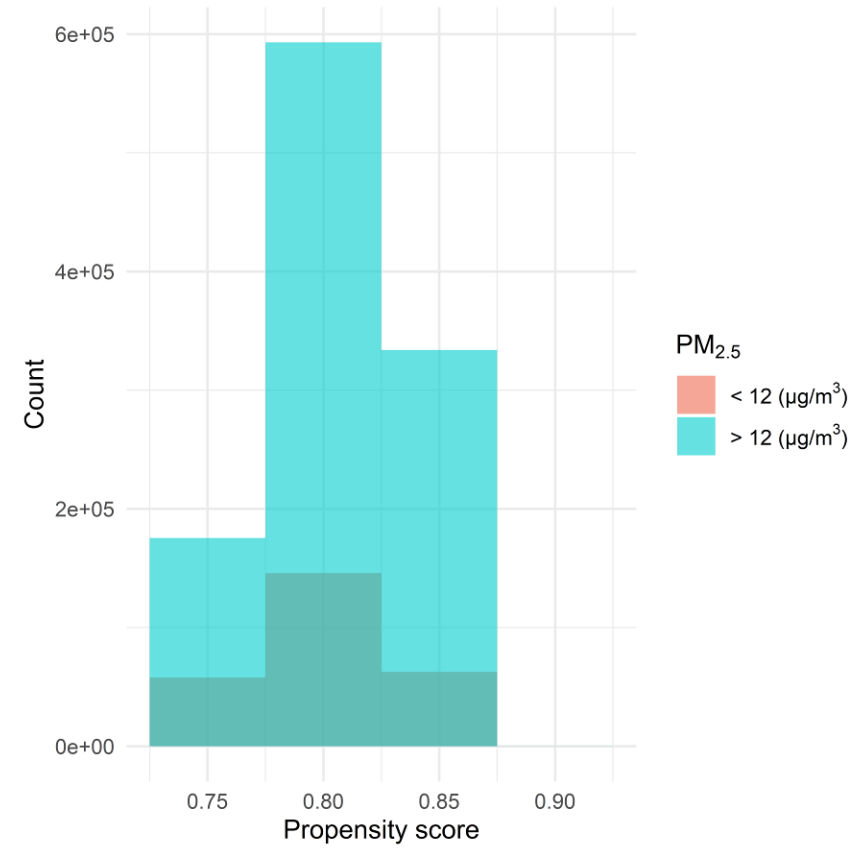
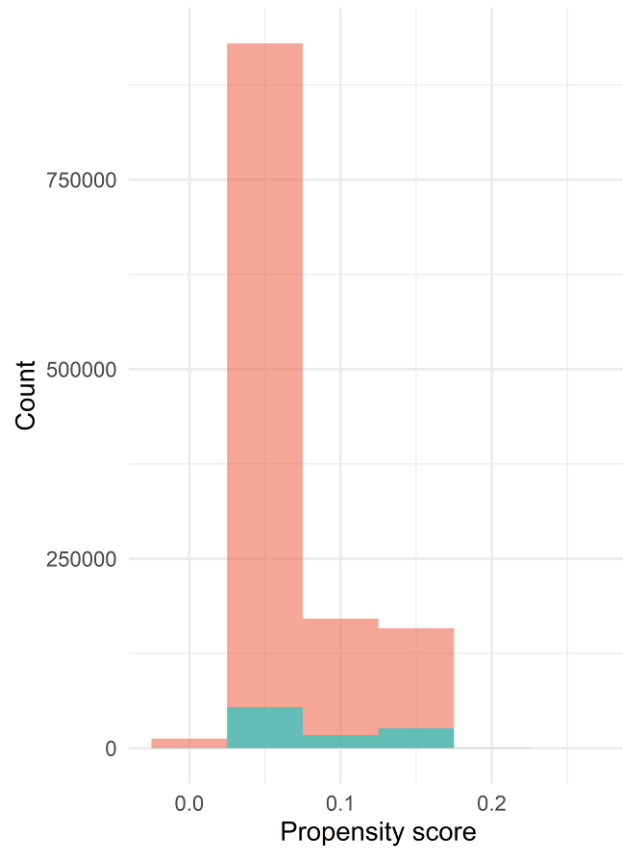
B Norwegian cohort



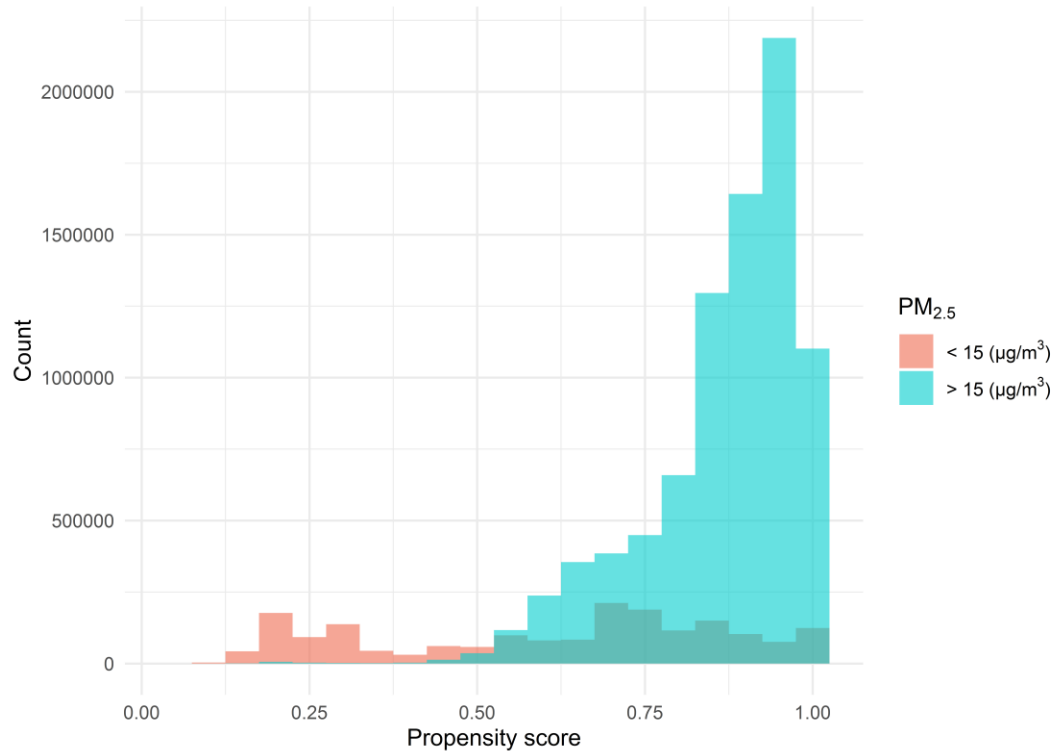
C Danish cohort



D English cohort



E Dutch cohort



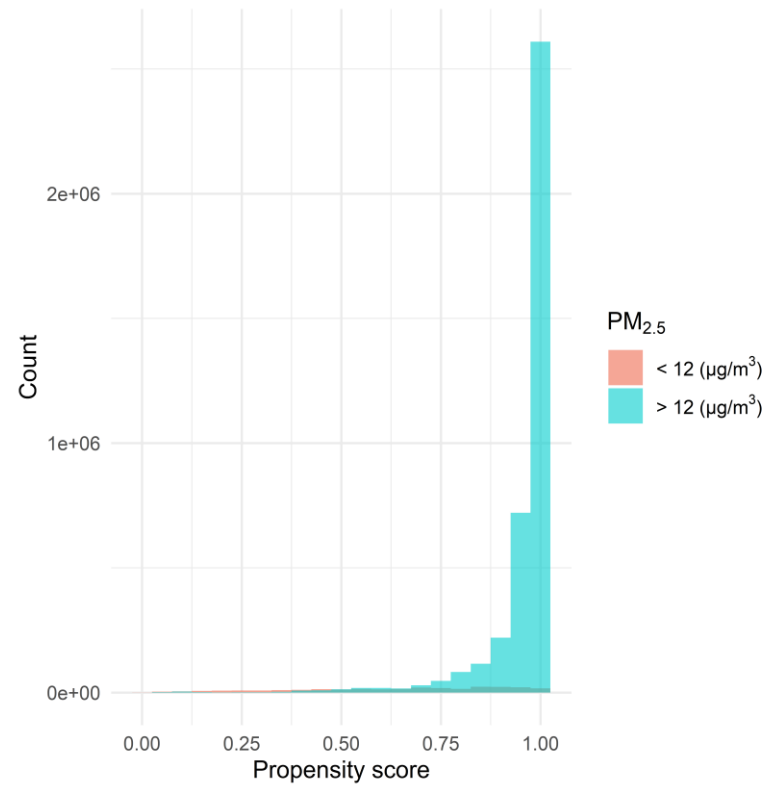
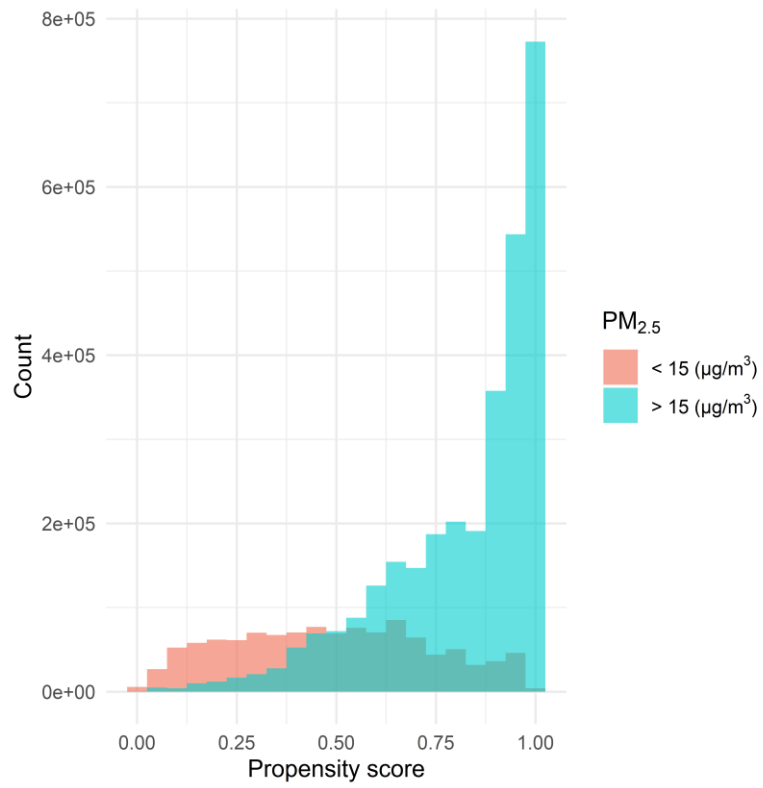
PM_{2.5} < 12 µg/m³: not enough data

F Belgian cohort

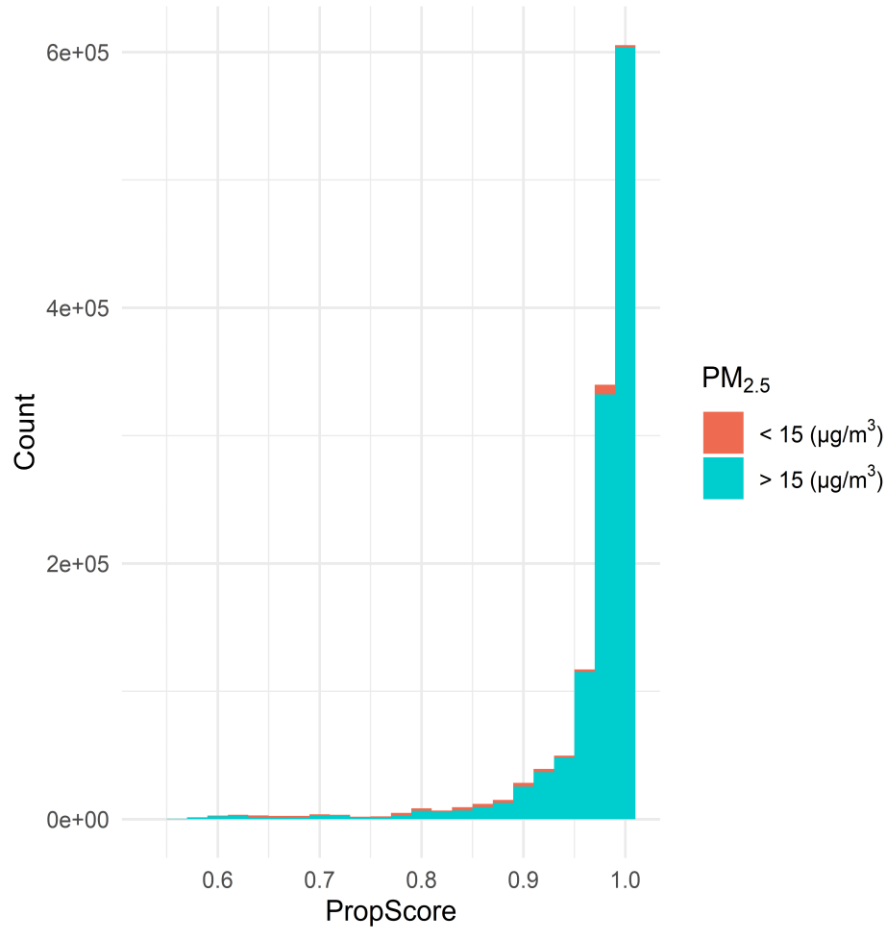
PM_{2.5} < 15 µg/m³: not enough data

PM_{2.5} < 12 µg/m³: not enough data

G Swiss cohort



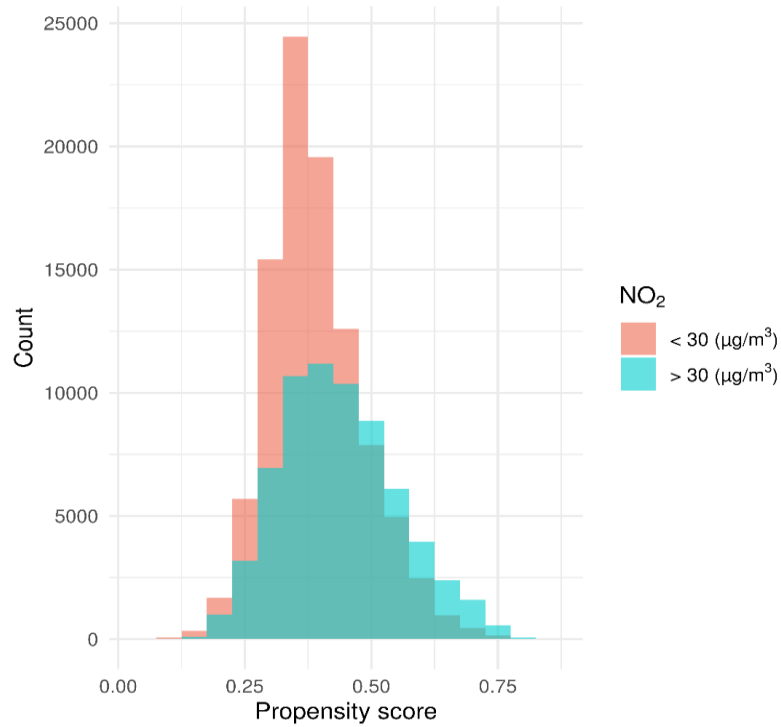
H Rome cohort



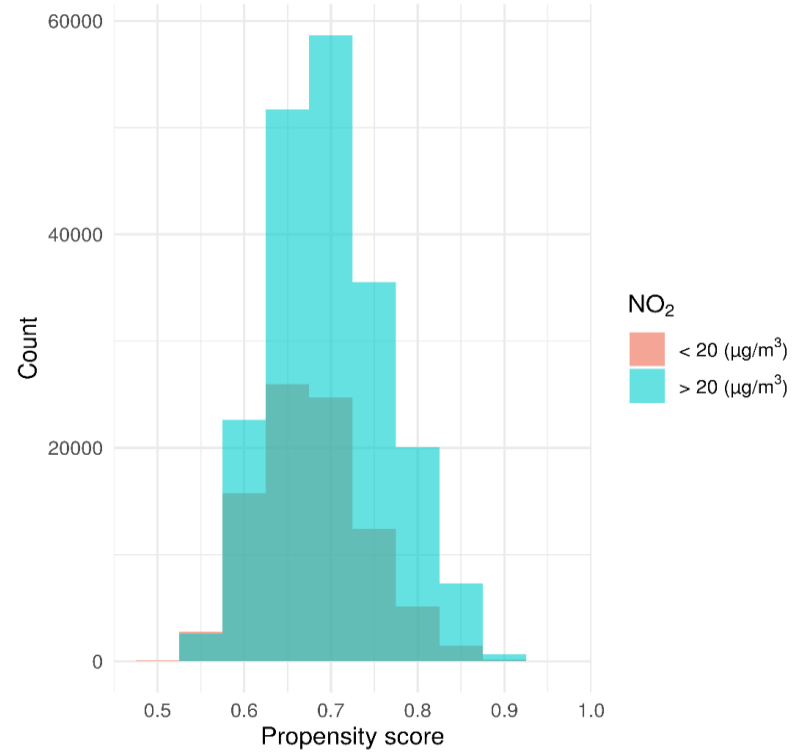
PM_{2.5} < 12 µg/m³: not enough data

Figure S3: Propensity score distribution for NO₂ by cohort

A Pooled cohort



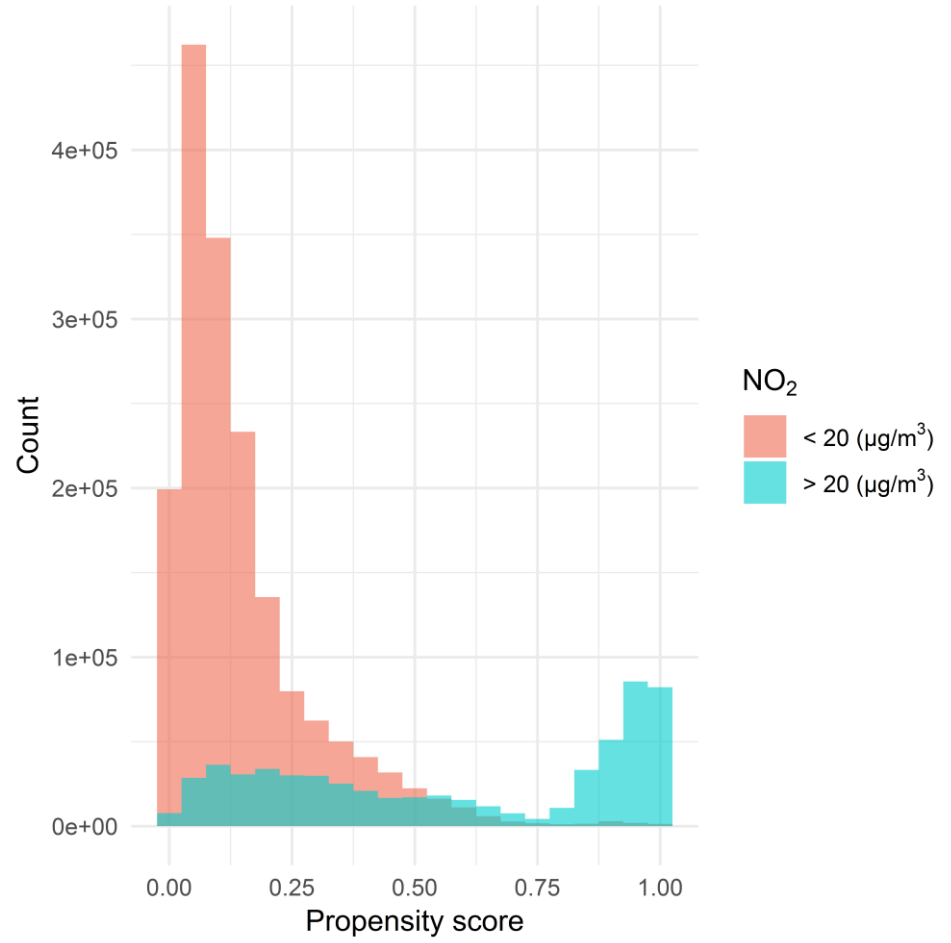
(Sub) Cohorts included: CEANS-SALT, CEANS-SIXTY, CEANS-SNACK, DCH, DNC-1993, DNC-1999, E3N, EPIC_NL-Morgen, EPIC_NL-Prospect



(Sub) Cohorts included: CEANS-SALT, CEANS-SDPP, CEANS-SIXTY, CEANS-SNACK, DCH, DNC-1993, DNC-1999, E3N, KORA-S3, KORA-S4, VHM_PP

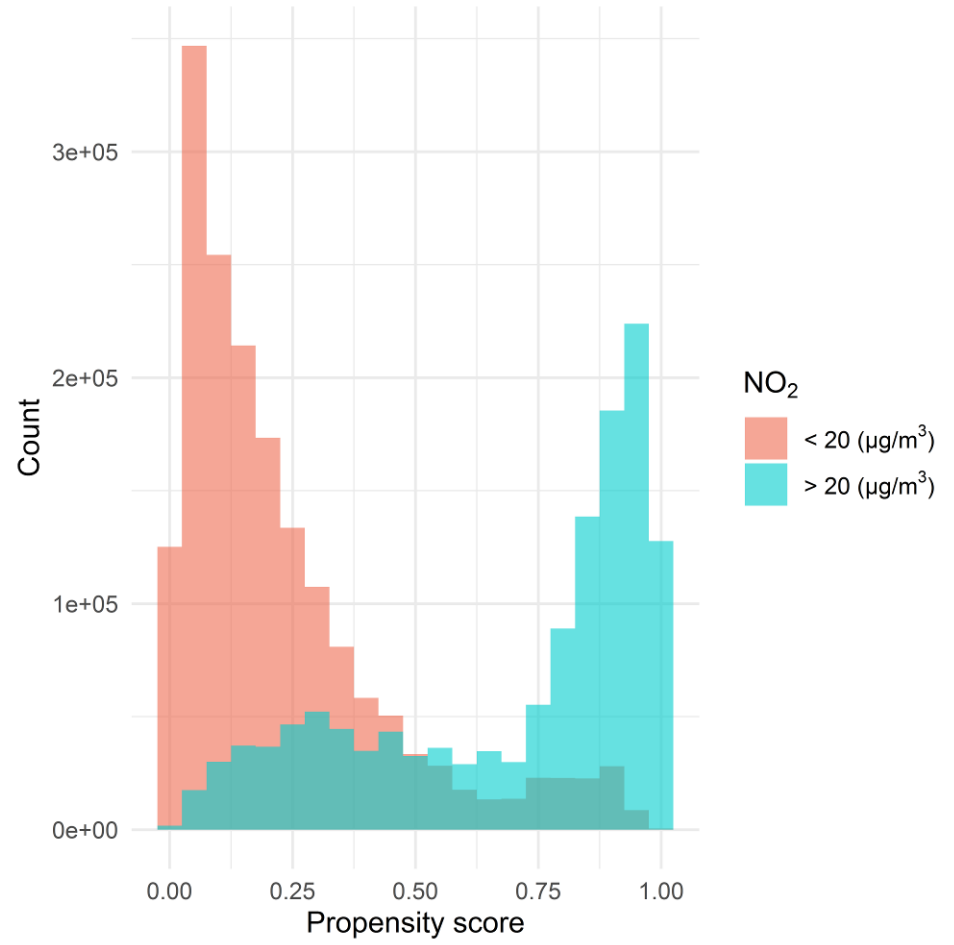
B Norwegian cohort

NO₂ < 40 µg/m³: not enough data



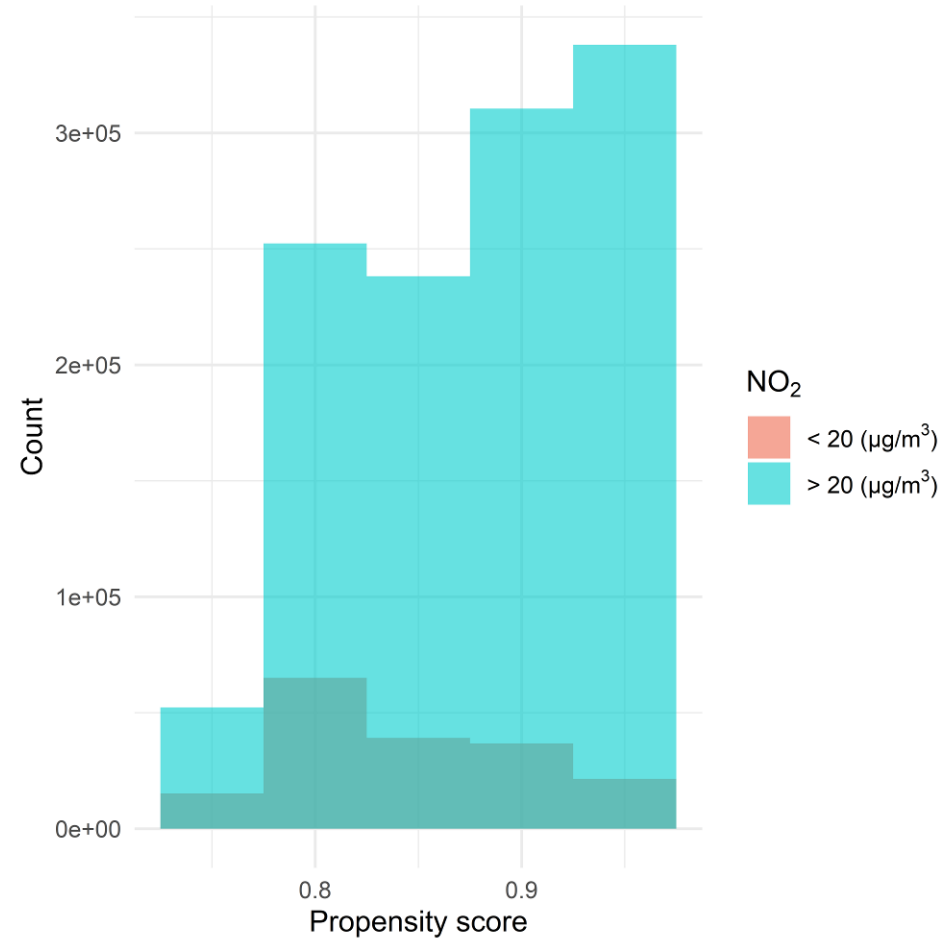
C Danish cohort

NO₂ < 40 µg/m³: not enough data

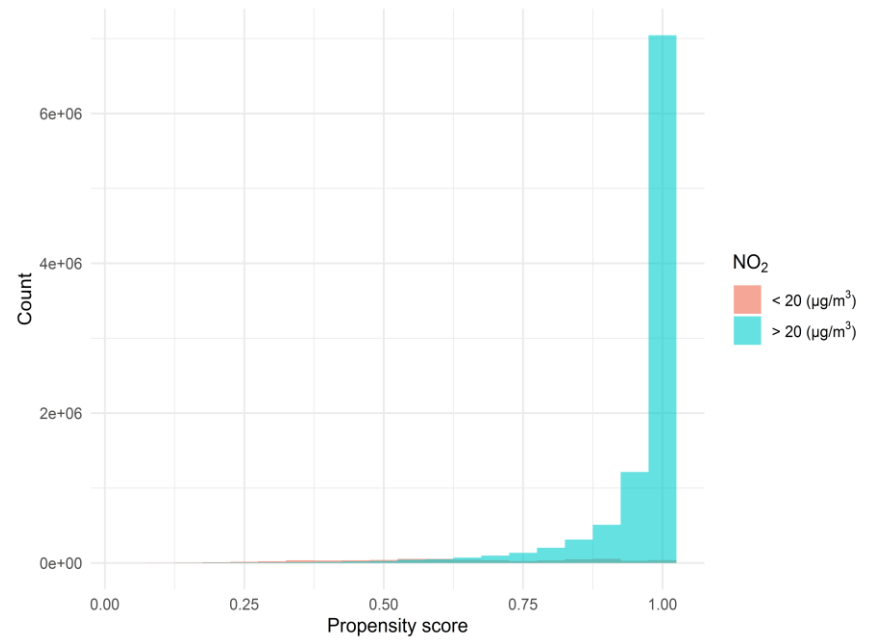
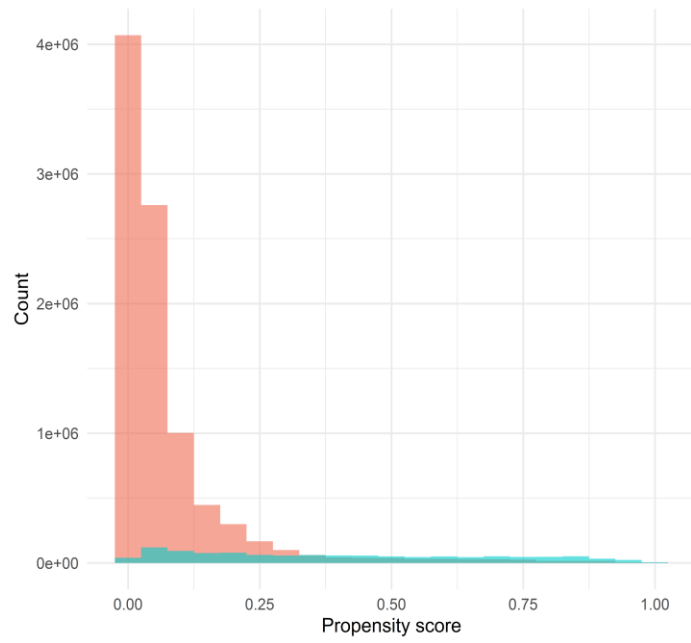


D English cohort

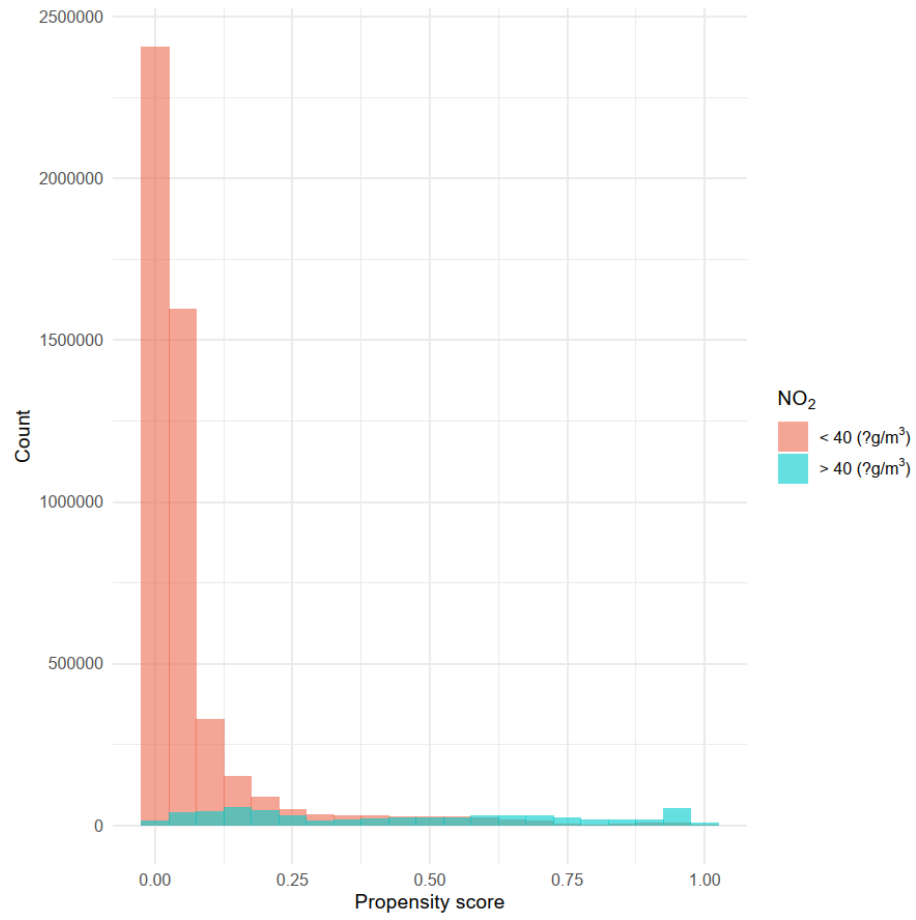
NO₂ < 40 µg/m³: not enough data



E Dutch cohort



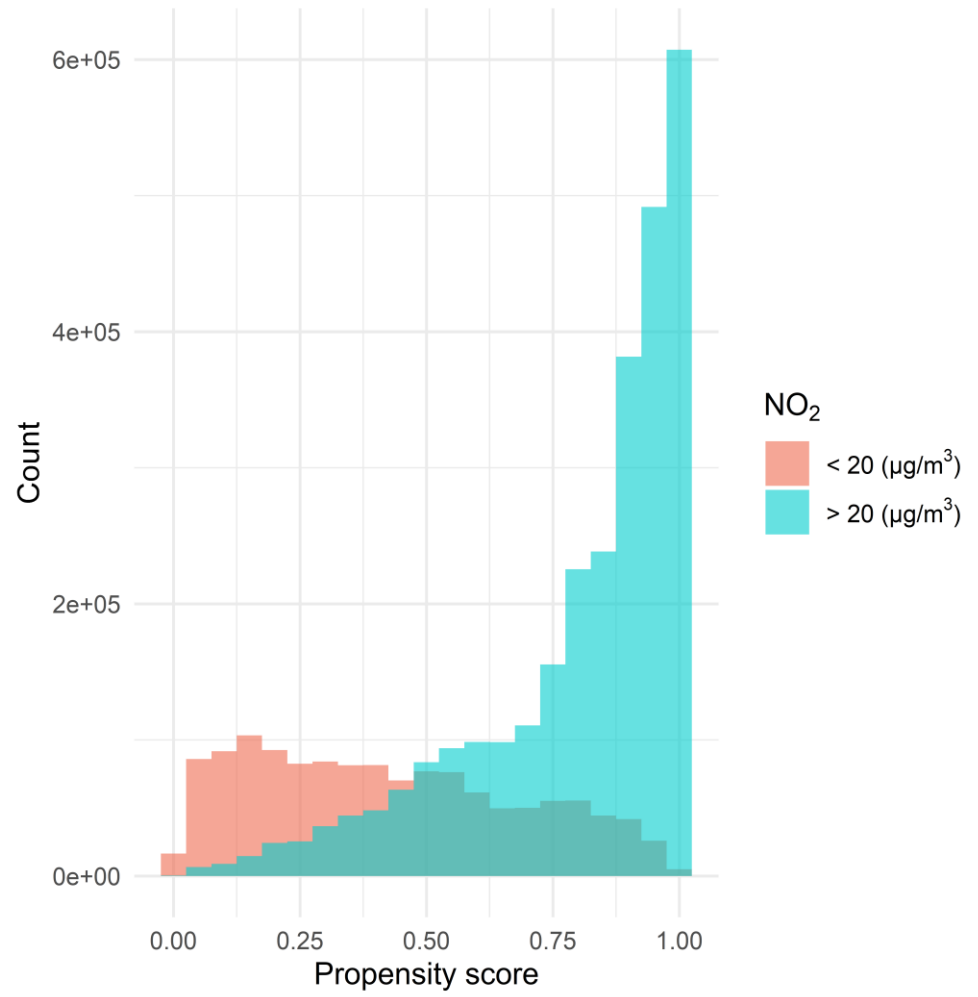
F Belgian cohort



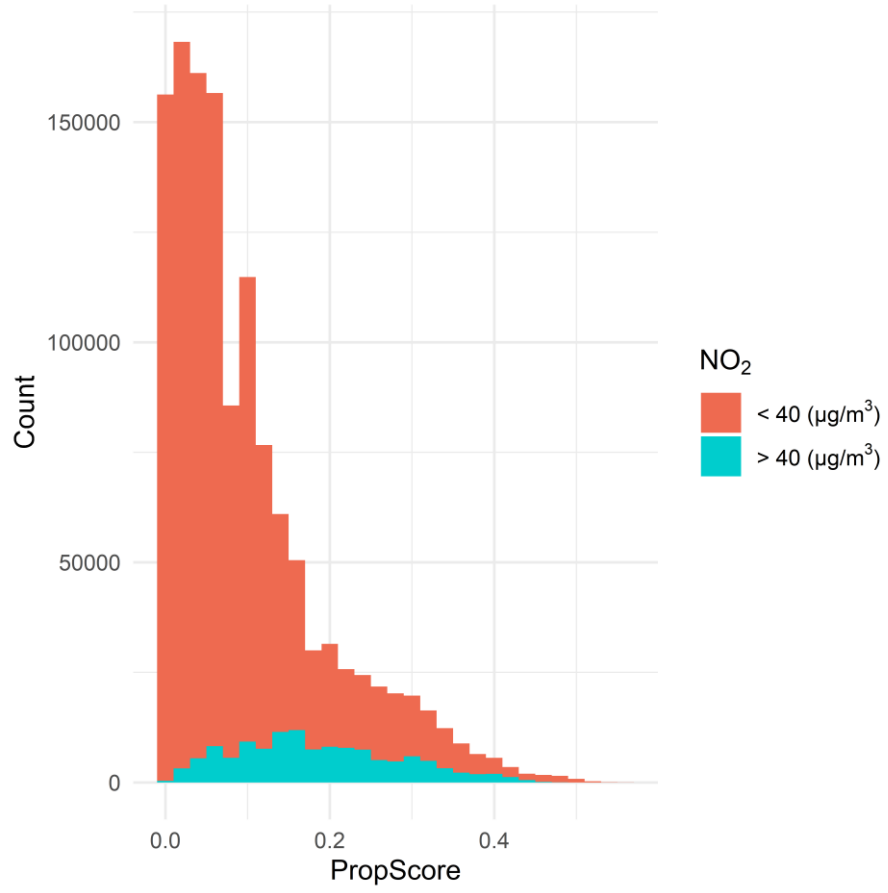
NO₂ < 20 μg/m³: not enough data

G Swiss cohort

NO₂ < 40 µg/m³: not enough data



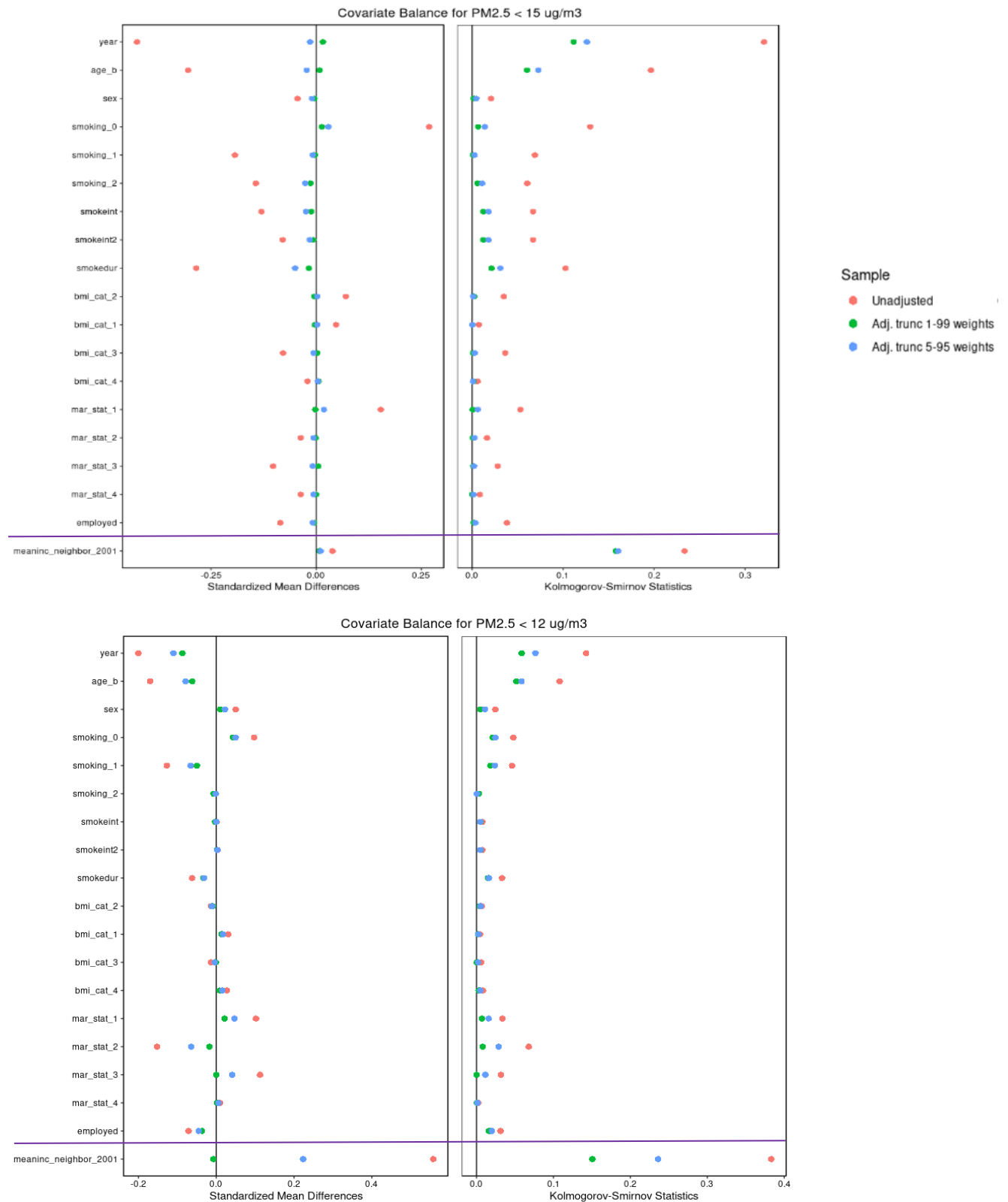
H Rome cohort



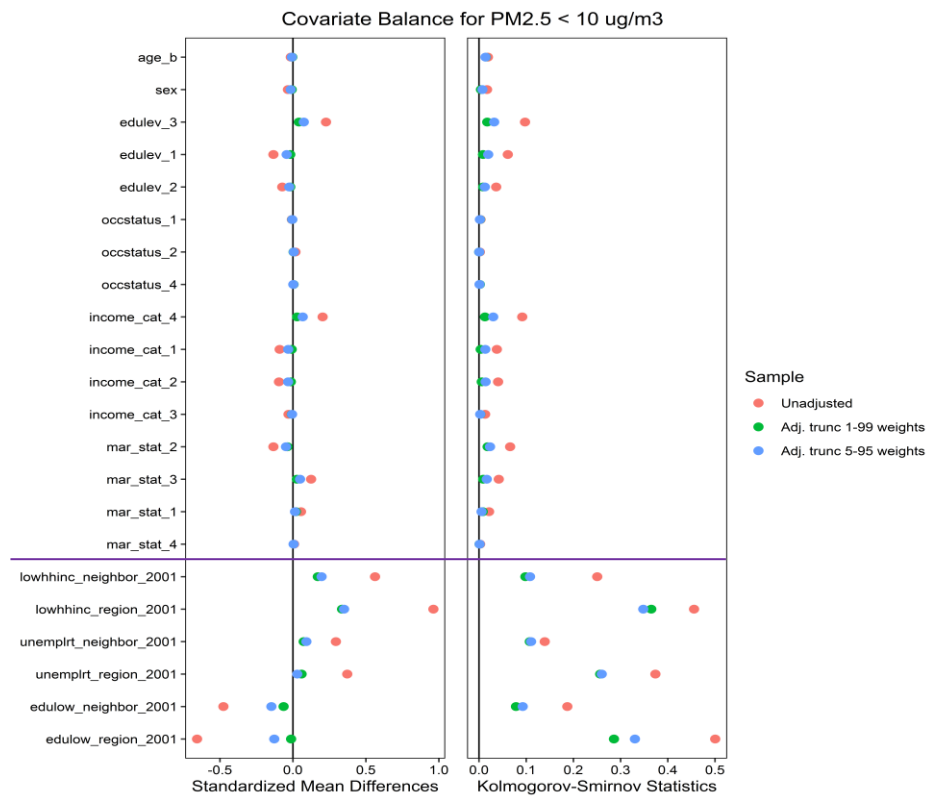
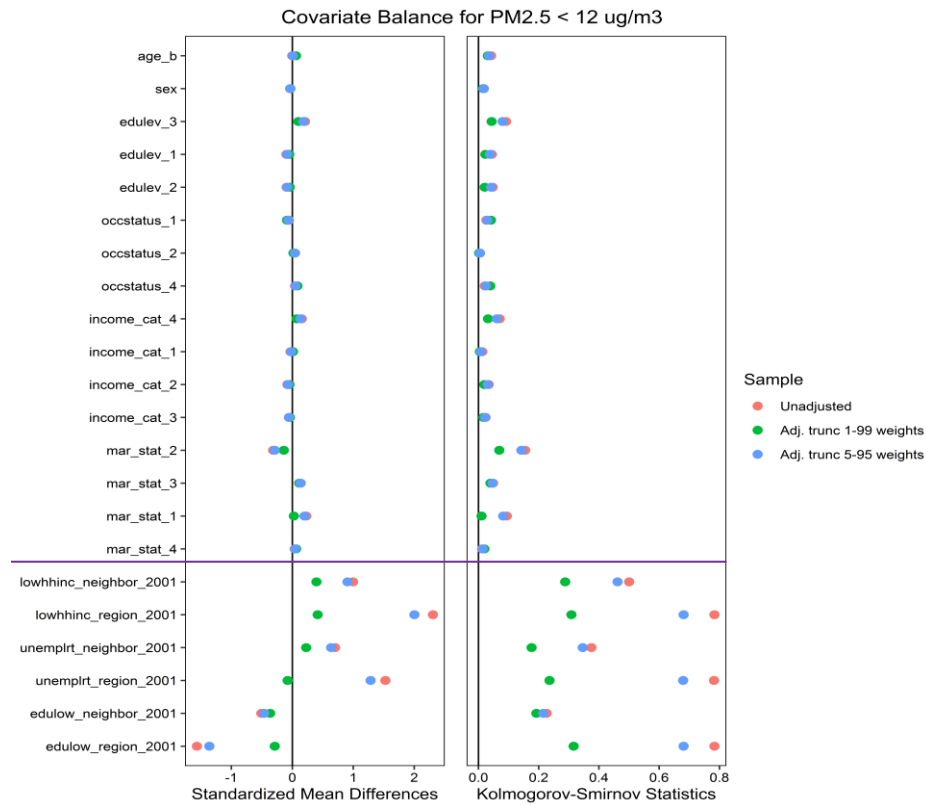
NO₂ < 20 µg/m³: not enough data

Figure S4: Covariates balance plots for PM_{2.5} by cohort

A Pooled cohort - individual covariates above and area-level covariates below the horizontal line

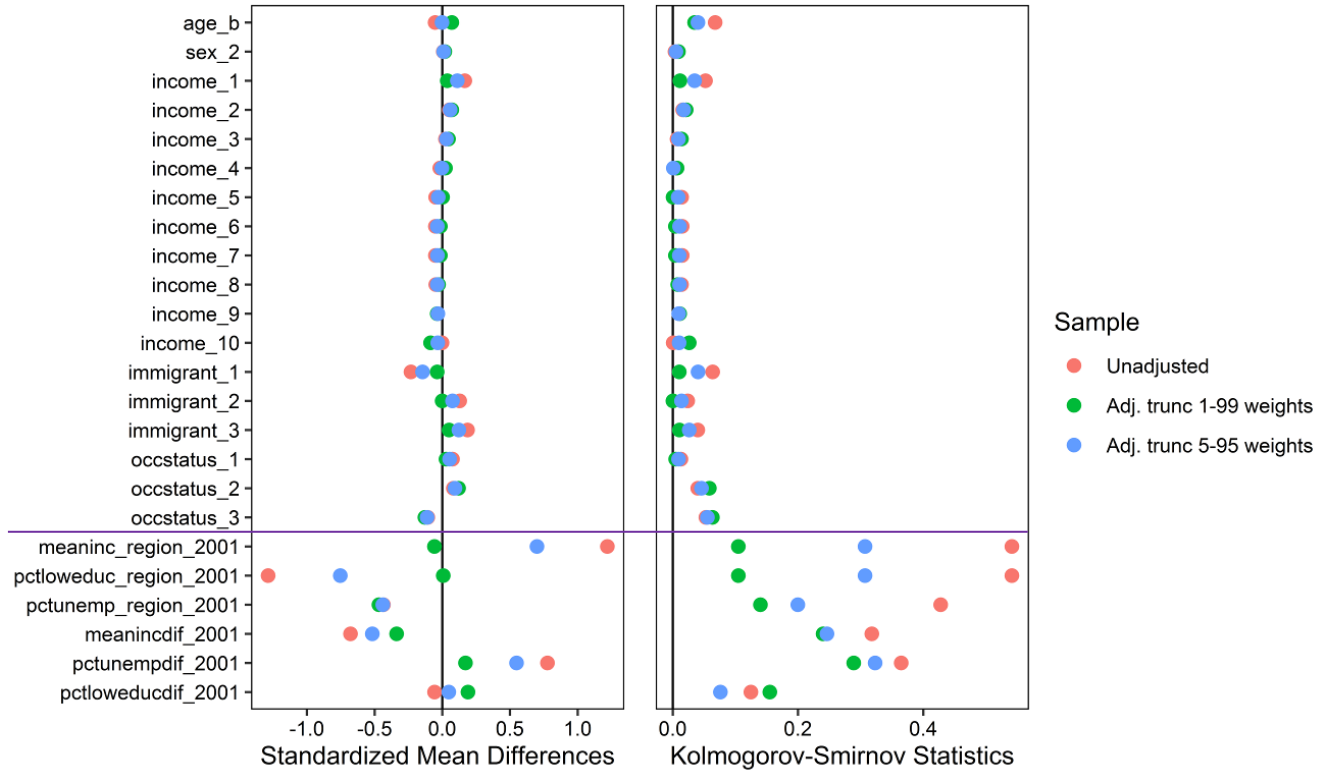


B Norwegian cohort - individual covariates above and area-level covariates below the horizontal line

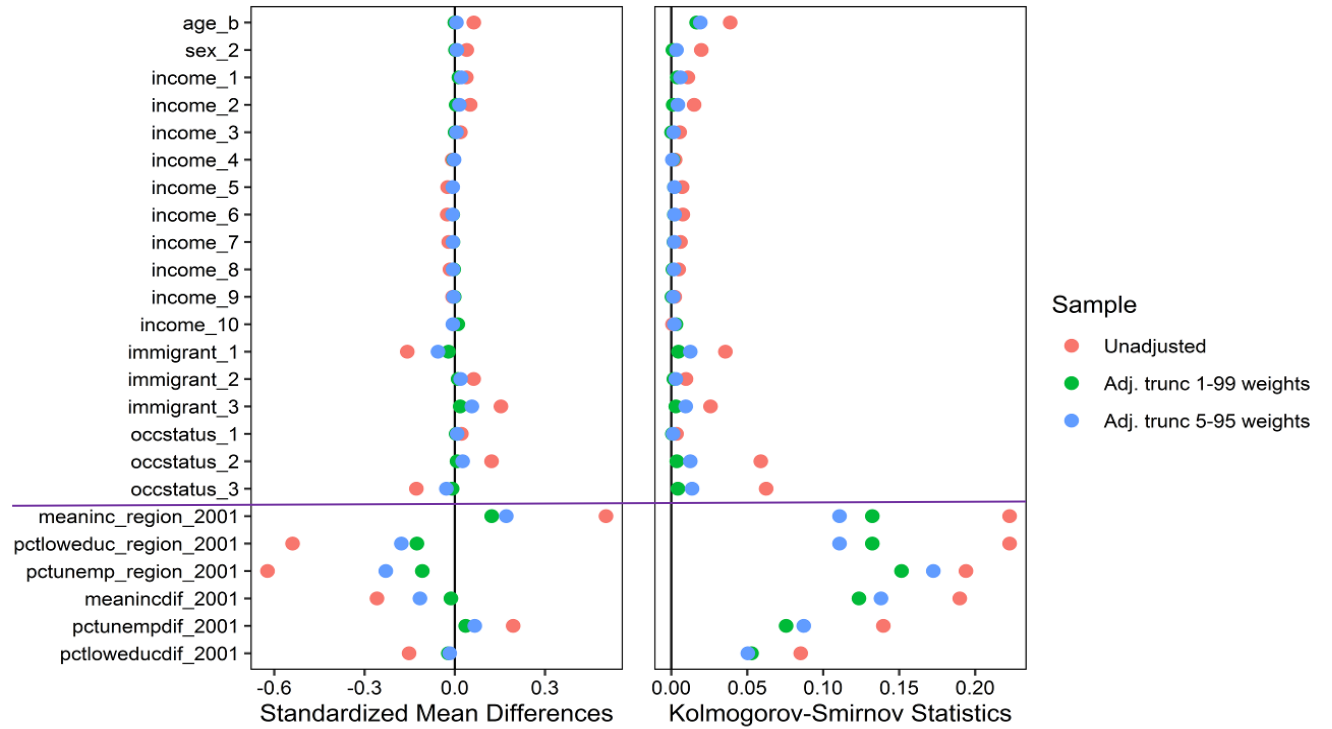


C Danish cohort - individual covariates above and area-level covariates below the horizontal line

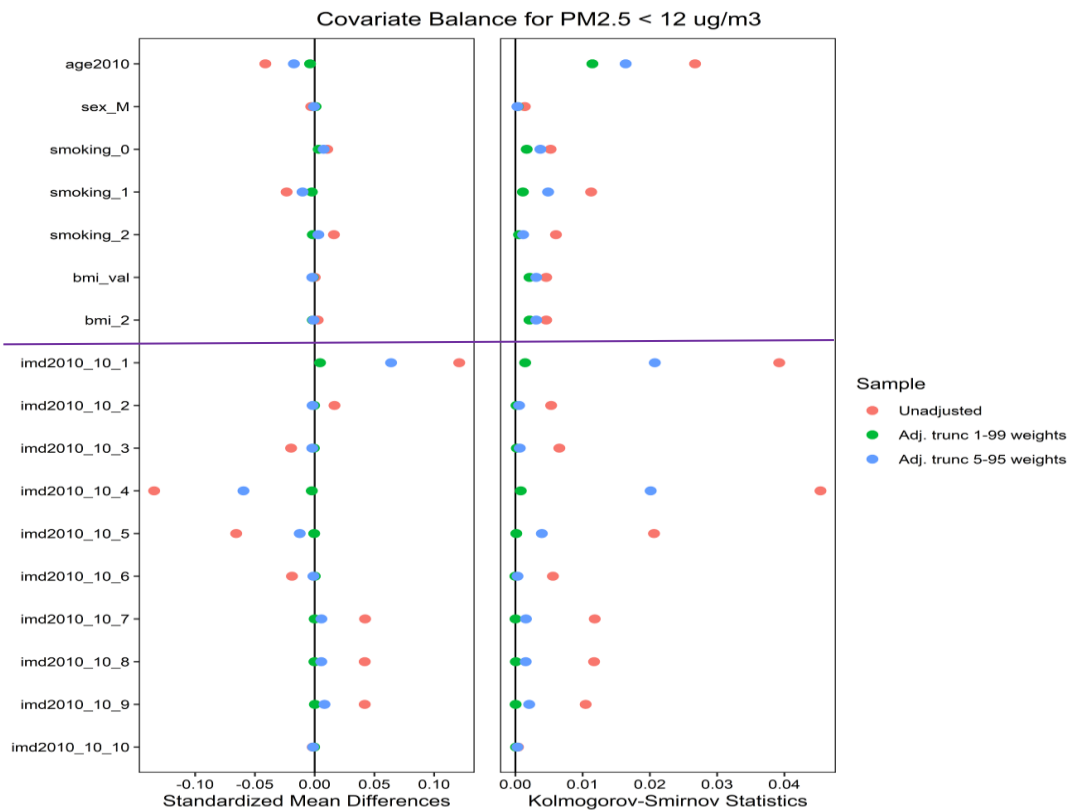
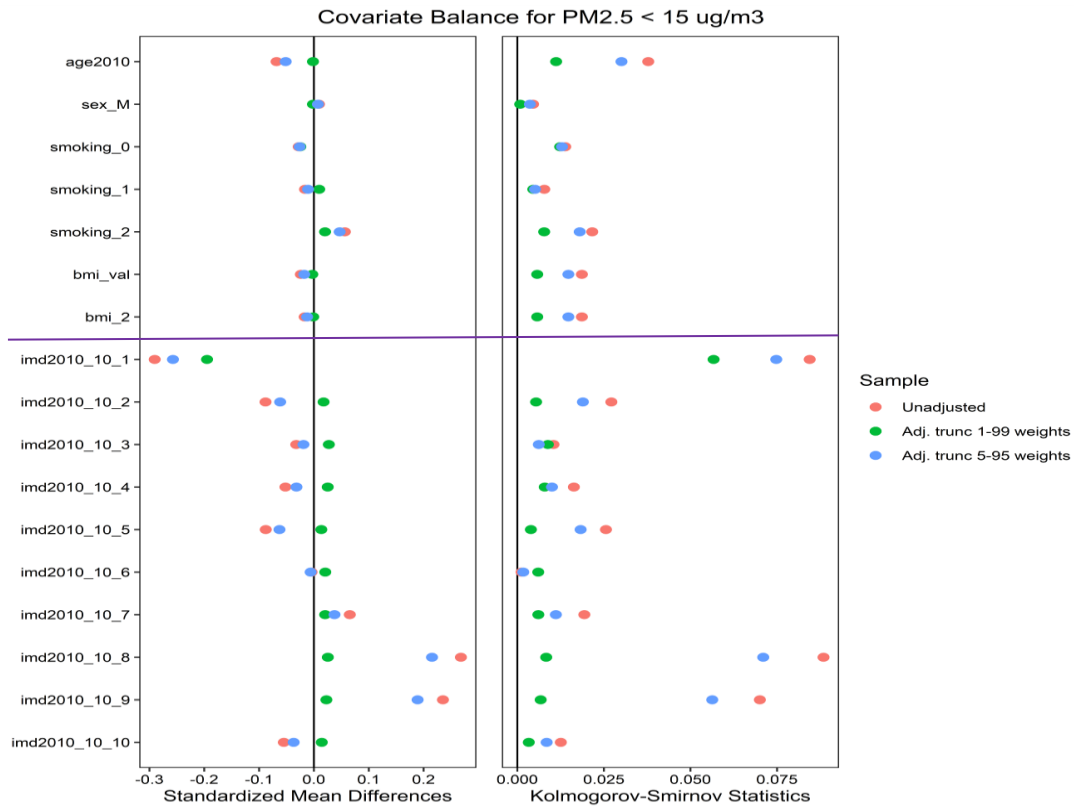
Covariate Balance for PM2.5 < 15 ug/m3



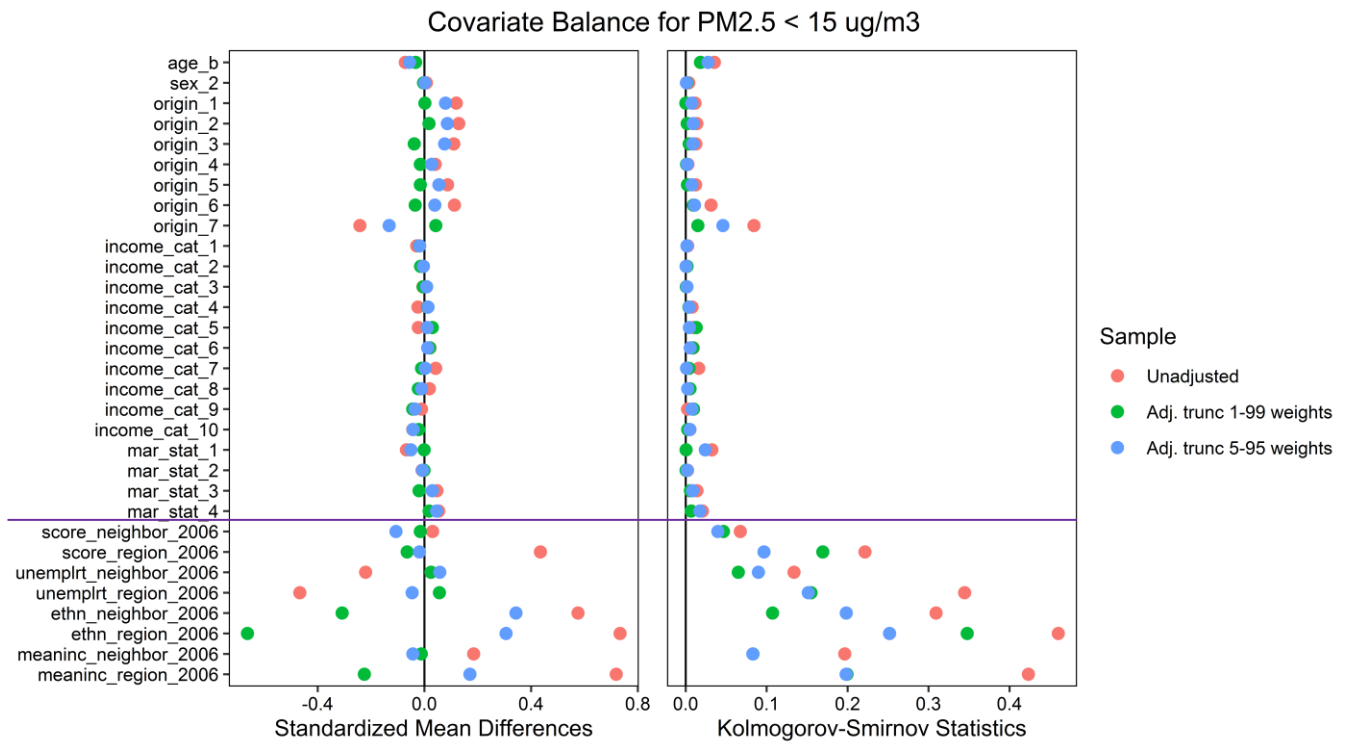
Covariate Balance for PM2.5 < 12 ug/m3



D English cohort - individual covariates above and area-level covariates below the horizontal line



E Dutch cohort - individual covariates above and area-level covariates below the horizontal line



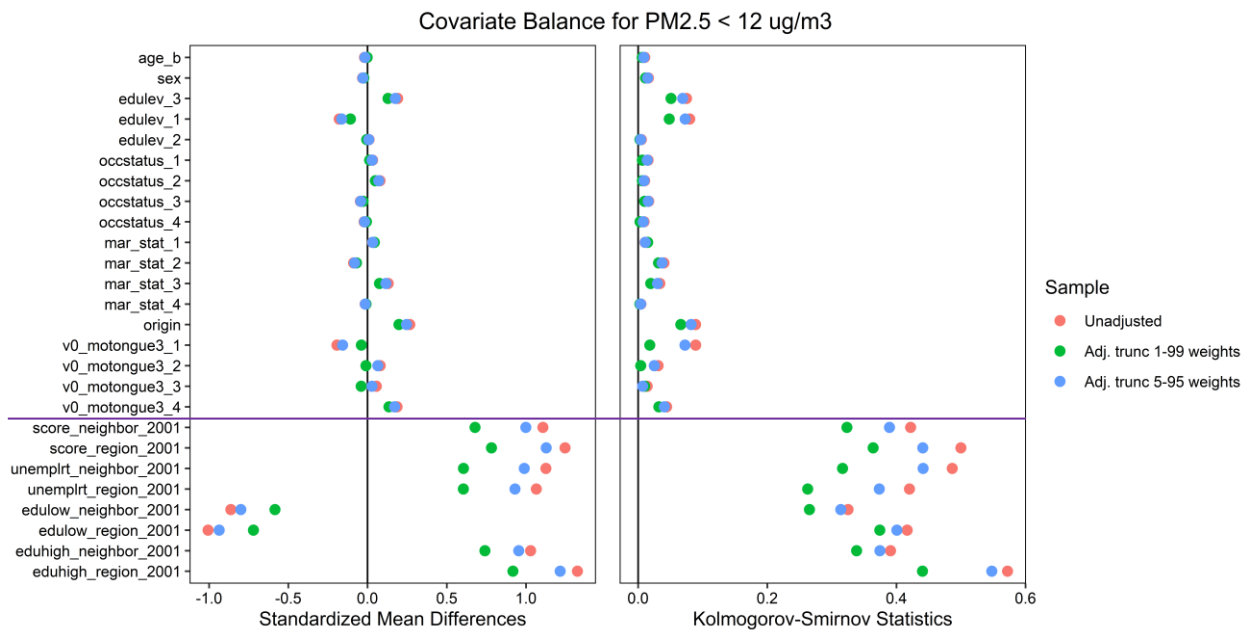
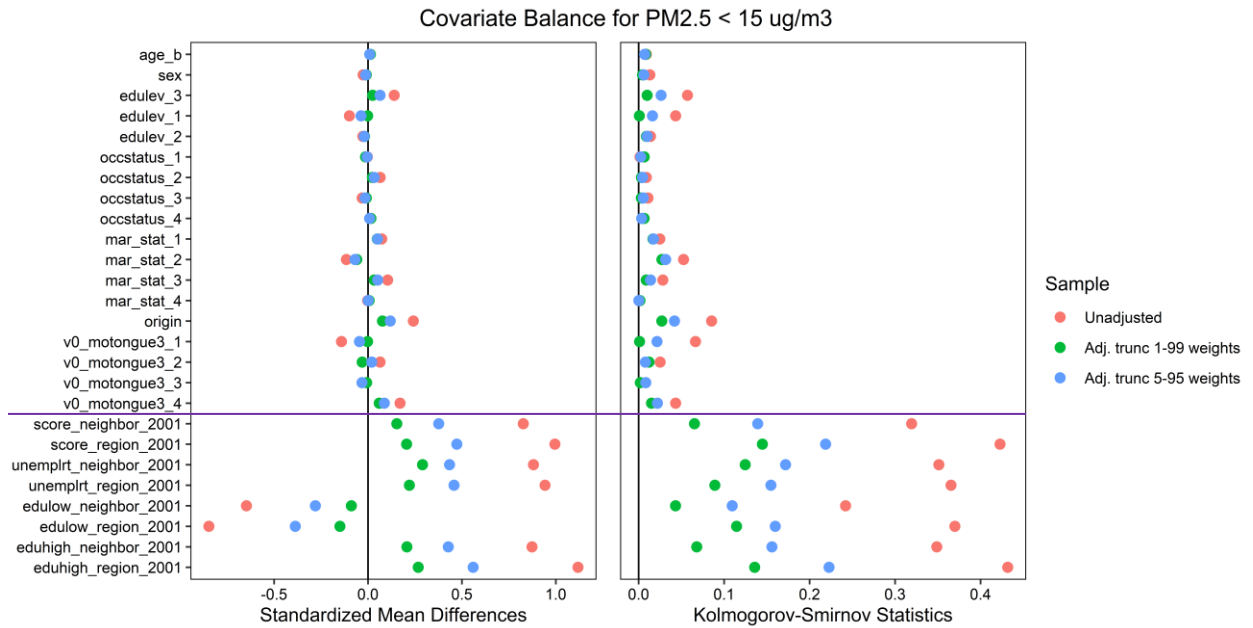
PM_{2.5} < 12 µg/m³: not enough data

F Belgian cohort

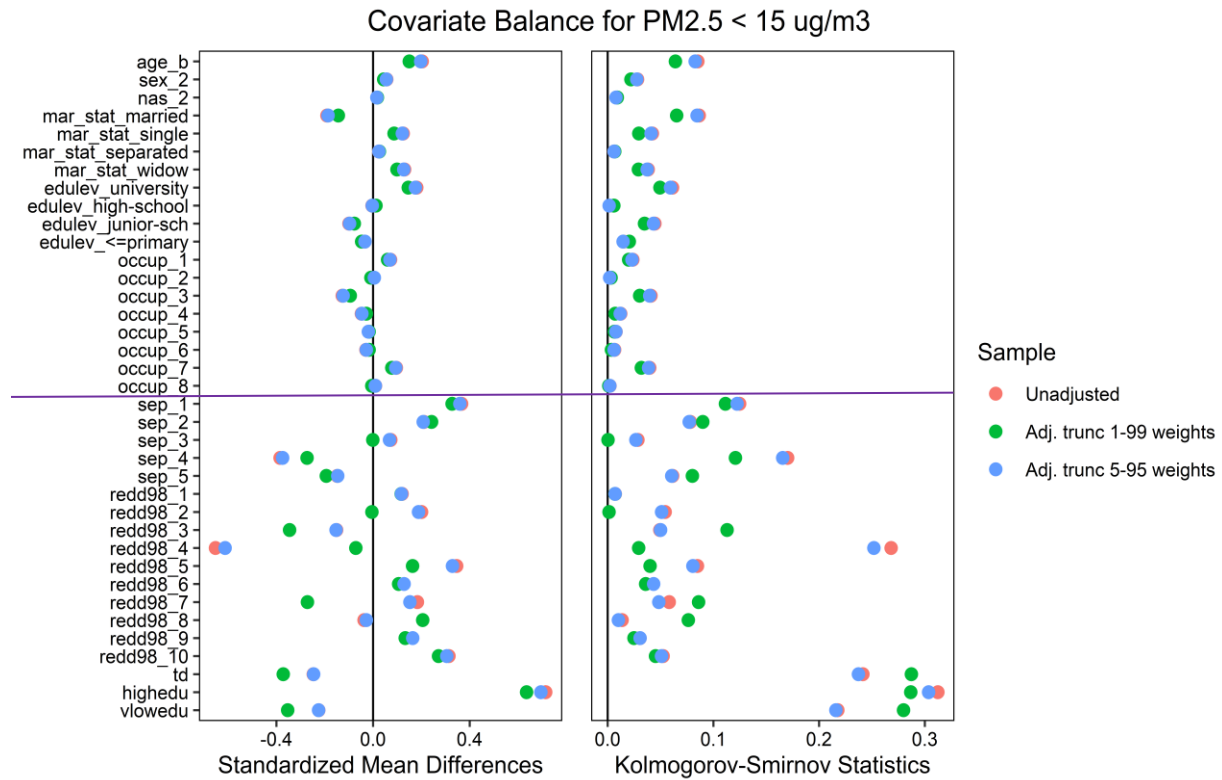
$PM_{2.5} < 15 \mu\text{g}/\text{m}^3$: not enough data

$PM_{2.5} < 12 \mu\text{g}/\text{m}^3$: not enough data

G Swiss cohort - individual covariates above and area-level covariates below the horizontal line



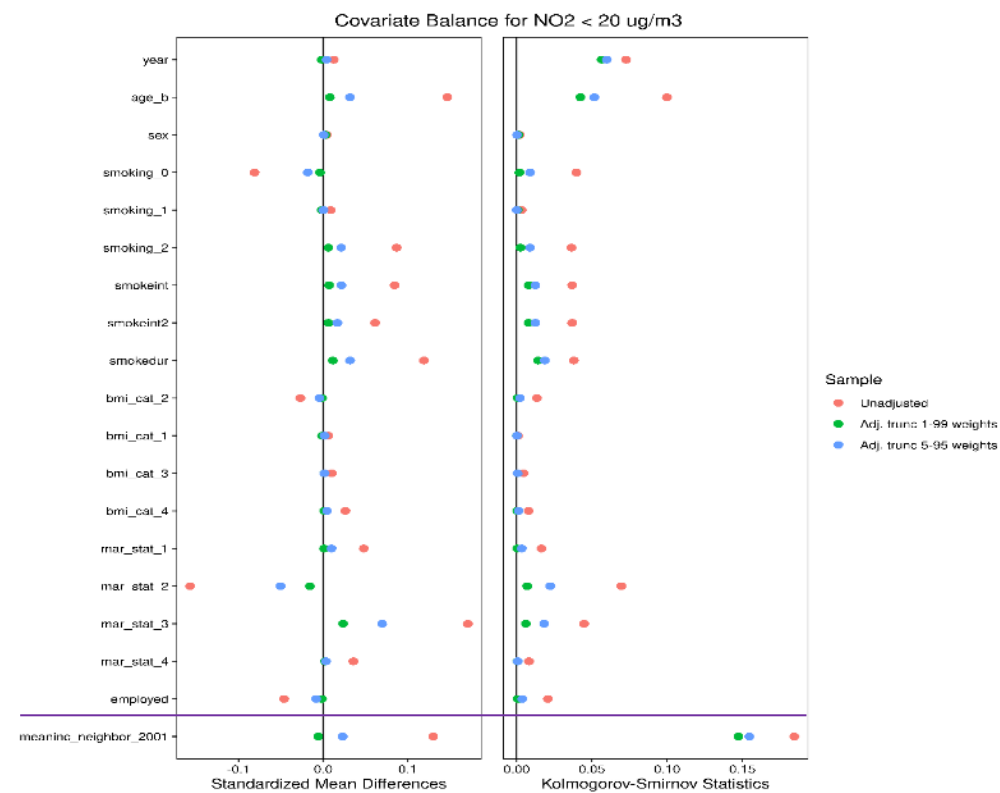
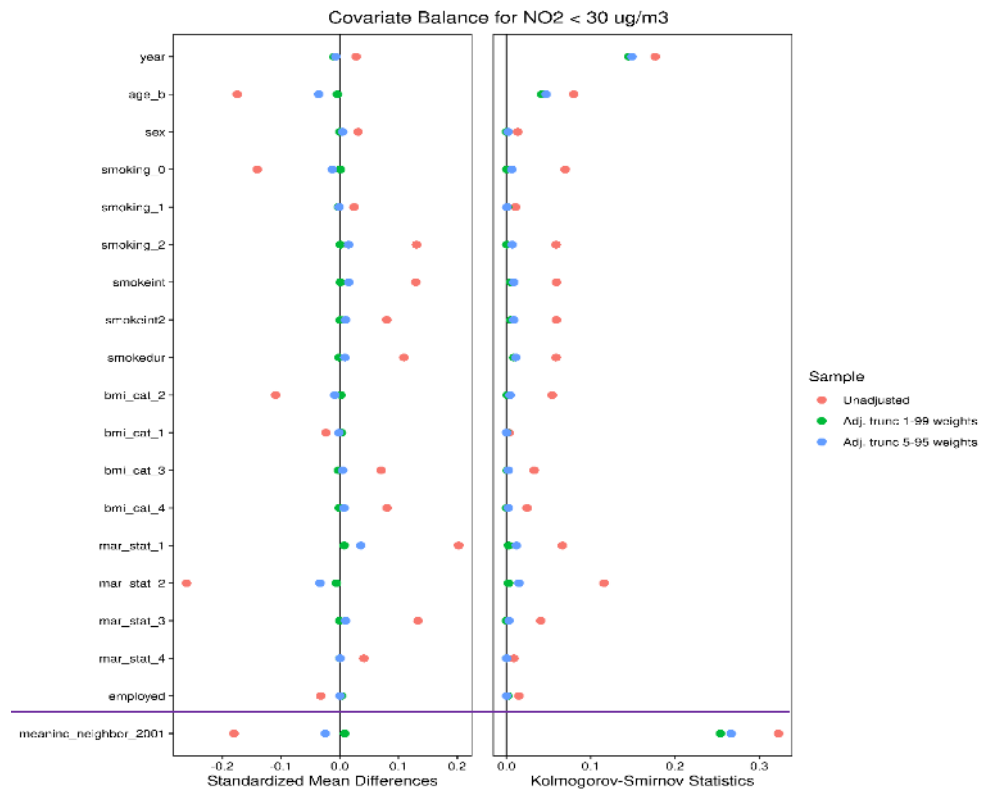
H Rome cohort - individual covariates above and area-level covariates below the horizontal line



PM_{2.5} < 12 µg/m³: not enough data

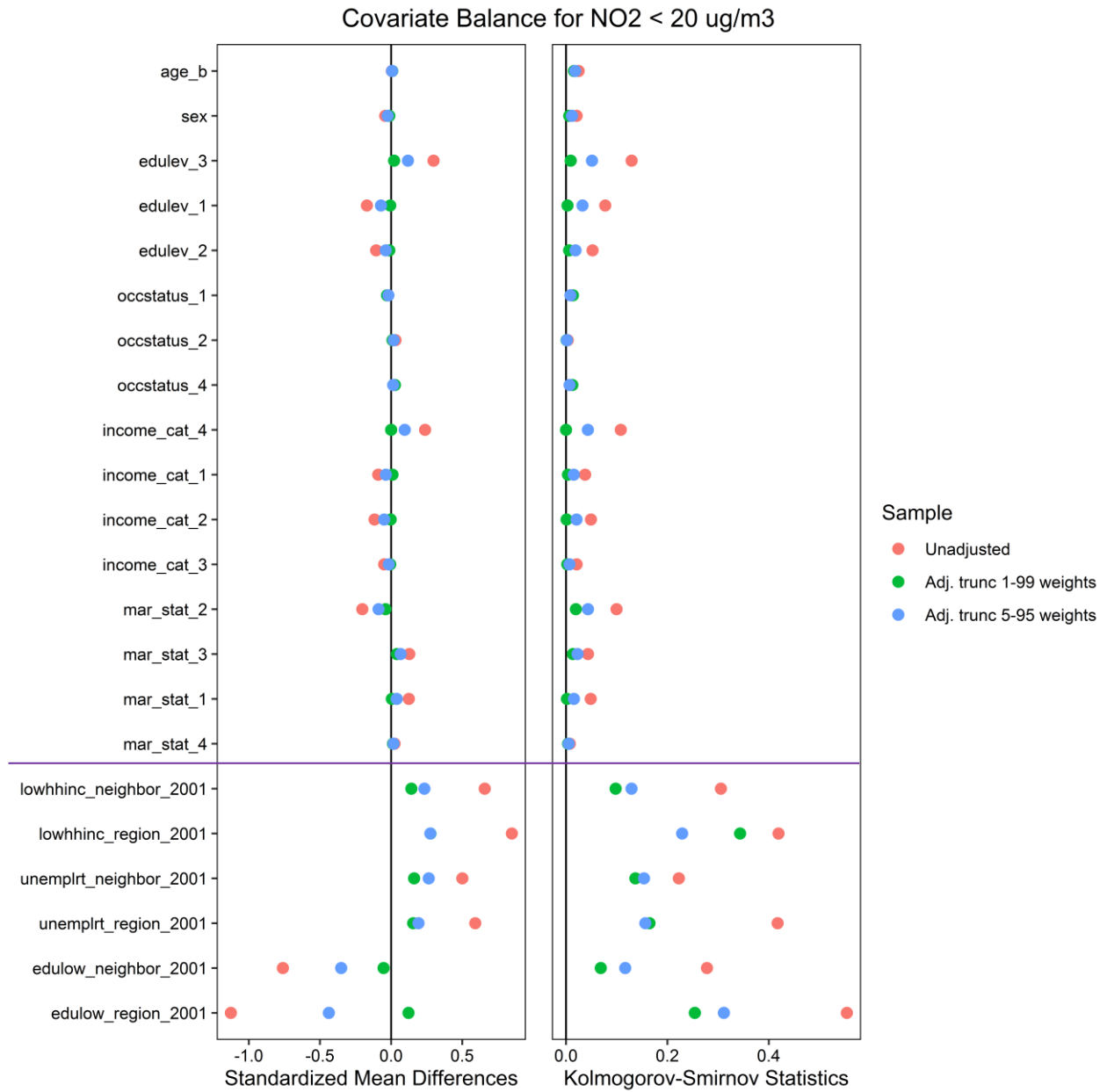
Figure S5: Covariates balance plots for NO₂ by cohort

A Pooled cohort - individual covariates above and area-level covariates below the horizontal line



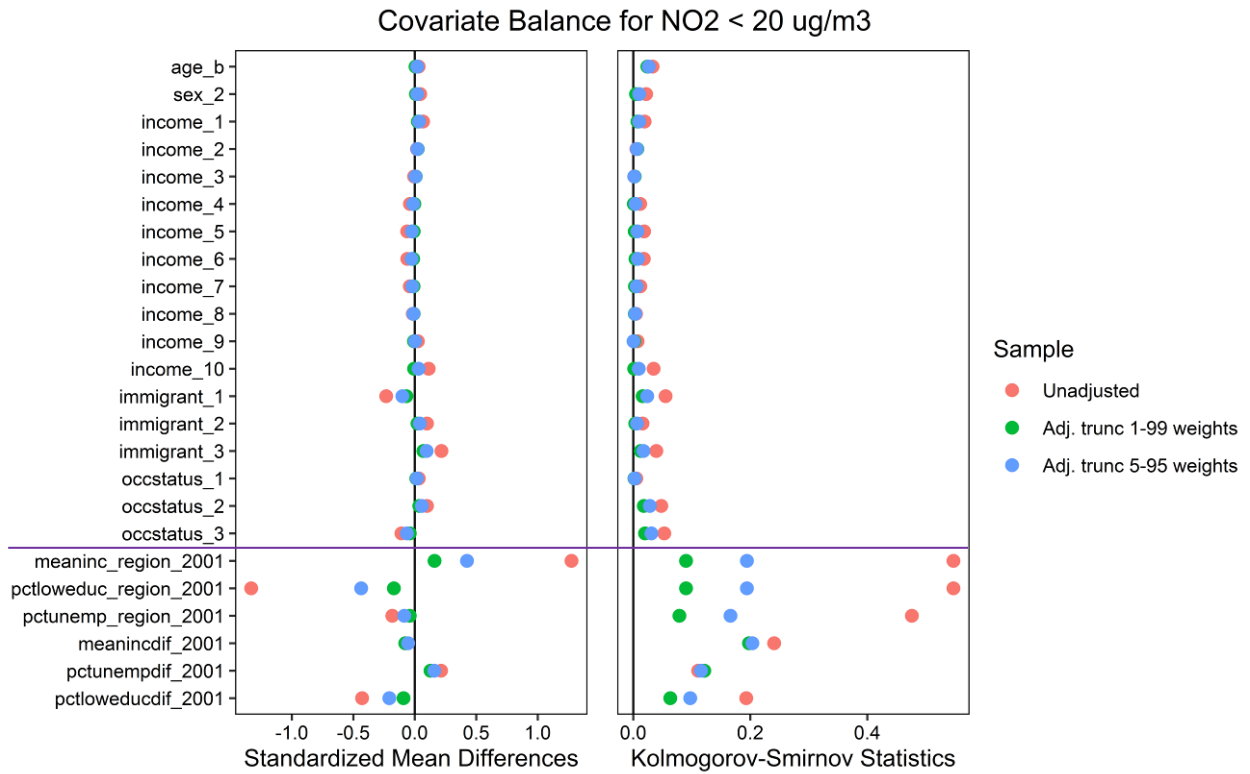
B Norwegian cohort - individual covariates above and area-level covariates below the horizontal line

NO₂ < 40 µg/m³: not enough data



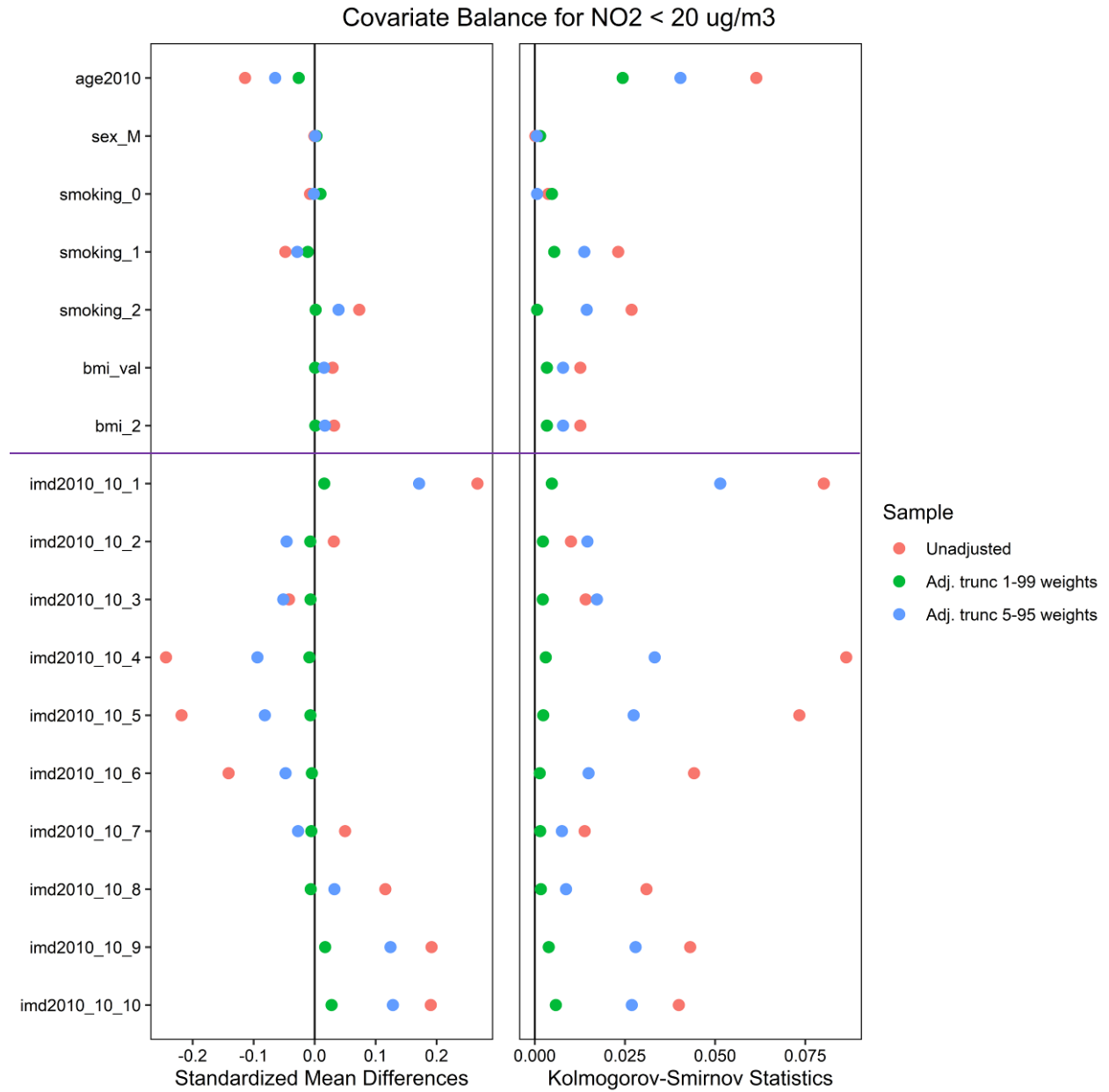
C Danish cohort - individual covariates above and area-level covariates below the horizontal line

NO₂ < 40 µg/m³: not enough data

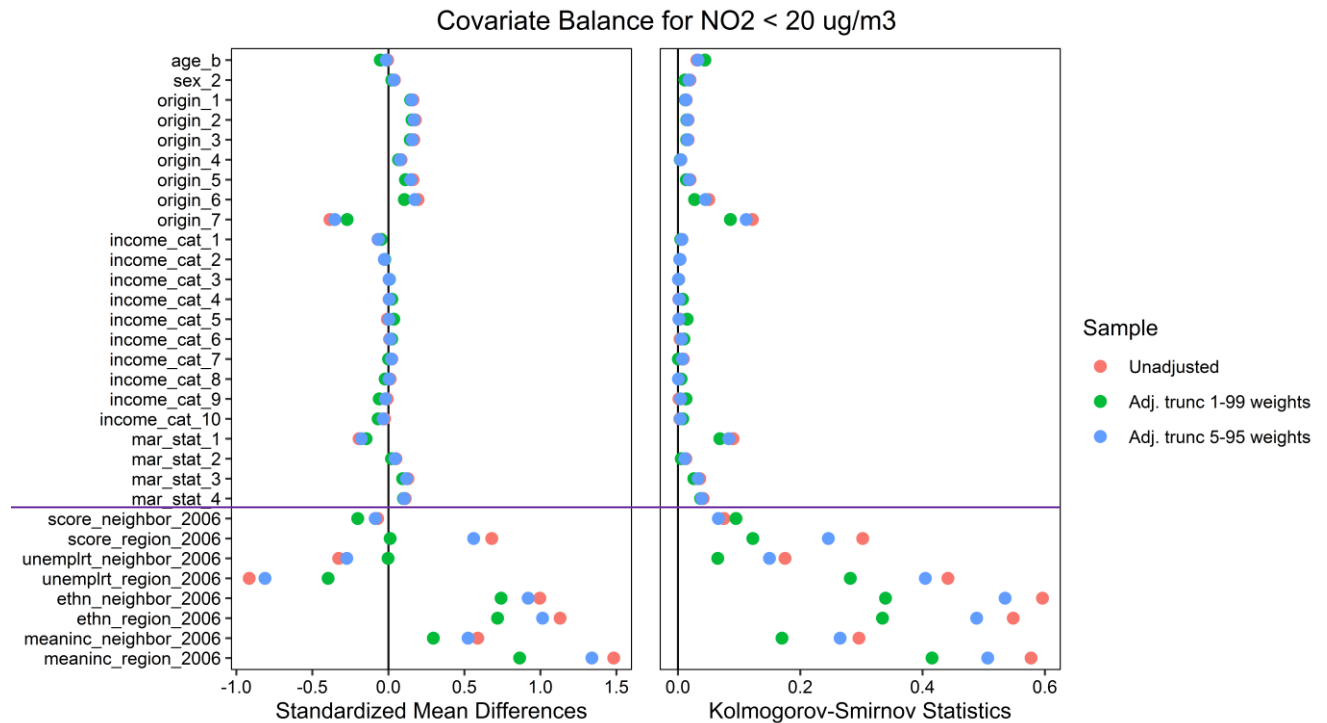
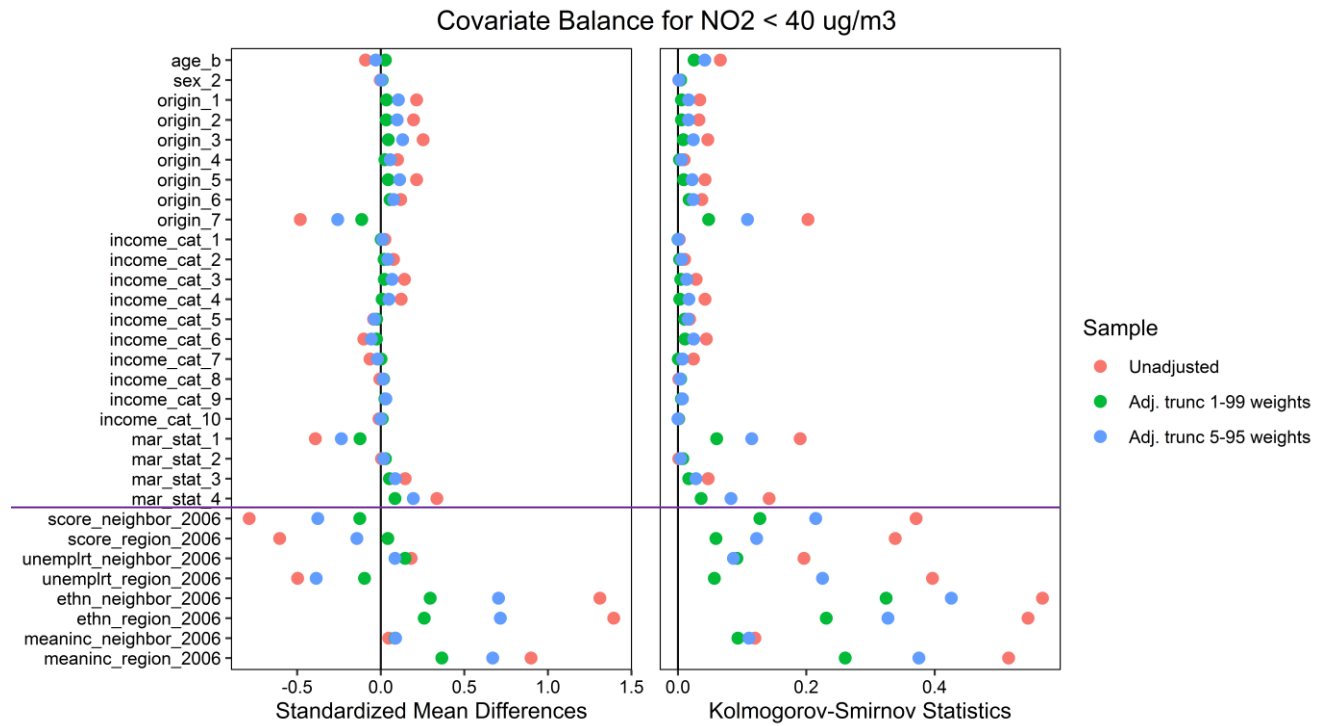


D English cohort - individual covariates above and area-level covariates below the horizontal line

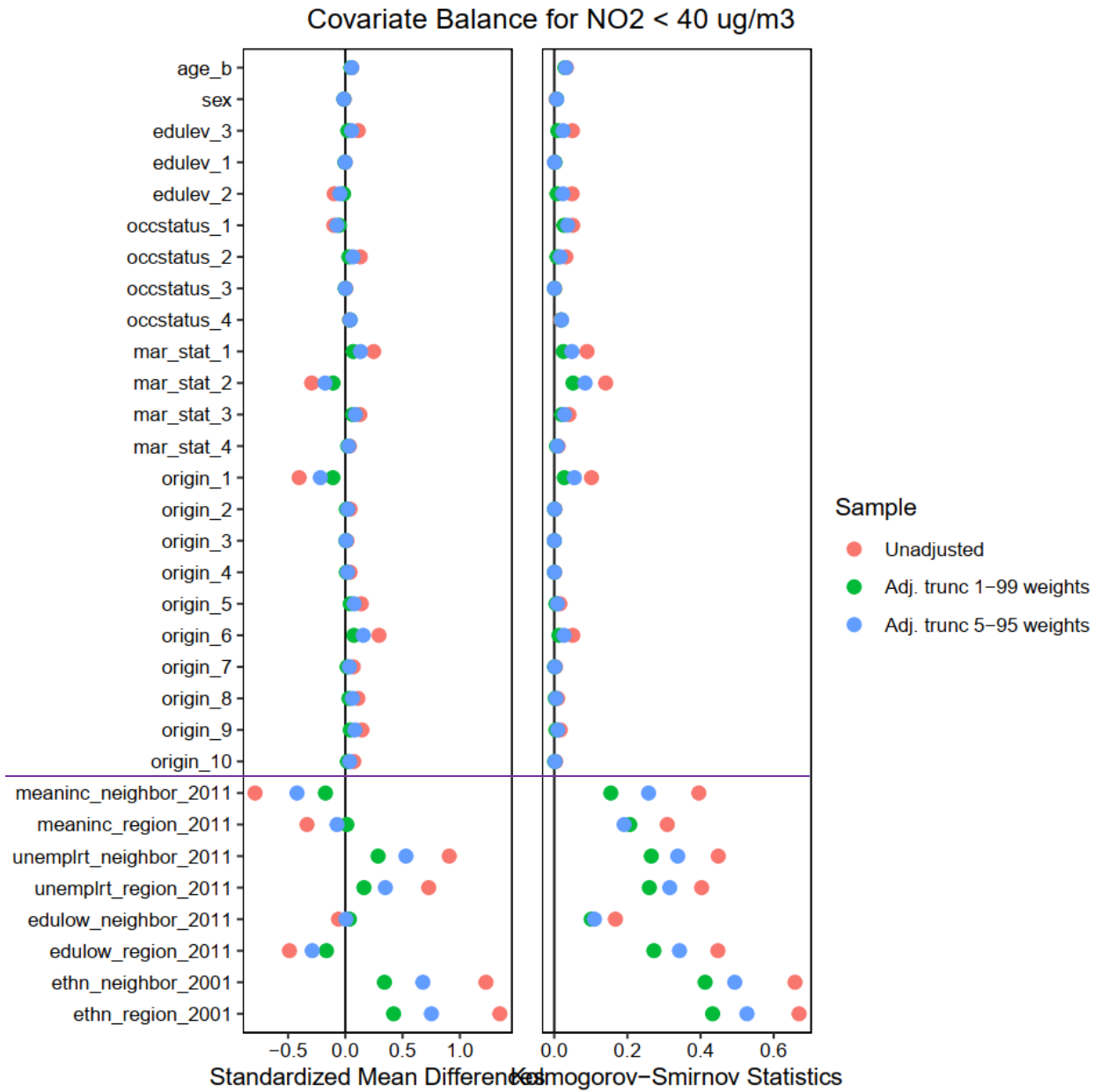
NO₂ < 40 µg/m³: not enough data



E Dutch cohort - individual covariates above and area-level covariates below the horizontal line



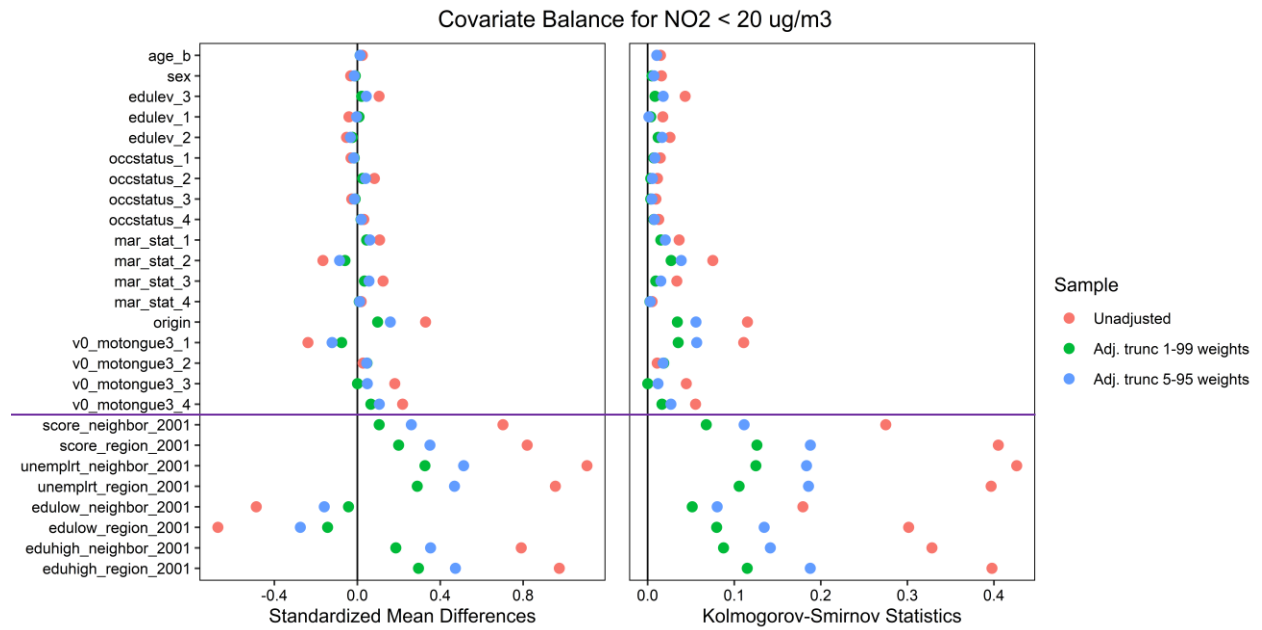
F Belgian cohort - individual covariates above and area-level covariates below the horizontal line



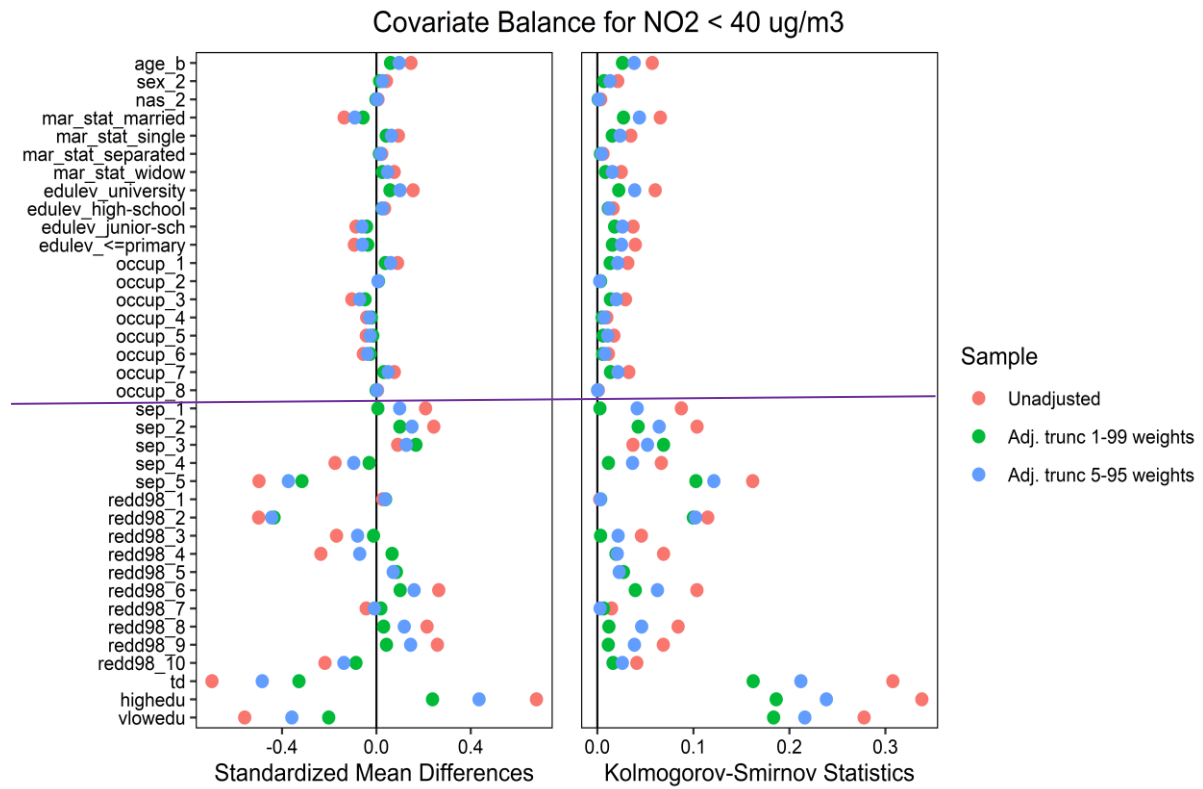
NO₂ < 20 µg/m³: not enough data

G Swiss cohort - individual covariates above and area-level covariates below the horizontal line

NO₂ < 40 µg/m³: not enough data



H Rome cohort - individual covariates above and area-level covariates below the horizontal line



NO₂ < 20 µg/m³: not enough data

Figure S6: Cohort-specific and meta-analytical associations between air pollutants above vs below the given cut-off values and natural-cause mortality derived from IPW model with weights truncation at the 5th and 95th quantiles. The size of the squares is proportional to the cohort-specific weight in the random-effects meta-analysis. Diamonds are centred on the point estimate and extend to the 95% CIs.

