4th International Workshop
on Uncertainty in Atmospheric Emissions

7-9 October 2015, Krakow, Poland

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Warszawa 2015

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Printed from the material submitted by the authors.

47786

Instytut Badań Systemowych PAN - w Warszawie -
BIBLIOTEKA

ISBN 83-894-7557-X
EAN 9788389475572

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About the Workshop

The assessment of greenhouse gases and air pollutants (indirect GHGs) emitted to and removed from the atmosphere is high on the political and scientific agendas. Building on the UN climate process, the international community strives to address the long-term challenge of climate change collectively and comprehensively, and to take concrete and timely action that proves sustainable and robust in the future. Under the umbrella of the UN Framework Convention on Climate Change, mainly developed country parties to the Convention have, since the mid-1990s, published annual or periodic inventories of emissions and removals, and continued to do so after the Kyoto Protocol to the Convention ceased in 2012. Policymakers use these inventories to develop strategies and policies for emission reductions and to track the progress of those strategies and policies. Where formal commitments to limit emissions exist, regulatory agencies and corporations rely on emission inventories to establish compliance records.

However, as increasing international concern and cooperation aim at policy-oriented solutions to the climate change problem, a number of issues circulating around uncertainty have come to the fore, which were undervalued or left unmentioned at the time of the Kyoto Protocol but require adequate recognition under a workable and legislated successor agreement. Accounting and verification of emissions in space and time, compliance with emission reduction commitments, risk of exceeding future temperature targets, evaluating effects of mitigation versus adaptation versus intensity of induced impacts at home and elsewhere, and accounting of traded emission permits are to name but a few.

The *4th International Workshop on Uncertainty in Atmospheric Emissions* is jointly organized by the *Systems Research Institute of the Polish Academy of Sciences*, the Austrian-based *International Institute for Applied Systems Analysis*, and the *Lviv Polytechnic National University*. The 4th Uncertainty Workshop follows up and expands on the scope of the earlier Uncertainty Workshops – the *1st Workshop* in 2004 in Warsaw, Poland; the *2nd Workshop* in 2007 in Laxenburg, Austria; and the *3rd Workshop* in 2010 in Lviv, Ukraine.

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

Alessandra La Notte[1], Stefania Tonin[1], Silvio Nocera[1]

[1]Department of Design and Planning in Complex Environments, IUAV-University of Venice
lanotte@iuav.it

Abstract

Emission inventories are compiled at national and regional levels and used without taking uncertainty into account. We attempt to check whether and to what extent uncertainty related to emission inventories affect quantitative analysis used by policy makers to set strategies and implement actions at regional and sub-regional levels. We consider the regional air emission inventory of the Piedmont region in Italy. Uncertainty is calculated by adapting the insurance-based method. A hybrid accounting matrix is built and a Shift-Share analysis is undertaken for manufacturing and construction activities, and for the transport sector at regional and provincial levels. The procedure is repeated for data without uncertainty and data with uncertainty. Although in absolute terms total emissions are remarkably different, the outcomes of the Shift-Share Analysis vary among provinces: sometimes the messages are misleading when uncertainties are not included in the calculation; sometimes the differences are negligible. Some general conclusion can be drawn.

Keywords: air emission inventory, uncertainty, Shift-Share Analysis, hybrid environmental accounts

1. Introduction

Air emission inventories, and in particular Green-House Gas emissions, have always been though as the primary source of information for the international Climate Change agreements and trading [1] and are usually compiled at national level. However, especially when developed at sub-national level, these datasets can be a precious source of information for policy makers at different administrative in accounting terms for descriptive analysis and for policy analysis [2]. Although few examples of air emission inventories used in policy analysis at subnational level already occur, uncertainty is never considered. In some cases uncertainty coefficients are not even available from the agencies and institutes responsible for the delivery of air emission inventories.

In this paper we are going to combine one particular technique to quantify uncertainty together with a hybrid environmental accounting framework and we are going to use a decomposition analysis tool to assess whether and to what extent estimates with and without uncertainty do affect the final message that policy makers use when planning strategy and actions for the territory they administer.

The case study we used to apply the methodology, accounting framework and the decomposition analysis is the Piedmont region and its provinces. Their air emission regional inventory is one of the best example existing in Italy. Their datasets are publicly available and the uncertainty coefficient are efficiently compiled by the functionaries in charge for the inventory.

After a brief description of the data, methodology and tool used (Section 2), the results are presented (Section 3) and some points for discussion raised (Section4). In the conclusion (Section 5) we summarise the main findings of this first application through key messages.

2. Materials and methods

The Piedmont region is located in the North-Western part of Italy. In Piedmont automotive (the FIAT group and its induced activities) is the dominating compartment, followed by chemical, food, textile, clothing, electronics and editorial compartments. The tools at the basis of this application are the hybrid environmental accounts and the shift-share analysis that will be described in the following paragraphs.

2.1 Calculation of uncertainty and hybrid environmental accounts

The CORe INventory AIR emissions (CORINAIR) method is the framework supported by the European Environment Agency. It was adopted by the national environmental protection agency in compiling the national inventory. At regional level and specifically in Piedmont, the EMEP-CorinAIR inventory is compiled since the beginning of 2000s and the procedure has been greatly improved and updated since the first release. The regional inventory records data according to the SNAP (Selected Nomenclature for Air Pollution) classification. The inventory is composed by 11 macro sectors, 75 sectors and 430 activities for the following pollutants: methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (N_2O), ammonia (NH_3), Volatile Organic Compounds (VOC), oxides of nitrogen (NO_X), sulphur dioxide (SO_2) and particulate matters (PM_{10} and $PM_{2.5}$).

Uncertainty is compiled according to inventory guidelines. For each pollutant at the activity level it is possible to calculate uncertainty according to the following formula:

$$UNCijk = UnEFijk * UnADi,k \quad (1)$$

where

UNC_{ijk} = total uncertainty coefficient for the activity i, pollutant j, fuel k; UnEF = uncertainty coefficient assigned to Emission Factor for the activity i, pollutant j, fuel k; UnAD = uncertainty coefficient assigned to Activity Data for the activity i, fuel k

Marland et al. [3] borrow their approach to estimate uncertainty from the insurance industry by adding a charge called risk charge that represents the insurance for the insurer. Uncertainty is calculated using the approach suggested in EMEP Guidelines and this value is used as risk charge. The formula to calculate the uncertainty maximum limit becomes thus:

$$EUnc_{ijk}=(E_{ijk}*(1- UNC_{ijk}))+E_{ijk} \quad (2)$$

where

$EUnc_{ijk}$ = total emissions and uncertainty for the activity i, pollutant j, fuel k; E_{ijk} = emissions for the activity i, pollutant j, fuel k

It is possible to connect air emissions to their generating activity. The NAMEA-type accounting module allows to frame together economic data and emissions and can be compiled at local level [4]. The first step to undertake is to harmonize the SNAP classification system that is based on production processes with the NACE (*Nomenclature générale des Activités économiques dans les Communautés Européennes*) classification system that is based on economic sectors. For this application we choose to focus on the whole secondary sector (that includes all manufacturing activities and construction) and on the transport sector. We thus do not consider the primary sector (agriculture and forestry) the tertiary (services) and households. Economic Data (local units and number of employees) are withdrawn from ASIA (register of active enterprises), and air emission data are withdrawn from EMEP-CorinAIR (in tonnes for all pollutants except CO_2 that is in 1,000 tonnes).

2.2 The Shift-Share Analysis

We apply decomposition analysis in order to investigate the mechanism that affects air emissions: the rationale for structural decomposition analysis is splitting an identity into its components. Changes in some variables are decomposed in changes in its determinants. The methodologies commonly used to decompose emissions trends are index decomposition analyses, input-output structural decomposition analysis and shift-share analysis [5].

The purpose of this application is to measure the role of the productive structure at the lower hierarchical level considered (in our case the provincial level) in explaining the emissions efficiency gap between this level (i.e. provincial) and the higher hierarchical level (in our case the regional level). Shift-share analysis in fact decomposes the source of change of the specified 'dependent variable' into provincial specific components (that constitutes the shift) and the portion that follows regional growth trends (that constitutes the share).

The question we aim to address is whether the gap between the considered province and the regional benchmark average depends on (lack of) environmental friendly technologies in the included economic sectors, and/or on a provincial specialization in sectors with higher/lower eco-efficiency.

We firstly calculate the intensity of emissions by considering the emission of each pollutant referred to the number of workers employed in each sector. This variable provides insights into the socio-environmental efficiency of the productive sectors, which is useful in order to plan a strategy to support environmental innovation at sector level. We then analyse the relative environmental efficiency of the provincial economic system with respect to the regional average, referring to the GHG pollutants and to the economic sectors included in the hybrid accounts.

The aggregate indicator of emission intensity is represented by 'total emissions [E] on number of employees[Empl]'. The benchmark is represented by the regional value. We define the index of emissions intensity as X for the regional average (X=E/Empl), as X_{Pr} for the province ($X_{Pr}=E_{Pr}/Empl_{Pr}$) and as X^s for each sector for the province and $X^s_{Pr}=E^s_{Pr}/Empl^s_{Pr}$ for the region $X^s=E^s/Empl^s$). We then define the share of sector value added as $P^s=Empl^s/Empl$ for the region and $P^s_{Pr}=Empl^s_{Pr}/Empl_{Pr}$ for the province.

$$X = \sum_s P^s X^s \tag{3}$$

$$X_{Pr} = \sum_s P^s_{Pr} X^s_{Pr} \tag{4}$$

The shift-share decomposition allows to identify three effects that explain the gaps in terms of aggregate emissions efficiency between the province and the region.

The first effect ('structural' or industry mix) is given by:

$$m_{Pr} = \sum_S (P^s_{Pr} - P^s) X^s \tag{5}$$

m_{Pr} assumes a positive (negative) value if the region is 'specialized' in sectors associated with lower (higher) environmental efficiency, given that the gap in value added sector shares is multiplied by the value of X of regional average ('as if' the province were characterized by average regional efficiency). The factor m_{Pr} assumes lower values if the province is specialized in (on average) more efficient sectors.

The second factor ('differential' or 'efficiency') is given by:

$$p_{Pr} = \sum_s (X^s_{Pr} - X^s) \tag{6}$$

P_{Pr} assumes a positive (negative) value if the region is less (more) efficient in terms of emissions (the shift between provincial and regional efficiency), under the assumption that ('as if') number of employees sector share were the same for the region and the province.

The third effect ('allocative component') is given by:

$$a_{Pr} = \sum_s (X^s_{Pr} - X^s)(P^s_{Pr} - P^s) \tag{7}$$

The a_{Pr} factor is positive (negative) if the province is specialized, relative to the regional benchmark, in sectors characterized by higher (lower) emission intensity.

Table 1. Data with and without uncertainty at regional and provincial level.

	CH_4	CO	CO_2	COV	N_2O	NH_3	NO_x	PM_{10}	$PM_{2.5}$	SO_2
Secondary sector Piedmont										
REG (W/O)	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
REG (W)	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	11.998,8
Δ_Reg	0,89	0,54	0,52	0,70	0,32	0,74	0,38	0,44	0,49	0,45
Transport sector Piedmont										
REG (W/O)	288,00	11.215,42	3.902,60	2.518,18	121,09	31,99	29.859,38	4.892,40	1.460,87	48,97
REG (W)	488,11	19.219,08	8.628,90	4.302,59	207,52	54,28	50.369,42	8.155,40	2.485,83	86,29
Δ_Reg	0,69	0,71	0,70	0,71	0,71	0,70	0,89	0,74	0,70	0,76
Secondary sector Biella										
Prov (W/O)	2.959,18	73,29	177,06	255,45	6,29	81,35	364,90	32,50	21,31	232,42
Prov (W)	5.652,81	115,20	301,58	471,16	11,10	134,85	565,19	58,71	35,70	416,51
Δ_Prov	0,91	0,57	**0,70**	0,84	**0,77**	0,66	0,55	**0,75**	**0,66**	**0,79**
Transport sector Biella										
Prov (W/O)	7,56799	363,95514	121,4479	77,90136	3,38207	1,06423	646,3386	169,552	46,2134	0,771862
Prov (W)	12,86	626,26	207,63	133,04	5,79	1,85	1.437,20	295,62	77,29	1,32
Δ_Prov	0,70	0,72	0,71	0,71	0,71	0,71	0,70	0,74	0,71	0,71
Secondary sector Torino										
Pro(W/O)	61.832,97	2.262,16	6.590,36	9.204,56	218,08	270,97	7.304,90	183,44	146,92	718,78
Prov (W)	116.244,10	3.190,53	9.921,59	15.437,08	396,09	474,77	10.138,77	256,35	209,00	1.143,14
Δ_Prov	0,88	*0,41*	0,51	0,68	**0,82**	0,75	0,39	0,41	0,42	**0,59**
Transport sector Torino										
Pro(W/O)	143,9462	5323,6086	1744,264	1220,169	55,0616	14,043	12621,56	1894,428	655,133	30,51204
Prov (W)	246,21	9.192,52	2.964,92	2.103,98	94,97	23,97	21.785,47	3.295,82	1.121,57	54,56
Δ_Prov	0,71	0,73	0,71	0,72	0,72	0,71	0,70	0,74	0,71	0,79
Secondary sector Vercelli										
Pro(W/O)	2.412,86	366,22	1.118,74	680,91	69,64	109,75	861,74	44,59	28,72	102,88
Prov (W)	4.475,64	694,15	1.593,49	1.048,54	120,05	197,48	1.154,17	53,10	37,14	167,17
Δ_Prov	0,65	**0,80**	0,43	*0,54*	**0,72**	0,80	0,34	*0,19*	*0,29*	**0,63**
Transport sector Vercelli										
Prov (W/O)	16,7377	641,8716	250,0528	140,6166	6,68947	2,03567	2071	326,973	89,5194	1,633566
Prov (W)	27,86	1.081,32	416,30	235,82	11,22	3,42	3.444,82	566,43	149,92	2,74
Δ_Prov	0,66	0,68	0,67	0,68	0,68	0,68	0,66	0,73	0,67	0,68

3. Results

The Piedmont region contains important industrial centers: from automobile to electronics, to mechanical, to food and beverage industries. Hybrid flow accounts have been compiled for all provinces of Piedmont and Shift-Share Analysis has been performed for regional-provincial cases. Results have been compared for estimates with and without uncertainties. Differences stand out in three cases that will be presented in details. The three provinces are Biella, Torino and Vercelli. Table 1 shows the estimates with (W) and without (W/O) uncertainties of these provinces compared with the regional level. It is important to consider the transport sector separately from the secondary sector. In the first case there are no remarkable differences between the regional and provincial deltas, while in the second case for some pollutants at provincial level shows remarkably higher differences.

In the province of Biella there are many factories working on spinning and weaving of wool and on other tissues. Table 1 shows that the difference in considering data with and without uncertainty for secondary sector diverges from the regional trend for the pollutants CO_2, N_2O, PM and SO_2. The shift-share analysis for Biella shows that when we consider uncertainty the productivity differential changes for two pollutants: NO_X and SO_2.

The second province we report is Torino: the most important province in the region from historical, economic and demographic points of view. The industrial sectors mostly developed in this province are the automobile industry and all its related industrial sectors, and electronics. Table 1 shows the estimates with (W) and without (W/O) uncertainties of this province compared to the regional level. Differently from the Biella province in Torino CO_2 and PM with and without uncertainty follow the regional trend. It is important to check on Table 1 that the only province of Torino generates almost half of CO_2 emissions due to traffic for the whole region. Clearly the province of Torino has a remarkable impact at regional level for some of the main pollutants due to traffic (i.e. CO_2 and PM). The shift-share analysis for Torino shows that the allocative component changes when data are computed with uncertainty: the main differences are recorder for the pollutants NH_3 and $PM_{2.5}$.

The last province we present is Vercelli, whose main economic activities are linked with the production of rice. Table 1 shows the estimates with (W) and without (W/O) uncertainties of this province compared with the regional level. This province shows different trends for many pollutants: in some cases the differences between data with and without uncertainties between the provincial and the regional levels are much higher (CO, N_2O, SO_2) and in some other cases are much lower (COV, PM_{10}, $PM_{2.5}$). The shift-share analysis for Vercelli shows that there are a lot of differences when data are computed with and without uncertainty. The structural component has a single critical pollutant: without uncertainty is NH_3 but with uncertainty is COV. The eco-efficiency component without uncertainty is favorable only for CH_4, COV and SO_2 while with uncertainty becomes favorable for all pollutants. The allocative component presents a more favorable condition without uncertainties where the only critical pollutants are CH_4, NH_3 and SO_2; with uncertainties in fact all pollutants become critical except CO_2 and COV.

4. Discussion and final remarks

Looking at the numbers, when considering the differences in absolute terms in most cases estimates with uncertainties double the initial estimates. However when using a tool such as Shift-Share Analysis, doubled estimates do not dramatically affect the outcomes. In some cases differences can be found but not as striking as initially expected. As source of air emissions we consider all secondary sector and from the tertiary sector only transport. For all provinces we consider separately the secondary sector and transport when comparing the difference of estimates with and without uncertainty between the regional trend and the provincial trend (ref. Table 1). For all provinces the regional and provincial levels in secondary sectors show important differences for N2O, PM and SO2 (the one exception is the province of Torino). When the two sectors are summed some of these difference disappear: e.g. the difference (higher or lower) in PM between the regional ad provincial trends disappear. Moreover, the territorial aggregation is impacted by some provinces which determine the weights of some pollutants (of course due to their generating activities) rather than others: Table 1 shows that it also applies in terms of uncertainties. For example the province of Turin has a considerable impact because it collects the major economic activities and host most of the population. In fact when comparing the regional and the provincial levels, for many pollutants that in other provinces shows important differences if considered with and without uncertainty, in the province of Torino the difference only emerge in two cases (N_2O and SO_2). In the province of Vercelli the economic activities and the number of inhabitants are less. This province records many differences in data with and without uncertainty compared to the regional level (ref. Table 1) and thus such a reality could not be represented by the regional level: it should be analyzed individually. If this difference shows up within a region like Piedmont, we can imagine the huge differences that would show at national level. In Italy for example the national level would never represent equally the Northern and the Southern parts: territorial policies, development and environmental policies not only must consider uncertainty but must also identify for the appropriate territories the appropriate administrative level.

However, the method we used to estimates uncertainty was applied in a very elementary way. In fact we did not make any difference among pollutants: we assumed that all measured data are underestimates. Some studies, e.g. [6], shows that some pollutants are prone to over estimates rather than underestimates and some other pollutants' estimates are fine. Moreover, we did not apply any refinement to the coefficient interval: we consider the worse hypothesis, i.e. the maximum possible applicable percentage of error.

Having set few statements in the previous section, we would like to conclude this paper with few remarks. Firstly, the calculation of uncertainty varies according to the administrative level considered. In our example we started from a sub-national level (the region) and further looked into a local context (the provinces). The message does thus amplify when the initial level is a nation or a macro-region. Secondly, by 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. Finally, a raw methodology, like the one we have applied in this paper, 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. To the identified pollutants and to the critical territorial contexts a more sophisticated approach should be applied in order to provide the policy maker with a correct and robust message.

References

[1] Lieberman D., Jonas, M., Nahorski Z., Nilsson S. (2007). Accounting for Climate Change. Springer Netherlands.

[2] La Notte A., Dalmazzone S. (2012). Feasibility and uses of the NAMEA-type framework applied at local scale: case studies in North-Western Italy, in V.Costantini, M.Mazzanti and A.Montini (Eds) Hybrid Economic-Environmental Accounts, Routledge studies in Ecological Economics, Taylor& Francis Group.

[3] Marland, E., Cantrell, J. , Kiser, K., Marland, G., Shirley, K. (2014). Valuing uncertainty part I: The impact of uncertainty in GHG accounting. Carbon Management, 5(1), 35-42.

[4] Dalmazzone S., La Notte A. (2013). Multi-scale environmental accounting: Methodological lessons from the application of NAMEA at sub-national levels, Journal of Environmental Management, 130, 405-416.

[5] Esteban, J. (2000) Regional convergence in Europe and the industry mix: a Shift-share Analysis, Regional Science and Urban Economics, 3, 353-364.

[6] Bergamaschi, P., Corazza, M., Karstens, U. , Athanassiadou, M. , Thompson, R.L., et al. (2015). Top-down estimates of European CH_4 and N_2O emissions based on four different inverse models. Atmospheric Chemistry and Physics, 15(2), 715-736.

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