Grant Agreement No. 2007105

GREQAM
GROUPEMENT DE RECHERCHE
EN ECONOMIE QUANTITATIVE
D'AIX-MARSEILLE

Aphekom

Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe

Report on economic benefits associated with the implementation of the 1996 EC regulation on SO_2

Deliverable D11bis

April 2011

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[1] We would like to thank Susann Henschel and Patrick Goodman who provided helpful comments and suggestions on an earlier version of this deliverable.

1. Introduction

This deliverable presents the monetary valuation of the health effects associated with the implementation of Council Directive **93/12/EEC*** regulating the SO_2 content in diesel fuels, for 20 cities in Europe (see Aphekom Deliverable D11, 2011; for a presentation of the methodology and the results). In addition to uncertainties and limitations specific to the health impact assessment, the economic values used in the computations carry their own uncertainties. It would therefore be better to consider the final figures obtained as reasonable orders of magnitude, rather than as accurate final figures.

Section 2 presents two features relevant to the monetary assessment as well as the different unit economic values used. Section 3 computes the monetary benefits for each of the 20 cities and Section 4 concludes.

2. Methods

The guidelines on monetary cost calculations related to air-pollution health impacts are detailed in Aphekom Deliverable D6 (2011). Below, we focus on two features relevant to the monetary assessment of the mortality impacts associated with the implementation of the 1996 EC regulation on SO_2 and detail the economic values chosen.

Metric chosen

The economic values used to assess mortality effects depend on the metric chosen in the epidemiological computations.

- **For acute (ST) mortality**, the annual number of premature deaths avoided per year is used. In view of the way these data are computed (through time-series analyses and proportional hazard models), the gains in life expectancy corresponding to each of these premature deaths can be considered to be in the range of a few months, certainly lower than one year (Cafe 2005a, p. 46).

- **For chronic (LT) mortality**, the number of premature deaths avoided is also provided by epidemiology. However, unlike the acute mortality computations, they are obtained through cohort studies that monitor populations exposed to different levels of pollution. One of the crucial issues is the magnitude of the gain in life expectancy related to these premature deaths. Although no definitive answer exists, a 10-year gain seems to be supported by three pieces of evidence: medical, epidemiological and past empirical practices (see Ezzati et al., 2002; Cafe, 2005a; Watkiss et al. 2005; or Janke et al., 2009).

Valuation from a timing standpoint

Depending on the acute or chronic nature of the mortality benefits, there are two possible approaches to deal with the time that elapses between a reduction in air pollution exposure and the achievement of full health benefits.

In the **"steady-state" approach,** the mortality effects corresponding to two different levels of air pollution are assessed and the number of premature deaths attributed to a change in air pollution exposure is computed as the difference between the numbers of premature deaths resulting from the respective steady states. It is accurate for acute (or short-term, ST) mortality effects, and provides an idea of the magnitude of the public health problem for chronic (or long-term, LT) health effects. This approach is clear, simple and informative.

In the "**marginal (benefit)" approach,** the impact of a reduction in today's air pollution exposure on the future flow of mortality effects is estimated. Indeed, a reduction in air pollution exposure today does not produce all chronic (or long-term) effects the same year, due to their cumulative properties (see Leksell and Rabl, 2001; Miller and Hurley, 2003; Röösli et al., 2005; or Chanel et al., 2006). Miller and Hurley (2006), for instance, provide a tool (IOMLIFET) that carries out the detailed calculations required by separating the dimensions of year and calendar year. This approach is appropriate for cost benefit analysis in which chronic mortality effects are involved: the flow of discounted future benefits can be properly compared with the costs of the policy that generates these benefits.

Although the two approaches are similar for acute (ST) mortality effects, they differ for chronic (LT) mortality effects due to the latency period before the achievement of full mortality benefits and the additional impact of discounting future monetary benefits.

The regulation on SO_2 has two potential effects on mortality: short-term and long-term. It has been decided that mortality effects will only be considered as short-term effects, because the health data analysis relies on time-series studies and not cohort studies (see Aphekom Deliverable D11, 2011). Since it takes a conservative standpoint, the economic evaluation thus constitutes a lower bound of the mortality effects of the regulation.

Economic values chosen

Regarding the valuation of mortality effects, we follow the standard valuation procedure adopted in ExternE (1999), New-Ext (2004) or Cafe (2005a, b), which consists in using **monetary values derived from stated preferences surveys**, hence relying on preference-derived values rather than market-derived values.

We agree with Cafe (2005a) that the use of a Value of a Statistical Life (VSL) to value acute mortality is certainly not relevant. Indeed, the gain in life expectancy related to a prevented premature death differs according to whether it concerns those affected by chronic or by acute effects: several years (see above) for the former versus "around 1 year" (Cafe, 2005a, p. 46) for the latter. Consequently a Value Of a Life Year (VOLY) approach is preferred to value short-term effects of SO_2 reduction on mortality, and the computations are made with the assumption that the gain in life expectancy associated with each of these premature deaths is one year.

Finally, to allow for the uncertainty pertaining to the economic valuation, we use a Low, a Central (also referred to as Best) and a High estimate of a VOLY. The full economic results will thus present a range of monetary valuations (Low, Central and High) for each premature death avoided. [2]

[2] A full and proper treatment of uncertainty would account for uncertainties concerning epidemiology and economic valuation through an integrated approach and Monte Carlo simulations (see for instance, Burmaster and Anderson, 1994; Cafe, 2005b; or Ostro et al., 2006).

We choose to rely on European studies when selecting the VOLY to be used. First, for the VOLY's low value, we decided to take the recent results from the NEEDS program (Desaigues et al., 2010, based on 3 months' LE gain with protesters and outliers deleted) realized on ten European countries. Then, we choose as high value the mean VOLY (annual change 5:10,000 scenario) obtained in a study representative of the European population, undertaken for the EC DG Research-funded New-Ext (2004) project and used in Cafe CBA (2005a, b). Finally, the respective arithmetic means of high and low values provide the central VOLY values (see Table 1).

	VOLY	**Source**
Low estimate	40,000	Mean value of Desaigues et al. (2010)
Central estimate	**86,600**	**Average of High and Low estimates**
High estimate	133,200	Mean value of New-Ext (2004)

Table 1 Monetary values chosen to assess mortality health effects (in € 2005)

Note that the valuation of mortality will use a common VOLY for all cities. Indeed, accounting for differences in countries' Gross Domestic Product (GDP) per capita seems ethically unacceptable: it would for instance lead to a fourfold lower VOLY in Hungary than in Ireland (World Bank, 2010).

3. Results

The 3rd implementation stage common to 20 EU cities is estimated to have saved **2,212** (95% Confidence Interval (CI): 772; 3,663) **lives per year** attributable to reductions in SO_2 for the 20 European cities, from the year 2000 onwards (see Aphekom Deliverable D11, 2011; for details of the computations). The column labelled « HIA » in Table 2 provides the figures for each city as well as the 95% CI. The lowest number of lives saved attributable to the regulation is obtained in Bilbao (14) and the highest in Budapest (390).

Based on these figures and the central estimate associated with a premature death avoided (€86,600), the annual economic burden related to the implementation of the 1996 EC regulation on SO_2 amounts to **€191.6 million (95% CI: €66.9 million; €317.2 million)**. The detailed results as well as the upper and lower 95% CI bounds for each city are given in Table 2. Bilbao obtains the lowest annual economic benefits with €1.2 million (95% CI: €0.4 million; €2.1 million) and Budapest obtains the highest with €33.8 million (95% CI: €11.8 million; €56.0 million).

We also perform a **separate assessment of uncertainties** when computing a) the number of premature deaths avoided attributable to the implementation of the regulation, and b) the VOLY. Indeed, we apply the Low (€40,000) and High (€133,200) estimates of the VOLY to the number of premature deaths provided by the epidemiological computations. The complete economic results are presented in Table 2 and represent a range of monetary benefits (Low and High) for the number of premature deaths as well as for the related upper and lower 95% CI bounds.

Centre	HIA			Monetary valuation (million € 2005)								
	# premature deaths			Central estimate (VOLY=€86,600)			Low estimate (VOLY=€40,000)			High estimate (VOLY=€133,200)		
	# cases	95 CI -	95 CI +	# cases	95 CI -	95 CI +	# cases	95 CI -	95 CI +	# cases	95 CI -	95 CI +
Athens	**507**	177	842	**43.9**	15.3	72.9	20.3	7.1	33.7	67.5	23.6	112.2
Barcelona	**35**	12	58	**3.0**	1.0	5.0	1.4	0.5	2.3	4.7	1.6	7.7
Bilbao	**14**	5	24	**1.2**	0.4	2.1	0.6	0.2	1.0	1.9	0.7	3.2
Bordeaux	**18**	6	29	**1.6**	0.5	2.5	0.7	0.2	1.2	2.4	0.8	3.9
Brussels	**54**	19	90	**4.7**	1.6	7.8	2.2	0.8	3.6	7.2	2.5	12.0
Budapest	**390**	136	647	**33.8**	11.8	56.0	15.6	5.4	25.9	51.9	18.1	86.2
Dublin	**37**	13	61	**3.2**	1.1	5.3	1.5	0.5	2.4	4.9	1.7	8.1
Le Havre	**23**	8	38	**2.0**	0.7	3.3	0.9	0.3	1.5	3.1	1.1	5.1
Lille	**96**	34	159	**8.3**	2.9	13.8	3.8	1.4	6.4	12.8	4.5	21.2
Ljubljana	**31**	11	52	**2.7**	1.0	4.5	1.2	0.4	2.1	4.1	1.5	6.9
London	**240**	84	396	**20.8**	7.3	34.3	9.6	3.4	15.8	32.0	11.2	52.7
Lyon	**62**	22	103	**5.4**	1.9	8.9	2.5	0.9	4.1	8.3	2.9	13.7
Marseille	**66**	23	108	**5.7**	2.0	9.4	2.6	0.9	4.3	8.8	3.1	14.4
Paris	**314**	110	519	**27.2**	9.5	44.9	12.6	4.4	20.8	41.8	14.7	69.1
Rome	**115**	40	191	**10.0**	3.5	16.5	4.6	1.6	7.6	15.3	5.3	25.4
Rouen	**46**	16	76	**4.0**	1.4	6.6	1.8	0.6	3.0	6.1	2.1	10.1
Stockholm	**20**	7	33	**1.7**	0.6	2.9	0.8	0.3	1.3	2.7	0.9	4.4
Strasbourg	**19**	7	31	**1.6**	0.6	2.7	0.8	0.3	1.2	2.5	0.9	4.1
Toulouse	**35**	12	58	**3.0**	1.0	5.0	1.4	0.5	2.3	4.7	1.6	7.7
Vienna	**90**	31	148	**7.8**	2.7	12.8	3.6	1.2	5.9	12.0	4.1	19.7
Total	**2,212**	**772**	**3,663**	**191.6**	66.9	317.2	88.5	30.9	146.5	294.6	102.8	487.9

Table 2: Annual monetary benefits for the 20 EU cities that implemented the 3rd implementation stage (Central, Low and High estimates of the number of premature deaths and of the upper and lower 95% CI bounds).

4. Conclusion

It has been decided that, although the regulation on SO_2 has two potential effects on mortality, short-term and long-term, a conservative standpoint will be taken and mortality effects will only be considered as short-term effects. The economic evaluation thus constitutes a lower bound of the mortality effects of the regulation.

Moreover, we should bear in mind that sulphur dioxide emissions also generate effects on morbidity, on crops (with a positive effect at low doses but a negative effect when doses increase), visibility or acid rain. We should be aware that what is being assessed only amounts to partial short-term benefits of the regulation.

Nevertheless, our results in 20 cities show that the marked and sustained reduction in ambient SO_2 levels due to the implementation of Council Directive **93/12/EEC*** prevents some 2,200 premature deaths valued at €192 million. These findings underline the health and monetary benefits to be obtained from drafting and implementing effective EU policies on air pollution and ensuring compliance with them over time.

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