I
U
A
V

Università Iuav
di Venezia

How uncertainty of air emission inventories impacts policy decisions at sub-national level. A Shift-Share Analysis undertaken in Piedmont (Italy)

Alessandra La Notte
Stefania Tonin
Silvio Nocera

4th International Workshop on Uncertainty in Atmospheric Emissions

Content

- Introduction: uncertainty in GHG emissions and its relevance for policy analysis at local level
- The background: review of techniques to deal with uncertainty employing the use-chain model
- The application: implementation of the insurance-based approach (by Marland)
- The application: hybrid environmental-economic accounts
- The application: Shift-Share Analysis at regional-provincial level

Uncertainty, pollutant emissions and policy making at sub-national level

Emission inventories can be used for a wide variety of decision making purposes

(e.g. development of control strategies for reducing emissions; permit limit determination; emission statements for fee collection purposes; international treaty reporting requirements ;

compliance determination; exposure and risk analysis etc.)

Some of the specific questions that decision-makers may ask are:

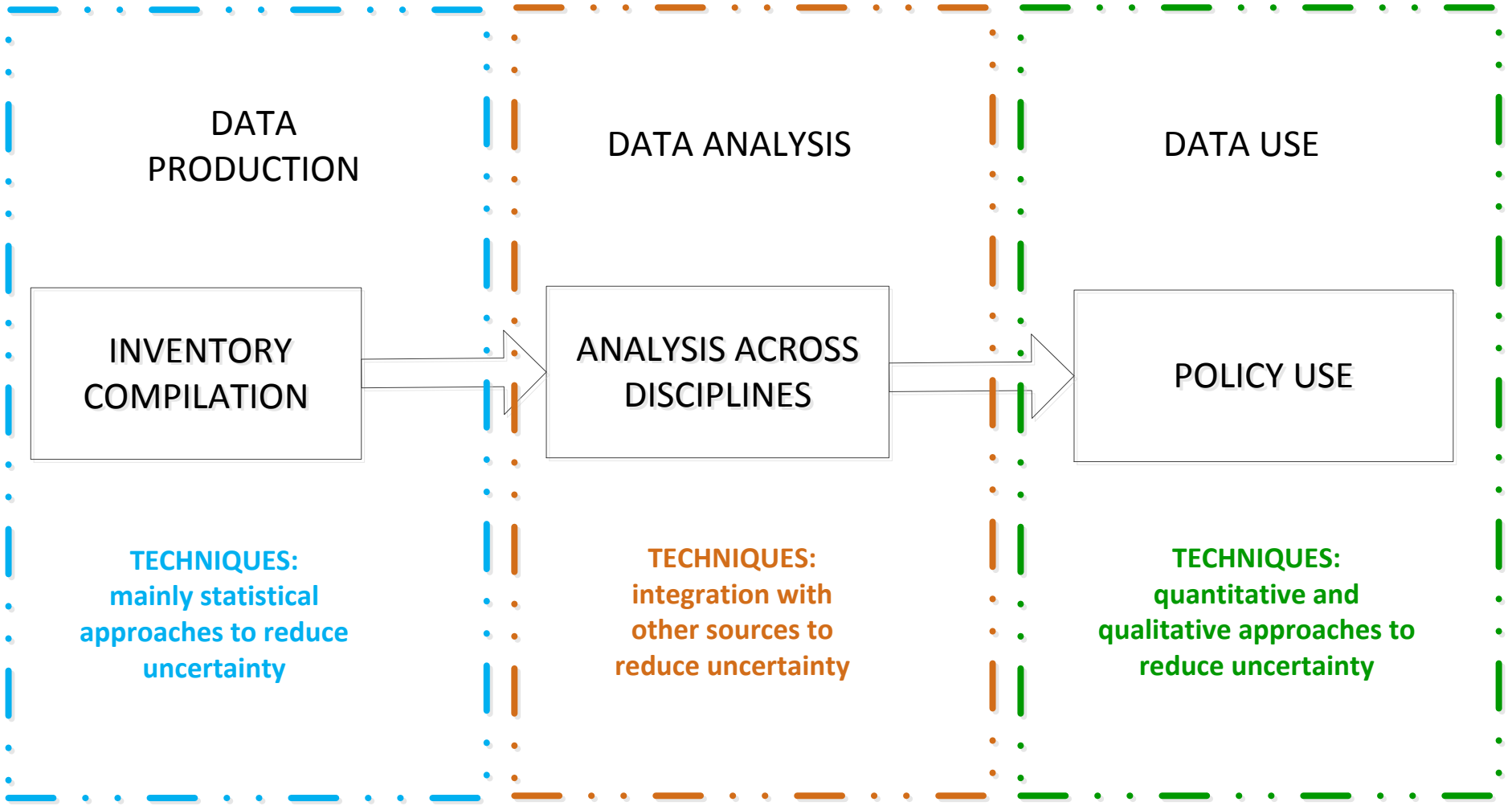
- How well do we know these numbers?
- What is the precision of the estimates?
- How significant are apparent trends over time?
- How effective are proposed control or management strategies?
- …

Background: the causes of uncertainty

Causes of uncertainty	IPCC proposed action to solve uncertainty	Characterization
Lack of knowledge	QA and QC should help avoid this	Scientific
Modelling approach	Statistical validation and expert judgment should help estimating model accuracy and precision	Estimation_model
Shortcomings of available data	Expert judgement can be used to make inference based on analogous data or theoretical consideration	Estimation_model
Lack of representativeness of data		
Insufficient precision	Statistical theory has to play a role in estimating confidence intervals based on variability in the data and sample size	Estimation_paramenter
Systematic errors	Statistics and expert judgment must provide insight about random components; QA/QC must provide insight about systematic components	Estimation_model
Misreporting and misclassification	QA and QC should help avoid this	Scientific and Estimation_model
Missing data	Statistical or judgment base approaches should help because of non-detected measurements or other type of missing data	Estimation_paramenter

Source: adapted from IPCC (2006)

Background: a model to sort the ways to deal with uncertainty



We call it *use –chain model*

Background: uncertainty addressed in different disciplines

Causes of uncertainty	Input from other literature	Data use-chain feature
Lack of completeness	From producer-based to consumer-based perspective (Caro et al. 2015)	Data use in policy analysis
Modeling approaches	Probability space and equitability constraints (Rodwell et al. 2010)	Data production
	Spatial (correlation) analysis and time series analysis (Smith et al. 2013)	Data production
Shortcomings of available data - - - Lack of representativeness of data	Bayesian approach with informative prior information (Cook 2013)	Data production
	Stratified sample (Moutopoulos and Koutsikopoulos 2014)	Data production
	Adding variable to the model (Punt et al. 2015)	Data production and Data analysis
	Validation methods: measures VS estimates (Mensink 2000)	Data analysis
Insufficient precision - - - Systematic errors	Target random sampling (Pinto et al. 2014)	Data production
	Count regression models considering other socio-economic indicators (Son et al. 2013)	Data analysis
	Uncertainty study to find out which are the missing variables to be introduced in sampling procedure and models (Hedley et al. 2012; Prechtel et al. 2009	Data production
Misreporting and misclassification	Resample simulation (Moe et al. 2015)	Data production
Missing data	Bayesian approach with informative prior information (Cook 2013)	Data production
	Stratified sample (Moutopoulos and Koutsikopoulos 2014)	Data production
	Adding variable to the model (Punt et al. 2015)	Data production and Data analysis
	Participatory approach (Legay et al. 2015)	Data use in policy analysis

Background: uncertainty addressed in emissions inventories

Causes of uncertainty	Input from the GHG specific literature	Data use-chain feature
Lack of knowledge	Need for participatory approaches (Nijnik and Pajot, 2014)	Data use in policy analysis
	Decomposition analysis (Rafaj et al. 2014)	Data analysis and data use in policy analysis
Modeling approach	(no case studies)	
Shortcomings of available data - - - Lack of representativeness of data	Moving from production-based method (Tier 1) to the combination of production-based and mass balance methods (Tier 2) (Uvarova et al. 2014)	Data production
	Spatial inventory approach (Bun et al. 2010)	Data production
	Cadastre of GHG emissions (Boychuk and Bun 2014)	Data production Data analysis
	Spatial inventory approach (Pugliafito et al. 2015)	Data production
	Fuzzy inference system to solve map overlay (Verstraete 2014)	Data production
	Conditional autoregressive model (Horabik and Nahorski, 2010)	Data production
	Maximum likelihood approach to inference (Horabik and Nahorski, 2014)	Data production
	Insurance approach (Marland et al. 2014)	Data production and use in policy analysis
Insufficient precision - - - Systematic errors	Prior probability distribution and Bayesian calibration(van Oijen and Thomson 2010)	Data production
	Bottom-up/top-down accounting exercise (Gusti and Jonas 2010)	Data production
	Bottom-up/top-down using inverse modelling (Bergamaschi et al. 2015)	Data production
	Bottom-up/top-down using inverse modelling (Zhang et al. 2015)	Data production
	Bottom-up/top-down using atmospheric measurements (Fairly et al. 2015)	Data production
Misreporting and misclassification	Comparison of different input data for the same variable (Ometto et al., 2014)	Data production
Missing data	Remote sensing input (Verstraeten et al. 2010)	Data production
	Maximum likelihood approach to inference (Horabik and Nahorski, 2014)	Data production

Application: steps

- Data collection: Piedmont region emission inventory (EMEP-CORINAIR)
- Uncertainty calculation for each activity and pollutant through the *insurance approach*
- Comparison between data w/o uncertainty and data with uncertainty
- Hybrid environmental-economic accounts
- Shift-share application based on the number of employees

Application: the insurance approach (by Marland et al. 2014)

- An analogy is made between the pricing of life insurance and the pricing of carbon emissions
- The insurance industry adds into their fees to cover the net present value of expected payouts an additional charge, i.e the risk charge (*insurance for the insurer*)
- The risk charge takes into account basic variability in the data and also the probability of rare events that might influence their costs
- The proposal is to add a risk charge to the emissions estimates, based on levels of estimated error and uncertainty in the calculations and measurements

Data comparison (2 examples)

Biella _ secondary sector

	MODULO AMBIENTALE									
	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
REG	107,657.17	6,089.22	15,564.02	27,109.20	2,276.79	1,209.42	21,830.46	785.44	558.87	8,281.56
REGinc	203,505.17	9,375.98	23,672.21	46,169.05	3,001.98	2,103.48	30,070.71	1,129.72	832.51	11,996.89
PROV	2,959.16	73.29	177.06	255.45	6.29	81.35	364.90	32.50	21.31	232.42
PROVinc	5,652.81	115.20	301.58	471.16	11.10	134.85	565.19	56.71	35.70	416.51

Biella _ transport

	MODULO AMBIENTALE									
	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
REG	288.00	11,215.42	3,902.60	2,518.18	121.09	31.99	29,859.36	4,692.40	1,460.87	48.97
REGinc	488.11	19,219.08	6,628.90	4,302.59	207.52	54.28	50,369.42	8,155.40	2,485.63	86.29
PROV	7.57	363.96	121.45	77.90	3.38	1.08	846.34	169.55	45.21	0.77
PROVinc	12.86	626.26	207.63	133.04	5.79	1.85	1,437.20	295.62	77.29	1.32

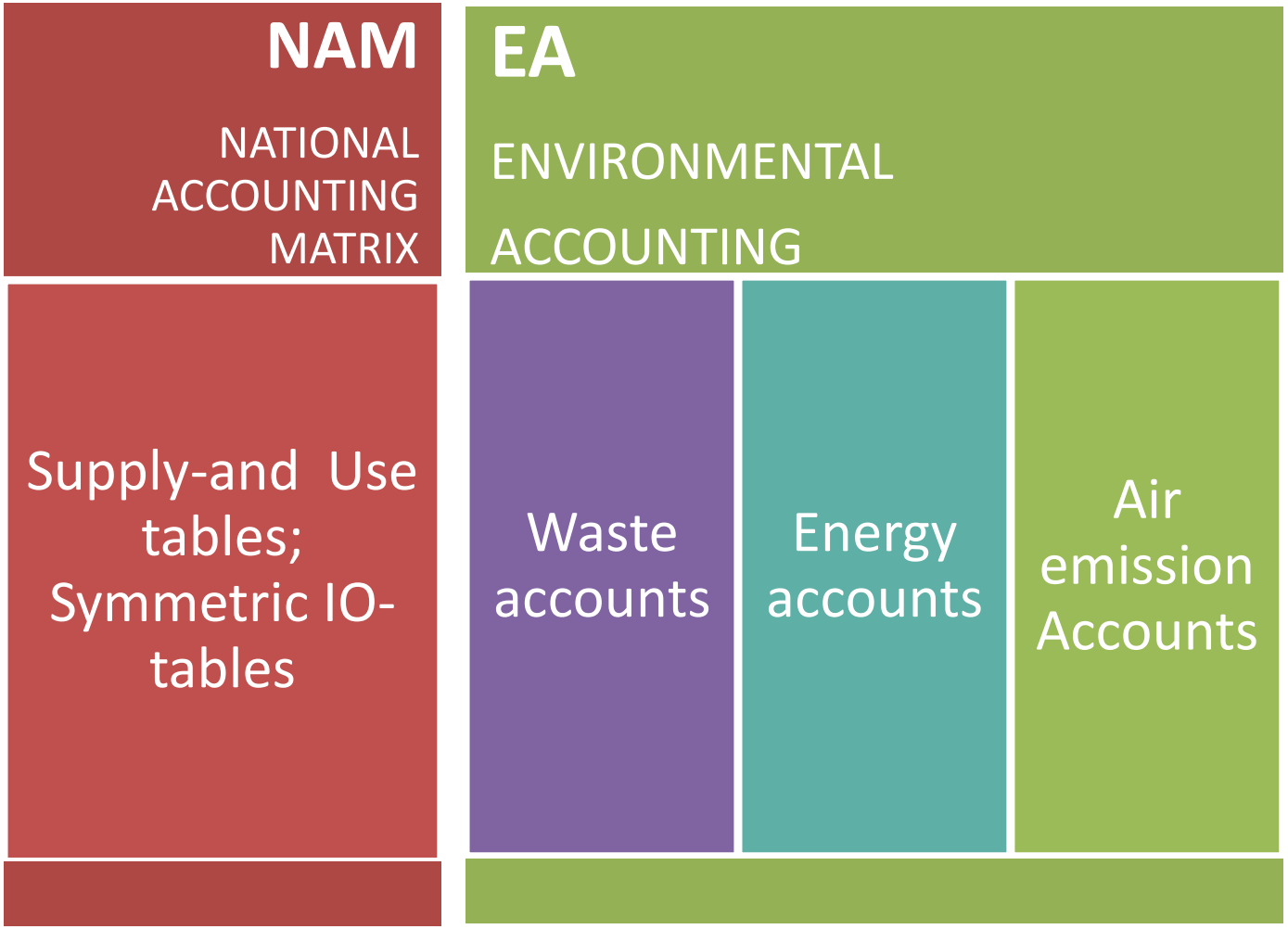
Cuneo _ secondary sector

	MODULO AMBIENTALE									
	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
REG	107,657.17	6,089.22	15,564.02	27,109.20	2,276.79	1,209.42	21,830.46	785.44	558.87	8,281.56
REGinc	203,505.17	9,375.98	23,672.21	46,169.05	3,001.98	2,103.48	30,070.71	1,129.72	832.51	11,996.89
PROV	17,488.18	1,649.34	2,242.85	3,142.84	19.52	250.75	4,279.30	229.83	129.88	674.77
PROVinc	33,236.16	2,513.53	3,524.60	5,432.17	34.82	433.80	5,869.04	292.17	174.84	1,123.86

Cuneo _ transport

	MODULO AMBIENTALE									
	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
REG	288.00	11,215.42	3,902.60	2,518.18	121.09	31.99	29,859.36	4,692.40	1,460.87	48.97
REGinc	488.11	19,219.08	6,628.90	4,302.59	207.52	54.28	50,369.42	8,155.40	2,485.63	86.29
PROV	29.62	1,372.39	476.15	303.21	14.06	4.18	3,516.55	742.89	177.95	4.47
PROVinc	50.01	2,352.83	809.59	517.19	24.04	7.10	5,940.04	1,294.98	302.91	7.79

Application: Hybrid environmental-economic accounts



Application: Hybrid accounting table W/O uncertainty

Economic activities	LU	Empl	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
Mining and quarrying	275	2,004.13	0.0008	0.0220	5.7544	0.0055	0.0009		0.0818			0.008
Manufacture of food, beverage and tobacco	4,743	38,266.79		8.8806	10.6732	4,941.4576		0.6240	112.1225	16.6592	0.0272	0.032
Manufacture of textiles, wearing apparel and leather and related products	3,232	33,844.48		4.7660		3.3490			2.6010	1.0110	1.0110	
Manufacture of wood, forniture, paper and printing	5,656	29,483.32		87.5036	460.1803	5,640.3506		16.4120	674.9306	102.3739	94.8597	14.252
Manufacture of coke and refined petroleum products	33	1,340.20		63.50	339.40	339.40		0.41	721.85	31.36	7.81	1,624.3
Manufacture of chemicals and chemical products	472	10,539.51	613.03	63.38	158.83	2,584.6380	1,822.00		538.8470	25.5517	20.5918	1,276.3
Manufacture of pharmaceutical products and preparations	42	2,425.55				76.09		0.5220	40.6170	1.9335	0.0383	0.019
Manufacture of rubber and plastic products	1,219	24,704.26		35.1330	5.7681	583.5920			39.6801	118.4936	46.1986	0.033
Manufacture of other non-metallic mineral products	1,611	13,388.79	13.4002	488.1807	1,225.9971	37.8998	12.4742	32.7400	3,771.5454	145.0778	81.8064	1,113.762
Manufacture of basic metals	418	11,297.82	13.0398	1,190.9268	119.1692	721.7481	2.2027	21.1190	453.7585	68.7973	45.3887	144.772
Manufacture, repair and installation of fabricated metal products, electrical equipment and general machinery	20,166	160,725.33		162.1915	16.9416	6,206.1107		13.90	269.0180	12.3944	0.6402	0.097
Manufacture of motor vehicles, trailers, semi-trailers and other transport equipment	955	66,115.68		6.2424	23.9627	1,790.7130			65.9717	2.2648	1.3648	0.137
Electricity, gas, steam and air conditioning supply	730	7,552.80	44,167.6151	3,737.9668	12,907.1745	2,377.8111	150.2181	5.6103	13,519.3831	212.8150	194.6742	3,934.841
Water supply; sewerage; waste managment and remediation activities	1,002	13,695.46	62,850.0822	239.7600	257.0502	260.7284	289.8944	1,118.0844	1,528.8666	46.5445	46.4645	172.787
Construction, civing engineering and specialised construction activities	56,609	139,987.93		0.7635	33.1214	1,545.3064			91.1866	0.1643	0.0384	0.190
Transporting	9,020	44,901.87	288.0032	11,215.4236	3,902.5995	2,518.1815	121.0870	31.9872	29,859.3566	4,692.4029	1,460.8692	48.971
Total	106,183	600,273.92	107,945.1711	17,304.6404	19,466.6221	29,627.3816	2,397.8774	1,241.4089	51,689.8166	5,477.8440	2,001.7830	8,330.527

Application: Hybrid accounting table with uncertainty

Economic activities	LU	Empl	CH4	CO	CO2	COV	N20	NH3	NOx	PM10	PM2.5	SO2
Mining and quarrying	275	2,004.13	0.0014	0.0404	7.8260	0.0102	0.0016		0.1506			0.016
Manufacture of food, beverage and tobacco	4,743	38,266.79		12.0776	12.7713	9,147.5455		0.9984	152.4874	23.6882	0.0413	0.032
Manufacture of textiles, wearing apparel and leather and related products	3,232	33,844.48		4.7660		3.3532			2.6010	1.0110	1.0110	
Manufacture of wood, forniture, paper and printing	5,656	29,483.32		107.8551	846.7317	8,309.1926		19.8192	809.7221	147.9096	138.3646	16.784
Manufacture of coke and refined petroleum products	33	1,340.20		86.36	461.58	864.01		0.56	981.72	42.65	10.62	2,209.0
Manufacture of chemicals and chemical products	472	10,539.51	1,127.98	116.12	216.01	4,715.6102	2,186.40		686.3544	31.4193	24.4493	1,735.7
Manufacture of pharmaceutical products and preparations	42	2,425.55				96.59		0.5240	40.6170	1.9375	1.9375	0.019
Manufacture of rubber and plastic products	1,219	24,704.26		35.1808	7.8446	731.1189			59.6770	120.4620	47.2950	0.045
Manufacture of other non-metallic mineral products	1,611	13,388.79	24.2227	579.0048	2,017.3725	52.3985	22.3950	44.5264	5,270.2375	242.5558	140.7229	1,954.335
Manufacture of basic metals	418	11,297.82	23.9932	1,961.9419	201.4366	1,019.4440	4.0530	21.3056	592.0223	89.1199	60.1430	235.833
Manufacture, repair and installation of metal products, electrical equipment, general machinery	20,166	160,725.33		217.0525	23.0406	10,948.8270		14.56	335.3826	15.6117	0.6824	0.132
Manufacture of motor vehicles, trailers, semi-trailers and other transport equipment	955	66,115.68		7.5792	32.5893	2,922.0143			89.7215	2.9705	1.8041	0.187
Electricity, gas, steam and air conditioning supply	730	7,552.80	81,240.2417	5,915.7067	19,394.4894	4,165.6619	262.2283	6.9870	18,553.2320	331.6509	302.3600	5,551.414
Water supply; sewerage; waste managment and remediation activities	1,002	13,695.46	121,088.7400	331.2557	405.4747	349.9071	526.8976	1,994.1991	2,372.7786	78.4817	78.3729	292.987
Construction, civing engineering and specialised construction activities	56,609	139,987.93		1.0384	45.0451	2,843.3724			124.0138	0.2521	0.2480	0.258
Transporting	9,020	44,901.87	488.1128	19,219.0817	6,628.9049	4,302.5943	207.5234	54.2801	50,369.4177	8,155.3981	2,485.6262	86.291
Total	106,183	600,273.92	203,993.2870	28,595.0616	30,301.1194	50,471.6461	3,209.4989	2,157.7598	80,440.1313	9,285.1178	3,293.6797	12,083.180

Application: the Shift-Share Analysis/1

- The basic rationale for decomposition analysis techniques is to spit an identity into its components

- Through SS analysis the role of economic activities can be isolated and the gap b/w emission efficiency in the different sectors explained at different administrative levels

Application: the Shift-Share Analysis/2

- The industry mix: describes how specialized the economic system is in some economic activities (when negative the indicator indicates that at the sub-hierarchical level the sectors that employs more workers are less polluting

- The productivity differential: compares the efficiency of a sub-hierarchical level with a superior one (economic activities pollute less than at a higher hierarchical level)

- The allocative component: presents the contribution of the sub-hierarchical levels to economic activity where the higher one shows a higher performance (the sub-hierarchical level is specialized in the economic activity that pollute less)

Industry mix effect	Differential effect	Allocative effect	Policy message
-	-	-	Optimal situation
+	+	+	Worse situation: environmental actions combined with sectoral actions
+	-	-	Sectoral actions to promote environmental friendly sectors; environmental efficiency to be developed in major sectors
-	+	-	Environmental policy to develop environmentally efficient technology in economic sectors
-	-	+	Not efficient combination of industry mix and differential effects. Further investigation on relative impacts
-	+	+	Environmental policy addressing sectoral innovation technology

Source: adapted from Bonazzi et al. 2008

Application: the policy matrix w/o and with uncertainty

BIELLA

Estimates w/o uncertainties

	Xreg	Xprov	Xp-Xr	m	p	a	m+p+a
CH4	0.1798	0.1099	-0.0699	-0.0758	0.0314	-0.0255	-0.0699
CO	0.0288	0.0162	-0.0126	-0.0145	0.0015	0.0004	-0.0126
CO2	0.0324	0.0111	-0.0214	-0.0169	-0.0092	0.0048	-0.0214
COV	0.0494	0.0124	-0.0370	-0.0237	-0.0252	0.0121	-0.0369
N20	0.0040	0.0004	-0.0036	-0.0023	-0.0035	0.0021	-0.0036
NH3	0.0021	0.0031	0.0010	0.0004	0.0007	-0.0001	0.0010
NOx	0.0861	0.0449	-0.0412	-0.0406	-0.0022	0.0017	-0.0412
PM10	0.0091	0.0075	-0.0016	-0.0042	0.0041	-0.0016	-0.0016
PM2.5	0.0034	0.0025	-0.0009	-0.0015	0.0010	-0.0003	-0.0009
SO2	0.0139	0.0086	-0.0052	-0.0081	-0.0001	0.0029	-0.0052

Estimates with uncertainties

	Xreg	Xprov	Xp-Xr	m	p	a	m+p+a
CH4	0.3398	0.2099	-0.1299	-0.1423	0.0601	-0.0477	-0.1299
CO	0.0476	0.0275	-0.0202	-0.0242	0.0036	0.0003	-0.0202
CO2	0.0505	0.0189	-0.0316	-0.0261	-0.0110	0.0055	-0.0316
COV	0.0841	0.0224	-0.0617	-0.0404	-0.0403	0.0192	-0.0615
N20	0.0053	0.0006	-0.0047	-0.0029	-0.0044	0.0026	-0.0047
NH3	0.0036	0.0051	0.0015	0.0008	0.0008	-0.0001	0.0015
NOx	0.1340	0.0742	-0.0598	-0.0629	0.0031	0.0000	-0.0598
PM10	0.0155	0.0131	-0.0024	-0.0070	0.0075	-0.0029	-0.0024
PM2.5	0.0055	0.0042	-0.0013	-0.0025	0.0018	-0.0006	-0.0013
SO2	0.0201	0.0155	-0.0046	-0.0114	0.0041	0.0027	-0.0046

Application: the policy matrix w/o and with uncertainty

VERCELLI

Estimates w/o uncertainties

	Xreg	Xprov	Xp-Xr	m	p	a	m+p+a
CH4	0.1798	0.0971	-0.0827	-0.0586	-0.0473	0.0232	-0.0827
CO	0.0288	0.0411	0.0123	-0.0114	0.0411	-0.0174	0.0123
CO2	0.0324	0.0546	0.0222	-0.0089	0.0464	-0.0153	0.0222
COV	0.0494	0.0328	-0.0165	-0.0031	-0.0080	-0.0054	-0.0165
N20	0.0040	0.0031	-0.0009	-0.0008	0.0009	-0.0010	-0.0009
NH3	0.0021	0.0045	0.0024	0.0014	0.0005	0.0005	0.0024
NOx	0.0861	0.1172	0.0311	-0.0303	0.1179	-0.0564	0.0311
PM10	0.0091	0.0149	0.0057	-0.0040	0.0178	-0.0081	0.0057
PM2.5	0.0034	0.0047	0.0014	-0.0013	0.0047	-0.0020	0.0014
SO2	0.0139	0.0042	-0.0097	-0.0045	-0.0088	0.0036	-0.0097

Estimates with uncertainties

	Xreg	Xprov	Xp-Xr	m	p	a	m+p+a
CH4	0.3398	0.0475	-0.2923	-0.1172	-0.2832	0.1081	-0.2923
CO	0.0476	0.0187	-0.0289	-0.0073	-0.0262	0.0045	-0.0289
CO2	0.0505	0.0212	-0.0293	-0.0016	-0.0272	-0.0005	-0.0293
COV	0.0841	0.0135	-0.0705	0.0128	-0.0676	-0.0138	-0.0686
N20	0.0053	0.0014	-0.0040	-0.0027	-0.0027	0.0014	-0.0040
NH3	0.0036	0.0021	-0.0015	-0.0009	-0.0007	0.0001	-0.0015
NOx	0.1340	0.0485	-0.0855	-0.0121	-0.0772	0.0039	-0.0855
PM10	0.0155	0.0065	-0.0089	-0.0019	-0.0079	0.0008	-0.0089
PM2.5	0.0055	0.0020	-0.0036	-0.0005	-0.0033	0.0002	-0.0036
SO2	0.0201	0.0018	-0.0183	-0.0032	-0.0182	0.0031	-0.0183

Few comments

- The way to address uncertainty changes according to the purpose of estimates' use (data production/data analysis/data use)
- For data analysis and policy uses a way to proceed is to integrate estimates with additional information and datasets
- Uncertainty does affect the message to policy maker and thus the strategy and actions to be implemented
- Adding uncertainty to estimates can affect the message to policy makers, even if in some case less than expected when looking at the differences in absolute terms
- The calculation of uncertainty varies according to the administrative level considered
- A raw methodology can help to identify which are the pollutants that require a deeper analysis: considering the limits of time, budget and data, this kind of methodologies can work as sieve.

I
U
A
V

Università Iuav
di Venezia

Thank you for your attention

lanotte@iuav.it