# Impacts of Greenhouse and Local Gases Mitigation Options on Air Pollution in the Buenos Aires Metropolitan Area: Valuation of Human Health Effects[*]

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The objective of this work is to assess through the "avoided health cost method" what would be the economic benefits of undertaking greenhouse (and local) gases mitigation policies in the Buenos Aires Metropolitan Area. To do so, we have developed six steps: Mitigation Scenarios (which policies to undertake), Emissions Inventory according to those, an Ambient Air Pollution Model to calculate the physical impacts, Health Effects Estimation to assess the health consequences of reducing air pollution, and Economic Valuation of those health impacts. The mitigation measures valued have to do with the transportation sector (greater penetration of compressed natural gas, consumption improvements, and some mode substitution) and the energy sector (the introduction of new dams and the rational use of energy by reducing energy consumption in residential, commercial and public buildings). There are three scenarios: a Baseline or Business-as-Usual scenario, a scenario that considers GHG mitigation options for Argentina with impacts in terms of local pollution, and an Integrated scenario which in addition to GHG mitigation includes policies related to local air quality and rational use of energy programs. All scenarios were built up to the year 2012. Particulate matter is the pollutant whose impact is valued.

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# I. Introduction

The process of valuation of human health effects of GHG and local air quality mitigation options on local air pollution in the Buenos Aires Metropolitan Area required undertaking five major steps. Each of which assesses: 1) GHG and Local Air Pollution Mitigation Scenarios, 2) Emissions Inventory and Related Data, 3) Ambient Air Pollution Models and Air Quality Changes, 4) Health Effects Estimation, and 5) Economic Valuation of those effects.

Results from step 1) can be found in Gaioli (2001), conclusions from step 2) can be obtained from Tarela (2001) for mobile sources and from Sorensson et al (2002) for stationary sources, and, findings from step 3) are reported in Tarela and Perone (2002). The general framework resulting from the first three steps can be summarized as follows:

a. The sectors considered in this work are transportation and energy. This is so because the rest of the sectors (mainly agricultural, industrial and waste management ones) have low impact in the area of study (the Buenos Aires Metropolitan Area, BAMA);
b. The options considered are: greater penetration of compressed natural gas (CNG), consumption improvements, and some mode substitution in the transportation sector, introduction of new dams (which impact the dispatch of thermal plants) and rational use of energy by reducing energy consumption in residential, commercial and public buildings in the energy sector;
c. There are three scenarios: a) Baseline or Business-as-Usual scenario (*Base*), b) Climate-Change-Mitigation-Policy scenario (*Mitigation*) that considers GHG mitigation options for Argentina with impacts in terms of local pollution, and c) an Integrated scenario (*Integrated*) which includes simultaneously GHG options and mainly local air quality and rational use of energy programs;
d. All scenarios were built for the years 2004, 2008 and 2012 (the Base scenario is also calculated for the year 2000);
e. The air quality model has outputs for long-term (annual average) PM2.5 and short-term (1-hour) NOx. The results are presented in a grid of 250x250 meters for the Buenos Aires Metropolitan Area, and then aggregated in few sections for "Barrios" (neighborhoods) for Capital Federal and in several sections of "Distritos" (districts) for Greater Buenos Aires.

There are in Argentina several laws related to performing Environmental Impact Assessments (EIA), inspired mainly by U.S. and European legislation (Iribarren, 1997). There is national sectoral regulation, which require EIA to the mining sector (law 24.585 of 1995) and to hydroelectric projects (law 23.879 of 1990) for example. Public sector investments must also pass an EIA under the National System of Public Investment (law 24.354 of 1994). There are also EIA laws in sub-national governments. However, despite the existence of regulation requiring environmental impact assessments, there are limited to public and private projects (and all EIAs are done calculating impacts in physical and not in economic terms). There is no such thing as Regulatory Impact Assessments for policies. Cost-benefit analysis related to environmental impacts is a very weak and unknown area in Argentina. This contrast with the work in this field performed in other developing countries in Latin America as Chile, Brazil and Mexico.

All economic valuations of environmental impacts were done or under a World Bank (WB) or Inter-American Development Bank (IADB) project or as thesis or working papers in some universities. More precisely, there are hedonic valuations: for floods on the río Matanza-Riachuelo (BAMA) in a IADB Project (cited by World Bank, 1995), for air and noise pollution by the transportation sector for the City of La Plata (Angeletti, 2000) and BAMA (Conte Grand, 2001), and also to value green spaces in the City of Buenos Aires (Gómez Mera, 1998). There are some contingent valuation method (CVM) calculations for floods in the Reconquista river (BAMA) in an IADB Project and another for the provision of sewage done by the Consejo Federal de Agua Potable y Saneamiento (both cited by World Bank, 1995). In terms of avoided costs, there are some precedents for health benefits of reducing air pollution in BAMA under a WB project (Conte Grand, 1997) and of converting (for BAMA) charge and public transportation to CNG (Barrera et al, 1999).

The benefits of reducing local air pollution can be assessed by valuing health and non-health effects that could be avoided by a decrease in ambient levels of air pollutants. Non-health avoidable costs include savings by eliminating unpleasant odors, by improving visibility, by avoiding the task of painting deteriorated buildings, among others. The lack of studies on the non-health effects of air pollution in developing countries and its lower contribution to the overall effects (according to Lvovsky et al 2000, non-health effects account for little more than 10% of the overall avoided costs) implies that only health avoided costs are quantified here.

The "avoided health costs" methodology has been used broadly in the world. There is pioneering work done by the US EPA under the Clean Air Act (EPA 1997 and 1999)[1]. There are also several World Bank valuations of air quality improvements in developing countries based on a review of international literature on health effects of pollution with an application to Jakarta (World Bank, 1994). More recently, European studies have also begun to increase considerably (in that respect, EC 1999a and 1999b). There is also work on this issue in other Latin American countries as Brazil (Serôa da Motta and Fernandes Mendes, 1996), Chile (Cifuentes et al 2000a and DICTUC 2000), and Mexico (Cesar et al, 2000), some of which is also under IES.

The same type of procedure is used here to value the health benefits of reducing pollution in the Buenos Aires Metropolitan Area (BAMA). The methodology can be summarized in three phases:

1) Aggregate the air quality changes (Base/Mitigation and Base/Integrated) each year for each "Barrio" and "Distrito", combining the information provided by Tarela and Perone (2002) for long-term PM2.5[2];
2) Given the air quality improvements scenarios, we quantify the health impact using the corresponding concentration-response (CR) functions. While it would be ideal to use such functions for each country, the lack of epidemiological studies in Argentina causes that CR functions for other countries are adopted[3]. Then, by knowing, for example, that a reduction of 10 $\mu g/m^3$ in annual average $PM_{10}$ concentrations decreases mortality approximately by 1%, it is possible to approximate the number of

[1] There is much work in the U.S. done by Abt Associates that has been the basis of some of EPA´s results, which is also an important reference for this study (Abt 1999 and 2000).

[2] Valuation for nitrogen oxides impacts is not performed here basically because there are few CR functions to be used and much less "proven" literature than for particulates. This could be done in a future paper.

[3] Studies for example for $PM_{10}$ in Santiago de Chile confirm somehow the reliability of such a procedure since the resulting dose-response coefficients were not significantly different than those for the U.S. or Canada (Ostro et al, 1996). According to Cesar et al (2000), "it appears that Mexico City time-series studies or particulate matter mortality find slightly greater unit effects than the worldwide average, although the values are well within the range reported elsewhere". There is more discussion on this issue below.

people who will not die due to this change in air quality is achieved. Similar results are available for morbidity. So, in order to undertake the health impact calculation (with CR function), two kinds of information are needed:

   a. Demographic data (mainly population by age range).
   b. Health incidence data (as mortality rates, hospital admissions, emergency room visits, number of symptoms, asthmatics, etc.); and,

3) Convert health data to economic values. This requires the use of unit economic values for mortality and morbidity. For the former, the Value of a Statistical Life (VSL) can be measured using the Human Capital (HC) approach (income lost) or by the Willingness to Pay (WTP) based on contingent valuation or hedonic pricing[4]. For morbidity, we need other unit values: direct Costs of Illness (COI) which include basically medical costs, and productivity losses (proxied generally by wages for full or partial days lost), and the value of individuals' WTP to avoid symptoms caused by pollution related illnesses (e.g., cough). Whenever possible, for example for HC VSL, unit values are calculated from national information. Others (like WTP measures) are U.S. and European estimates adjusted by the relative GDP per capita, WTP-income elasticity, etc. (because there are no values available for Argentina).

The absence of good information for each of those three steps implies that some assumptions have to be made to obtain approximations to the benefits of reducing pollution. Lower and upper bounds for health impacts. In addition, as in Cesar et al (2000), aggregation of the economic value results is such that four totals are presented:

Option 1: Mortality valued by the HC approach, Morbidity based on Medical costs and Productivity losses.

Option 2: Mortality valued by the HC approach, Morbidity based on WTP, Medical costs and Productivity losses.

Option 3: Mortality valued by WTP, Morbidity based on Medical costs and Productivity losses.

Option 4: Mortality valued by WTP, Morbidity based on WTP, Medical costs and Productivity losses.

This paper describes the use of all available data to value local co-benefits of GHG mitigation options in the Buenos Aires Metropolitan Area. Sections II to IV deal with the three phases described above, and Section V presents the monetized results.

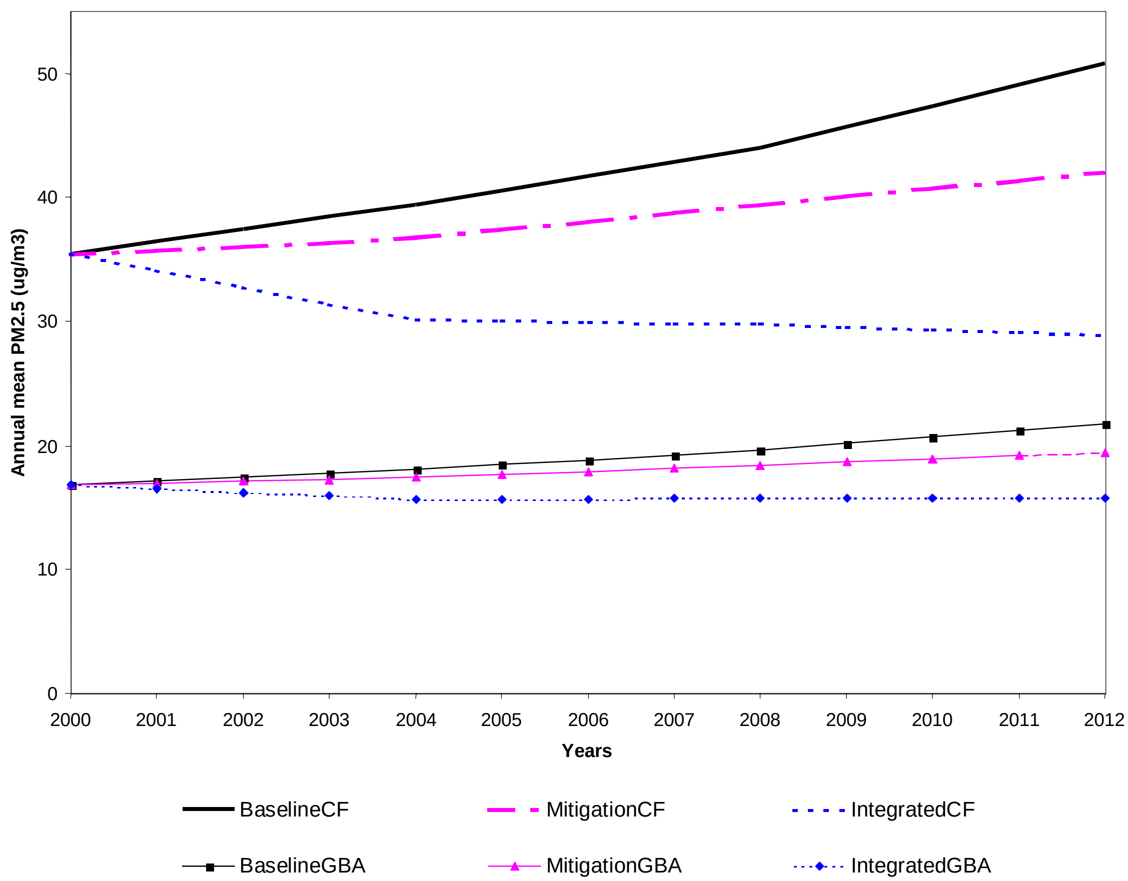
## II. Air Quality Changes

Air quality information (Tarela and Perone, 2002) is available for 47 sections in Capital Federal (CF) and 117 sections in the Great Buenos Aires (GBA). Here we aggregate by political division: "Barrios" (neighborhoods) for CF and "Distritos" (districts) for GBA. Aggregation is based on a weighted (by the number of points for which there was data in each section) average. And, as a result, there are 44 barrios and 19 districts in the database. As an illustration of the magnitude of changes in air quality among the different scenarios in different years, Figure 1

[4] To be more precise, WTP can be deduced from two type of studies: direct (or state preference) methods which are mainly contingent valuation based, and indirect (or revealed preference) methods that are based on hedonic pricing, avoided costs, etc. However, we will call here WTP all that is not directly market price based (as lost income for mortality and lost wages or medical costs for morbidity).

shows the simple average of PM2.5 absolute levels for CF and GBA, and Table 1 shows simple average changes. However, when economic valuation is the issue, changes in air quality become as important as the number of people affected by those changes. Then, Figure 2 summarizes population exposure to PM2.5 in the year 2000. Table 2 shows a weighted (based on population in each barrio and district) average of changes in air quality.

**Figure 1. Air pollution (PM2.5) in BAMA: different scenarios**



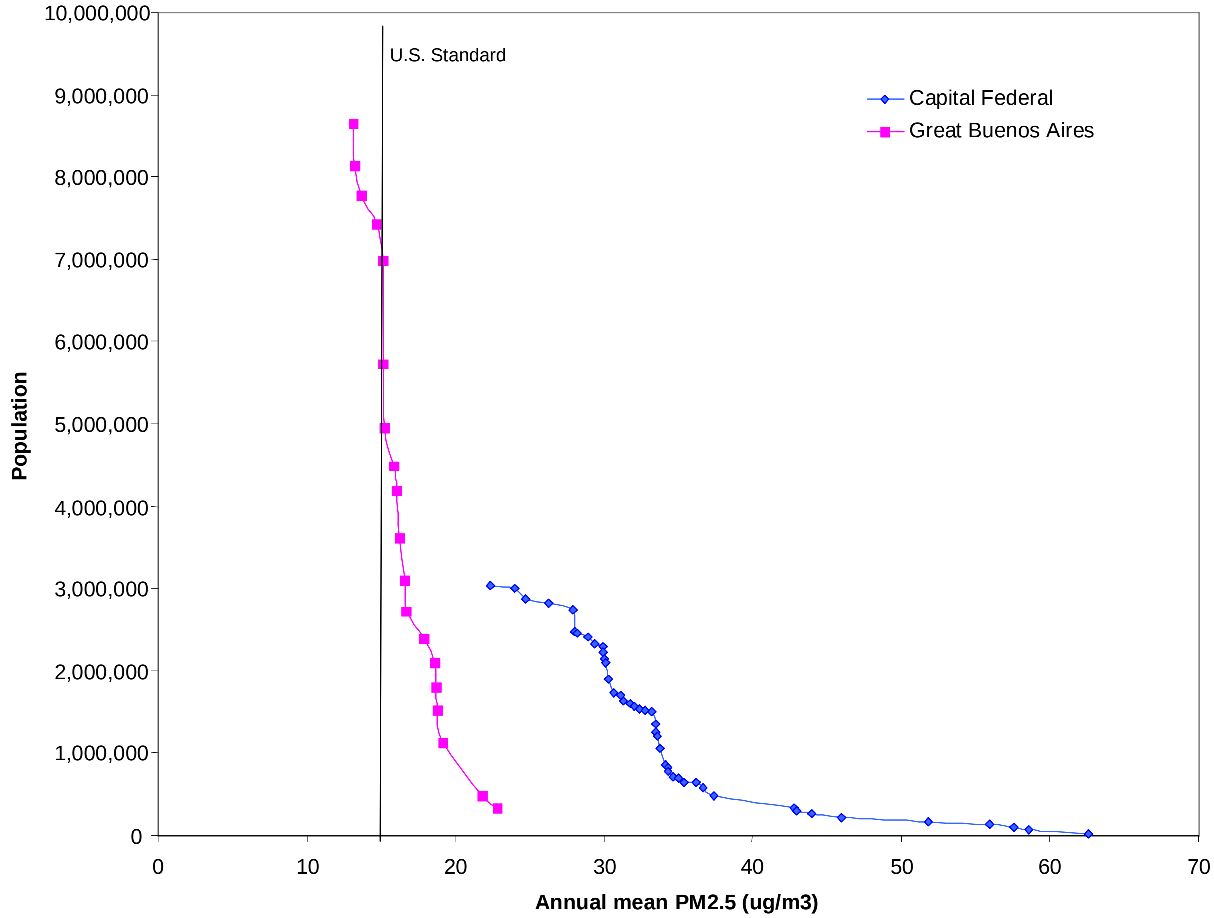

Source: own calculations based on Tarela and Perone (2002).

**Table 1. Air Pollution Changes (Base-Control): absolute (ug/m3) and percentage change**

| ***Annual Average PM2.5*** | | | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **Cum.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *CF* | *Mitigation* | *Abs.* | 0.7 | 1.4 | 2.0 | 2.7 | 3.2 | 3.6 | 4.1 | 4.6 | 5.6 | 6.6 | 7.7 | 8.7 | **50.9** |
| | | *%* | 2% | 4% | 5% | 7% | 8% | 9% | 10% | 10% | 12% | 14% | 16% | 17% | **10%** |
| | *Integrated* | *Abs.* | 2.3 | 4.7 | 7.0 | 9.4 | 10.6 | 11.8 | 13.0 | 14.3 | 16.2 | 18.1 | 20.0 | 22.0 | **149.6** |
| | | *%* | 6% | 13% | 18% | 24% | 26% | 28% | 30% | 32% | 35% | 38% | 41% | 43% | **29%** |
| *GBA* | *Mitigation* | *Abs.* | 0.2 | 0.3 | 0.5 | 0.7 | 0.8 | 0.9 | 1.1 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | **13.2** |
| | | *%* | 1% | 2% | 3% | 4% | 4% | 5% | 6% | 6% | 7% | 8% | 9% | 10% | **6%** |
| | *Integrated* | *Abs.* | 0.6 | 1.2 | 1.8 | 2.4 | 2.8 | 3.1 | 3.5 | 3.8 | 4.4 | 4.9 | 5.5 | 6.0 | **40.2** |
| | | *%* | 4% | 7% | 10% | 13% | 15% | 17% | 18% | 20% | 22% | 24% | 26% | 28% | **17%** |

Source: own calculations based on Tarela and Perone (2002).

**Figure 2. Population exposure to PM2.5 at BAMA in the year 2000**




Source: own calculations based on Tarela and Perone (2002).

**Table 2. Weighted (by Population) Air Pollution Changes (Base-Control): absolute (ug/m3) and % change**

| *Annual Average PM2.5* | | | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Cum. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *CF* | *Mitigation* | *Abs.* | 0.6 | 1.2 | 1.9 | 2.5 | 2.9 | 3.4 | 3.8 | 4.2 | 5.2 | 6.1 | 7.1 | 8.0 | **47.0** |
| | | ***%*** | 2% | 4% | 5% | 7% | 8% | 9% | 9% | 10% | 12% | 14% | 15% | 17% | **10%** |
| | *Integrated* | *Abs.* | 2.2 | 4.3 | 6.5 | 8.6 | 9.7 | 10.8 | 12.0 | 13.1 | 14.8 | 16.5 | 18.3 | 20.0 | **136.8** |
| | | ***%*** | 6% | 12% | 18% | 23% | 26% | 28% | 30% | 32% | 35% | 37% | 40% | 42% | **28%** |
| *GBA* | *Mitigation* | *Abs.* | 0.2 | 0.3 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.4 | 1.6 | 1.9 | 2.1 | **12.3** |
| | | ***%*** | 1% | 2% | 3% | 4% | 4% | 5% | 5% | 6% | 7% | 8% | 9% | 10% | **6%** |
| | *Integrated* | *Abs.* | 0.6 | 1.1 | 1.7 | 2.3 | 2.6 | 2.9 | 3.3 | 3.6 | 4.1 | 4.6 | 5.1 | 5.6 | **37.5** |
| | | ***%*** | 3% | 7% | 10% | 13% | 15% | 16% | 17% | 19% | 21% | 23% | 25% | 27% | **17%** |

Source: own calculations based on Tarela and Perone (2002).

From both Figures and Tables 1 and 2, it is clear that PM2.5 levels in CF are much higher than in GBA, that more improvement is expected in CF than in GBA, and that projected changes increase the closer the year 2012. At a more micro level, some barrios and districts appear to be more polluted than others. For CF, in the year 2000 there is no barrio with PM2.5 levels below the U.S. 15 ug/m3 standard[5]. This is not the case of the GBA, where for the same year, several (four) districts have PM2.5 levels below the U.S. standard.

## III. Human Health Impacts

As stated in Section I, the link between air quality (so, level of pollutants) changes and health is based on "epidemiological" studies. Those studies can be classified according to different characteristics: a) the type of exposure they are related to (short-term or long-term), b) the coverage (cross-section or longitudinal), c) the implicit functional form (linear, log-linear, logistic, etc.), and the type of population considered (only children, only adults, asthmatics, etc).

Short-term impacts have to do with acute exposure to a pollutant (i.e., exposure on a particular day that may imply an impact on that given day or the few days following that one) and long-term impacts have to do with a chronic exposure to a pollutant (i.e., exposure during a year or more).

With respect to coverage, epidemiological studies can be basically cohort or time-series based. Cohort studies follow selected individuals in the population during a period of time and evaluate if long-term exposure is related to some health impact (i.e., to mortality, hospital admissions, etc.). Time-series studies look at changes in pollution level and link them with health events in the overall population.

In turn, the form taken by the relationship between pollutants levels ($x$) and health ($y$), the latter can take several forms. The most usual are linear, log-linear and logistic. The linear form is simply: $y_s = \alpha + \beta \cdot x_s$, where s indicates the scenario and α summarizes all other variables that determine health different from pollution. So:

$$\Delta y = y_b - yc = \beta \cdot (x_b - xc) = \beta \cdot \Delta x \tag{1}$$

Where c is the control scenario (here, Mitigation or Integrated) and b is the Base scenario. The log-linear form is: $y_s = A \cdot e^{\beta \cdot x_s}$, which (after taking natural logarithms) can be written as: $\ln y_s = \alpha + \beta \cdot x_s$.

[5] National law 20.284 of 1973 does not establish standards neither for PM10 nor for PM2.5. The Province of Buenos Aires (decree 3.395 law 11.459 of 1996) does have the same standards as in the U.S. for PM10, but no limit for PM2.5 Finally, the City of Buenos Aires (ordenanza municipal 39.085 of 1983 does not have now any air quality standard for Particulate, but is projecting to have the U.S. one in a new Clean Air law, which is close to approval (Gómez, 2001).

Then,

$$\Delta y = y_b - y_c = A \cdot e^{\beta \cdot x_b} - A \cdot e^{\beta \cdot x_c} = A \cdot e^{\beta \cdot x_b}\left[1 - e^{-\beta \cdot (x_b - x_c)}\right] = -y_b \cdot \left[e^{-\beta \cdot \Delta x} - 1\right]$$

(2)

Finally, some CR are logistic and the way of calculation is similar, the only change is that the analogue formula for (1) and (2) is (for more details on its derivation, Abt 1999):

$$\Delta y = -\left[\frac{y_b}{(1 - y_b) \cdot e^{\beta \cdot \Delta x} + y_b} - y_b\right] \tag{3}$$

Finally, the corresponding middle value for human health impacts arise in each case from:

$$\Delta Health = \Delta y \cdot Population \tag{4}$$

A lower and an upper bound for human health effects is derived in the same way but using a lower and an upper limit for β, according to: $\beta_{low} = \beta - 1.96 \cdot \sigma_{\beta}$ and $\beta_{high} = \beta + 1.96 \cdot \sigma_{\beta}$.

But, there are no epidemiological studies in Argentina that link PM to any health impact. This lack of background is rare given the fact that countries as Chile, Brazil and Mexico (which can be thought as "comparable") have developed during the 90s lots of work on CR functions (for example, for Chile: Ostro et al 1996, Illabaca et al 1999, Ostro et al 1999 or Cifuentes et al 2000b, for Brazil: Saldiva et al 1994 and 1995 or Conceição et al 2001, and for Mexico: Romieu et al 1996, Borja-Aburto et al 1998, Loomis et al 1999, or Castillejos et al 2000). A clear example of this assertion is that only Mexico has six time-series published studies which link premature mortality to air pollution, when for Buenos Aires there is none.

Studies as $PM_{10}$ impacts for mortality (Ostro et al 1996) and medical visits (Ostro et al 1999) in Santiago de Chile and PM10 for mortality in Mexico City confirm the reliability of such a procedure since the resulting CR results were not significantly different than those in Western industrial countries. Other developing countries CR functions are not used here because they are the result of single studies not confirmed through meta-analysis (EPA´s argument to reject the inclusion of PM infant mortality study in its calculations), and anyway are also performed in a different situation than in Buenos Aires. This does not mean that all conditions for transferability are met, but this is at the moment the only way available.

### III.1. Selection of CR functions

Here, calculations for BAMA are performed without any threshold (including one may be considered in a later version of this work). This implies that reductions of air quality from any level are supposed to have a health impact. There is no level (threshold) that involves unobservable health effects. This is now the accepted practice both in the U.S. -EPA, 1999-, in the European Union and the World Health Organization -EC 1999a and 1999b-. For the reasons explained above, the selection of CR functions was based in a review of the literature. Table 3 summarizes the exact CR functions used here[6].

One of the keys in using dose-response functions to value health impacts for the different scenarios relies on avoiding double counting. Hence, for each of the four categories of health endpoints (and CR functions) listed in Table 3 (mortality, hospital admissions and emergency room visits, chronic morbidity and acute morbidity plus work losses due to morbidity), some CR are added in total health impacts (dark gray), some may be included in a later version sensitivity analysis (light gray), and others are not used but considered valid alternatives[7].

For long-run mortality, while Pope et al (1995) is the most usual CR function, we employ (as in Abt 2000) the newer Krewski et al (2000) because we do not have information on the annual median PM2.5 but on the average. Results from the classic Dockery et al (1993) can be presented in a sensitivity analysis. For short-term mortality, Schwartz et al (1996) is the study selected, but is only saved for the sensitivity analysis because of the possible double counting with long-term mortality. Finally, neonatal mortality impact is also excluded because according to EPA (1999) that pollution/health relationship is based on a single study (Woodruff et al, 1997) and so can not be considered sufficiently proven.

For Respiratory Hospital Admissions (RHA), separate CR functions are used for Pneumonia (ICD-9 480-7), Chronic Obstructive Pulmonary Disease (ICD-9 490-2, 494-6), and Asthma (ICD-9 493). Here, there are relatively older CR for Pneumonia and COPD by Moolgavkar et al (1997), may be presented in a sensitivity analysis. However, given the fact that they are related to the same pollutant measured in the same way, their incidence baseline rate and population to which it applies is the same, it would yield lower impacts basically because they only differ in the estimated coefficient. For sensitivity analysis, a CR function for "all respiratory hospital admissions" obtained as a pooling analysis in Abt (1999) can be used to cover the case that Pneumonia, COP, and Asthma may be underestimating this effect. For Cardiovascular Hospital Admissions (CHA), Samet et al (2000) was adopted. The alternative Schwartz et al (1993) is included in the sensitivity analysis. Finally Emergency Room Visits (ERV) for Asthma as calculated by Schwartz et al (1997) is added to the final impacts. However, as will be explained below ERV for asthma impact is not expected to be very realistic for BAMA because local data on ERV is not centralized and so is available only at each hospital level. Hence, local information with which to complement CR extrapolations is poor.

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[6] Note that as in Tarela and Perone (2002), PM2.5/PM10 ratio is 0.71. In addition, for those CR functions for which daily averages are needed as inputs, we made the raw guess of multiplying annual data by 3 in the case of PM10 and 4.33 in the case of PM2.5. This is clearly just a guess, based on the relationship among daily and annual average standards for PM10 and PM2.5.

[7] We do not present here a sensitivity analysis because we consider that the ranges would be too large because of the enormous uncertainties we had to deal with ath the moment of the calculations.

In terms of chronic bronchitis, we have only included the CR function by Abbey et al (1993), and not Schwartz (1993) or any pooled of those. We do so also on the base of poor local information. Hence, since we have only with very partial data, we are not able to consider separating prevalence rate from incidence rate as in Schwartz (1993)[8].

**Table 3. PM Health Endpoints/C-R Functions**

| | Source | Pollutant | Measurement | Func. form |
|---|---|---|---|---|
| **1. Mortality** | | | | |
| Long-term | Pope et al (1995) | PM 2.5 | annual median | log-linear |
| Long-term | Krewski et al (2000) | PM 2.5 | annual average | log-linear |
| Long-term | Dockery et al (1993) | PM 2.5 | annual average | log-linear |
| Neonatal | Woodruff et al (1997) | PM 10 | annual average | log-linear |
| Short-term | Schwartz et al (1996) | PM 2.5 | daily average | log-linear |
| **2. Hospital Admissions** | | | | |
| *Respiratory* | | | | |
| Pneumonia | Moolgavkar et al (1997) | PM 10 | daily average | log-linear |
| Pneumonia | Samet et al (2000) | PM 10 | daily average | log-linear |
| COPD | Moolgavkar et al (1997) | PM 10 | daily average | log-linear |
| COPD | Samet et al (2000) | PM 10 | daily average | log-linear |
| Asthma | Sheppard et al (1999) | PM 2.5 | daily average | log-linear |
| All respiratory | Pooled Abt Assoc. (1999) | PM 10 | daily average | log-linear |
| *Cardiovascular* | | | | |
| Cardiovascular | Samet et al (2000) | PM 10 | daily average | log-linear |
| Cardiovascular | Schwartz (1997) | PM10 | daily average | log-linear |
| *Emergency Room Visits* | | | | |
| Asthma | Schwartz et al (1993) | PM 10 | daily average | log-linear |
| **3. Chronic Morbidity** | | | | |
| Chronic Bronchitis | Abbey et al (1993) | PM10 | annual average | log-linear |
| **4. Acute Morbidity** | | | | |
| Acute Bronquitis | Dockery et al (1989) | PM 2.5 | annual average | logistic |
| Acute Bronquitis | Dockery et al (1996) | PM 2.5 | annual average | logistic |
| Lower Respiratory Symptoms | Schwartz et al (1994) | PM 2.5 | daily average | logistic |
| Upper Respiratory Symptoms | Pope et al (1991) | PM 10 | daily average | logistic |
| Asthma Attacks | Whittemore and Korn (1980) | PM 10 | daily average | logistic |
| Any of 19 Respiratory Symptoms | Krupnick et al (1990) | PM 10 | daily average | linear |
| **Work Losses Morbidity** | | | | |
| Work Loss Days | Ostro (1987) | PM 2.5 | daily average | log-linear |
| Restricted Activity Days | Ostro (1987) | PM 2.5 | daily average | log-linear |
| Minor Restricted Activity Days | Ostro and Rothschild (1989) | PM 2.5 | daily average | log-linear |

Source: Review of several related publications
Note: *COPD is Chronic Obstructive Pulmonary Disease
Dark gray CR summed in health impacts. Light gray are for sensitivity analysis. White rows are those similar but discarded.

[8] The incidence rate is related to the number of new cases that occur over a given period of time. Note that this is different from prevalence rate, which refers to the percentage of individuals which have a particular disease (does not estimate when it first began).

For acute morbidity (those illnesses not requiring hospitalization), there is a wide array of functions. However, in the same line as for RHA, we calculate the impact of some of them (Acute Bronchitis, Lower Respiratory Symptoms, Upper Respiratory Symptoms and Asthma Attacks). Then, as an alternative for sensitivity analysis, we include "Any of 19 Respiratory Symptoms", which covers the above and others. Due to the same argument used above (the lack of national data for symptoms), no further calculations are done because of the low local validity expected of the results. Finally, Restricted Activity Days (RAD) are defined as "days where a respondent was forced to alter his normal activity... The RAD measure includes days of work loss or bed disability as well as minor restrictions" (Ostro, 1987). Thus, to include RAD together with Work Loss Days (WLD) and Minor Restrictions in Activity Days (MRAD) would imply double counting. So, only the latter two are included in the estimations.

The use of CR functions to value avoided health costs due to air quality improvements requires then local information inputs: mainly Population and Health Incidence Baselines. The details on them for the case of BAMA follow in the next two subsections.

### III.2. Population[9]

The information for population needed for the analysis has to do with present and future (up to the year 2012) population. Population comes from census that take place every 10 years in Argentina (the last two ones were in 1991 and 2001: 1991 data are final and easily available but 2001 are limited). Many epidemiological studies deal with particular age cohorts (gender specifications are not present), so population data has to be detailed by age group. For example, Hospital Admissions (except for Asthma) have to do with people 65 or older, while WLD or MRAD refer to population between 18 and 65 years old. Published population information is not available in a way to match exactly the raw air modeling data by Tarela and Perone (2002) with grids of 250 m. by 250 m., but is available by political division.

In fact, for CF, census population is organized by "distritos escolares" and in GBA by "distritos". Because "distritos escolares" is not an appealing division in terms of characteristics of neighborhoods, in CF, after census, all information is usually matched to "barrios". Hence, population information is taken by political division of barrios for CF and distritos for GBA. More precisely, for CF, population for 2001 by political division is from projections by the Dirección General de Estadística y Censos del Gobierno de la Ciudad de Buenos Aires[10]. For GBA, 2001 population is census based.

However, those projections (and preliminary census results) are not by age groups. Hence, to be able to make such a division, 1991 census demographic structure by barrios and distritos was taken to be holding for the present and the projections (INDEC 1996a and INDEC 1996b). But, this is not all, because this information has only 5 age groups. To get more detail

[9] A quite important point to make here is that by population we mean those who live there and not people who travel for work. This could be included if there was information on those flows. In any case, if data became available and such issue was incorporated, it would yield higher benefits estimates (because net flows are from GBA to CF, where reductions are expected to be larger).

[10] It was not taken from census data because of two reasons. One is that the 2001 census information is not yet available at level of barrios, and the other is that the aggregate population for CF according to the census is quite far from the projections (2.759.971 people versus 3.043.431 people) but it is not clear if the cause of such a decrease is that people left the city for the week-end and simply did not reply the census questionnaire or if the effect is real (in that respect, Clarín 2002).

within those groups (i.e. for example, how many of those people of those in the range between 0 and 4 are below 1 year old), we use ECLAC/CELADE (2000).

In addition to population by age group (and baseline health data, we deal with in the next subsection), another input for some of the CR is the number of asthmatics in the overall and the children population. In the U.S. (as reported by Abt 2000), the estimated number of people who suffer from asthma is 5.61% for the overall population and 6.91% for children (under age 18). In Argentina, asthma incidence rate available refers to children and seems to have been increasing.

Here again, the geographic coverage of the study is important. Since, Salmún et al (1994) have the detail to separate asthma incidence rates for CF and for GBA, we take those figures for our calculations[11]. Hence, the incidence rate is 8.15% for CF (the average of 10.2 and 6.1%, for 6 and 12 age old respectively) and 15.89% for GBA (the average of 16.95% and 14.83%, for 6 and 12 age old respectively). Then, asthma for the overall population is calculated using the overall/children asthma rate reported for the U.S. (5.61%/6.91% = 0.81). However, those figures seem high, not only compared to the U.S. one but also with the European Community one: 3.5% of asthmatics in the overall population (EC 1999a and 1999b).

### III.3. Baseline incidence rates

As above, non-linear CR functions require information on baseline incidence rates. When possible, that baseline was obtained from Argentina information. Table 4 summarizes (when available) the ratio of U.S.' health endpoint incidence rates with respect to those in Argentina (no comparison to Europe is made because there is no such detailed information readily available). This calculation pretends only to check for the order of magnitude of the Argentina's rates. We assume that all of them are constant in time because there is no known projection.

In general, RHAs are lower (except perhaps for All RHA) in BAMA than in the U.S.. Of those, the main difference in the baseline incidence rates is in Asthma Hospital Admissions. They appear to be approximately six times greater in the U.S. than in Argentina. This contrast with the higher percentage of asthmatics found in studies for Argentina (discussed in Section III.2.).

**Table 4. Baseline Incidence rates for CR functions: ratio U.S. to Argentina's figures Year 2000**

| | CF | GBA |
|---|---|---|
| Daily Pneumonia Hospital Admissions/ person >=65 | 1.95 | 2.36 |
| Daily Chronic Obstructive Pulmonary Hospital Admissions/ person >=65 | 3.13 | 3.64 |
| Daily Asthma Hospital Admissions/ person | 2.98 | 6.46 |
| Daily All Respiratory Hospital Admissions/ person >=65 | 1.10 | 1.45 |
| DailyHospital Admission Cardiovascular disease/person>=65 | 1.60 | 2.64 |
| Daily WLD/person | 0.80 | 1.01 |
| Daily MRAD/person | 0.80 | 1.01 |

Source: own calculations based on information by Dirección de Estadísticas de la Salud (GCBA) and Dirección de Información Sistematizada (Min. de Salud, Provincia de Buenos Aires) and Encuesta de Indicadores Laborales.

[11] As other references for the number of asthmatics in Argentina: For the 70´s Crisci and Asrilant found rates of 2.5% and 3.4%, then, for the 80´s Bustos (all cited in Salmún 2001) reports rates of 5.3%, and for the 90´s Salmún et al (1994 and 1999) report (for a study made in 1993) rates of 15% and 10.4% for children 6 and 12 years old respectively, while ISAAC (International Study of Asthma and Allergies in Childhood) project state that those percentages are 17.2% and 11.2% for children aged 6 and 13 respectively.

For CF and GBA, the general mortality rate is 11.04 and 8.12 per 1000 people for the year 2000. When calculated for people above 30, the result changes to 18.27 and 16.04 per 1000 persons above 30 (INDEC, 2001).

Morbidity data is different from mortality information because it comes generally from an expanded sample, not from the actual register of hospitalizations. Baseline incidence rates for hospital admissions are based on first-listed discharge figures in public hospitals for CF and GBA in the year 2000. Information on other sectors' hospitalizations is not centralized. According to the newest information available (Catastro Nacional de Recursos y Servicios, 1998), for CF, 23.1% of hospitals are public and they deal with 39.1% of hospital admissions. For GBA, the information from the National Health Ministry is considered here more reliable (in particular, because of the gap between national data 1995 and the Province of Buenos Aires – PBA- 2000 ones[12]). Hence, for GBA, to extrapolate all hospital admissions based on public sector ones, we use the percentage of number of beds in public hospitals over those in the whole system (we do not use percentage of hospital admissions for PBA because they are not published at the national level).

The only centralized register for ERV by diagnose is at the level of each hospital, and so there is no aggregate number we can use for that endpoint[13]. Hence, the US figure is used instead. There is no available data for ERV for the same reason as for CF.

There is no information for illnesses not requiring hospitalization. For example, for chronic bronchitis, the only register available for CF are the hospitalizations due to that cause (9 cases in CF public hospital registered for the year 2000). Hence, as for ERV, we use the U.S. baseline instead.

Finally, there are two known sources of information for the baseline of WLD. One is a monthly serie of work loss days in the industry sector for the City of Buenos Aires, for which there is data from 1977 to 1989 (DataFIEL based on information Ministerio de Economía de Argentina). Another (newer) source is a special module of a survey of Labor Indicators performed annually and by the Ministry of Labor since July 1999, which includes a variety of sectors (EIL, 2001). There is no information in any form for MRAD. Hence, the ratio annual MRAD/WLD per person 18-65 in the US (7.8/2.36 = 3.3) is used to adjust the MRAD baseline based on the BAMA baseline for WLD.

### III.4. Health impacts: Results obtained

Table 5 summarizes the results obtained for the period 2000-2012 by health endpoint. Health impacts are calculated at the level of each barrio and district, and then aggregated for CF and GBA. The results obtained show that:

1) Premature mortality avoided can be considered high. People in Santiago de Chile or Mexico City are used to accept that pollution can cause premature death but people in

[12] For the Province of Buenos Aires, the data reported by the Dirección de Información Sistematizada for the year 2000 is: 83.8% for number of public hospitals and 65.3% for rate of beds in public hospitals over the total of the health system. Note that there is no separate information for the 19 districts of PBA, but for the province as a whole.

[13] The only information on doctor visits known to the Health Ministry is the total number of visits to "consultorios externos" (usual -not emergency- medical visits) of public hospitals (in Capital Federal, and by Regiones Sanitarias for the Conurbano Bonaerense). Doctor visits in public hospitals correspond to 25.31% of the overall doctor visits (Fosco, 1995).

Buenos Aires may find surprising that some thousand people die before what they would have if air quality was higher. However, this result is not due to a high CR function coefficient, but to a large population (around 12 million people) and to high reductions expected. In fact, CF with 1/3 of the population of GBA has higher long-term mortality impacts because reductions (as shown in Table 1) are expected to be considerably higher (also, mortality rate for people over 30 is higher in CF than in GBA).

2) Hospitalizations and Emergency Room Visits yield relatively low estimates. One of the main reasons of it may be bad quality information because we have only data on the public health sector. This implies that (even extrapolating for the whole sector, by the % of hospitalizations and number of beds), baseline incidence rates are very low. For example, as already discussed in Section III.3 (Table 4), when compared to the U.S., Asthma Hospital Admissions per person are computed 3 to 6 times lower in BAMA than in the U.S. An extra reason may be that (except for Asthma) those impacts apply for people over 65 years old, which accounted (in the year 1991) just for 16% and 8% of the overall population of CF and GBA respectively.
3) With respect to symptoms, the most important remark may be that in that case GBA suffers greater harm than in CF. The origin of such difference cannot be found in the baselines health rates because as there is no data for Argentina the same (U.S.) estimation is used for both zones. The explanation is then that the relationship children in CF to children in GBA lowers (with respect to overall population) to 0.23. In the case of URS and Asthma Attacks for which input to the CR functions is not children but asthmatics (as % of children 9-11 years and in the overall population respectively), as discussed in Section III.2, those percentages are almost half in CF than in GBA.
4) WLD and MRAD seem high, but they are not. For example for Chile, a reduction of Pm2.5 from 35 to 15 ug/m3 yields savings of around 1 millions of days (WLD) in year 2000. But, baseline incidence rates are lower in Argentina than in other countries (Table 4 for a comparison to the U.S.).

## IV. Valuation of Human Health Impacts

For mortality, there are several alternatives on how to calculate the value of a statistical life. The most well known are the Human Capital approach and the WTP (or, "willingness to accept" a given mortality risk) studies mostly based on CVM and hedonic pricing. The former is considered a lower bound of the latter since it uses foregone future incomes as the valuation vehicle, but does not include the subjective value people assign to life (in terms of consumption, leisure, etc.). In fact, studies in the United States suggest that WTP estimates are 8 to 20 times those under the HC approach (Viscusi, 1993).

In a similar way, for morbidity (illnesses which do not imply death), there are three type of values involved (also in increasing order of difficulty for calculation): the value of time lost due to illness (leisure and work), the medical costs (for hospitalization, medicines, etc.), and the value of pain and suffering. As was the case for the forgone income in mortality, the time lost to work because of illness and medical costs define a lower bound. Work losses imply productivity losses (proxied by wages) and medical costs are calculated directly or indirectly through medical expenses. Both form the so-called Cost of Illness (COI). But, the upper bound can only be reached when the subjective value (mainly value of pain and suffering and leisure lost) is added to those costs (we will call this subjective value the WTP, which is additional to the COI[14]).

**Table 5. Cummulative Health Impacts according to PM Reductions bewteen Different Scenarios: 2000-2012**

| | | Base/Mitigation | | | Base/Integrated | | |
|---|---|---|---|---|---|---|---|
| | | Central | Lower | Upper | Central | Lower | Upper |
| **Long-term Mortality** | | **11,148** | **(5,485,** | **16,756)** | **32,393** | **(16,066,** | **48,305)** |
| | CF | 7,022 | (3,461, | 10,535) | 19,978 | (9,957, | 29,650) |
| | GBA | 4,126 | (2,024, | 6,221) | 12,415 | (6,109, | 18,656) |
| **Hosp. Adm. Pneumonia** | | **332** | **(289,** | **345)** | **356** | **(345,** | **358)** |
| | CF | 158 | (150, | 159) | 160 | (159, | 160) |
| | GBA | 174 | (139, | 186) | 196 | (186, | 198) |
| **Hosp. Adm. COPD** | | **128** | **(49,** | **133)** | **134** | **(89,** | **135)** |
| | CF | 58 | (32, | 59) | 59 | (50, | 59) |
| | GBA | 70 | (17, | 74) | 76 | (39, | 76) |
| **Hosp. Adm. Asthma** | | **110** | **(71,** | **116)** | **118** | **(102,** | **119)** |
| | CF | 46 | (38, | 47) | 47 | (45, | 47) |
| | GBA | 64 | (33, | 69) | 72 | (57, | 72) |
| **Hosp. Adm. Cardiovascular** | | **1,360** | **(1,308,** | **1,398)** | **1,537** | **(1,522,** | **1,546)** |
| | CF | 787 | (773, | 796) | 820 | (819, | 821) |
| | GBA | 573 | (534, | 602) | 716 | (703, | 725) |
| **ERV Asthma** | | **986** | **(825,** | **1,015)** | **1,032** | **(995,** | **1,035)** |
| | CF | 236 | (227, | 237) | 237 | (237, | 237) |
| | GBA | 750 | (598, | 778) | 794 | (758, | 798) |
| **Chronic Bronchitis** | | **6,909** | **(8,** | **13,465)** | **19,570** | **(22,** | **36,711)** |
| | CF | 4,077 | (5, | 7,861) | 11,161 | (13, | 20,364) |
| | GBA | 2,832 | (3, | 5,604) | 8,409 | (9, | 16,347) |
| **Symptoms Acute Bronchitis** | | **23,519** | **(-5,739,** | **50,091)** | **65,737** | **(-17,388,** | **130,902)** |
| | CF | 10,047 | (-2,537, | 20,710) | 26,255 | (-7,594, | 48,223) |
| | GBA | 13,472 | (-3,203, | 29,381) | 39,482 | (-9,794, | 82,679) |
| **LRS Symptoms** | | **26,018** | **(25,618,** | **26,045)** | **26,046** | **(26,035,** | **26,046)** |
| | CF | 4,653 | (4,652, | 4,653) | 4,654 | (4,654, | 4,654) |
| | GBA | 21,365 | (20,967, | 21,392) | 21,391 | (21,381, | 21,391) |
| **URS Symptoms** | | **378,479** | **(220,301,** | **397,078)** | **405,719** | **(349,940,** | **408,046)** |
| | CF | 40,725 | (35,119, | 40,955) | 40,983 | (40,178, | 40,984) |
| | GBA | 337,753 | (185,182, | 356,123) | 364,735 | (309,762, | 367,062) |
| **Asthma Attacks** | | **339,697** | **(183,954,** | **380,321)** | **406,893** | **(318,176,** | **416,711)** |
| | CF | 58,747 | (46,030, | 60,229) | 60,832 | (57,946, | 60,917) |
| | GBA | 280,950 | (137,924, | 320,092) | 346,061 | (260,231, | 355,794) |
| **WLD** | | **570,348** | **(565,188,** | **573,941)** | **585,889** | **(585,283,** | **586,235)** |
| | CF | 177,350 | (177,132, | 177,470) | 177,632 | (177,631, | 177,632) |
| | GBA | 392,998 | (388,056, | 396,471) | 408,257 | (407,652, | 408,603) |
| **MRAD** | | **1,912,825** | **(1,901,604,** | **1,919,766)** | **1,934,988** | **(1,934,348,** | **1,935,237)** |
| | CF | 585,799 | (585,599, | 585,871) | 585,917 | (585,917, | 585,917) |
| | GBA | 1,327,027 | (1,316,005, | 1,333,896) | 1,349,072 | (1,348,432, | 1,349,320) |

Note that applying the CR function reported in Table 3 for Symptoms of Acute Bronchitis yield a negative lower bound.

[14] COI has to be added to the WTP estimates only if individuals do not include productivity losses and medical expenses in WTP because, for example, they do not believe they directly pay for them.

Here, estimates of HC for mortality and Productivity Losses for morbidity are national estimates. But, there is information in Argentina neither for the WTP for life or for the WTP to avoid hospitalizations or symptoms. Hence, other countries estimates are transferred to BAMA. Such adjustment occurs by multiplying each relevant figure by the ratio of Argentina/other country GDP per capita. A further adjustment by WTP-income elasticity is also performed. COI is a hybrid because there is very little national information, so some transfer calculations are also performed and local values are used for comparison. Basically, COI in other countries are adjusted by the ratio of medical visit costs or GDP health expenditure ratio. In any case, valuation of health effect calculations are based on (4):

$$\Delta ValueHealth = \Delta y \cdot Population \cdot UnitEconomicValue \qquad (5)$$

If there are uncertainties for human health impacts, those also exist for their respective valuation. The main reason of that is the need of lots of information from different sources (and some values, which are simply non existent as WTP). But, most of all, the main difficulty is that since Argentina abandoned the convertibility system (1 U$S = 1 $) in January 2002, the economy has taken such a shock that previous projections (as those in SRNyDS 1999) cannot be taken from granted. While we use an assumption of GDP per capita growth to calculate HC value of life, for the rest, we will assume that everything (unemployment rate, wages, etc.) remain what they were in year 2000. Only a central value will be provided in this version. Obviously, this is a strong but it is basically impossible to project the economic future of Argentina for the medium and more so for the long run at this point.

Hence, the absence of good information for each of those values implies that some assumptions have to be made to obtain approximations to the benefits of reducing pollution. As in Cesar et al (2000), aggregation of the economic value results is such that four totals are presented[15]:

Option 1: Mortality valued by the HC approach, Morbidity based on Medical costs and Productivity losses.

Option 2: Mortality valued by the HC approach, Morbidity based on WTP, Medical costs and Productivity losses.

Option 3: Mortality valued by WTP, Morbidity based on Medical costs and Productivity losses.

Option 4: Mortality valued by WTP, Morbidity based on WTP, Medical costs and Productivity losses.

### IV.1. Mortality Valuation

This estimate is key because, for example in EPA (1997 and 1999), 80% of monetized benefits due to air quality improvements are attributed to reductions in premature mortality.

[15] Those options are taken as the whole interval of the valuation section. No confidence interval for each one of them is performed. We consider that it would complicate the exposition and will not add to the order of magnitude of the results.

### IV. 1. 1. Human Capital Approach

Deriving the VSL by the HC approach requires calculating the present value of future earnings and so applying the following formula for each age range:

$$PVFE_i = \sum_{j=i}^{65} p(alive)_i^j \cdot p(working)_i^j \cdot Income_j \cdot (1+g)^{j-i} \cdot \left(\frac{1}{1+r}\right)^{j-i} \qquad (6)$$

where $p(alive)_i^j$ is the probability of a person of age i to be alive at the age j, $p(working)_i^j$ is the probability of a person of age i to be working at the age j, $Income_j$ is the expected income of a person at the age j, g is the growth rate of per capita income, and r is the discount rate.

The data for *p(alive)* were calculated directly from the survival function (*l*) reported in Grushka (1996)[16]. The *p(working)* is taken from the October 2000 Encuesta Permanente de Hogares (EPH) surveyed by INDEC as reported under Employment rate (percentage of working population over all population by age range for BAMA, and we suppose it remains approximately constant). *Income* is based on a special processing of EPH with detail of hourly income (this includes wages, and any other income) by political division (CF and GBA) and, more importantly, by age ranges (INDEC, 1999). Income per capita growth rate, *g*, as in Gaioli (2001) and Tarela and Perone (2002), is based on the average scenario projected by FIEL (SRNyDS, 1999), so is 2.4%. Finally, the discount rate r is taken to be 7%[17] (alternative rates of 3 and 10% are thought for the sensitivity analysis).

Based on the mortality distribution for CF and GBA by age range (MS, 2001), a single number for VSL based on HC approach results in: $63,564 for Capital Federal and $44,109 for Conurbano Bonaerense. Note that those are pesos ($) of 1997, not actualized because Consumer Price Index has been stable or even decreasing during the period 1997-2000[18].

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[16] INDEC publishes after each census a mortality table for actuarial calculations. The last one is dated 1995 and reproduced in Grushka (1996).

[17] As is well-know, the choice of the discount rate is a controversial issue, especially when dealing with environmental costs (in that respect, refer to Portney and Weyant, 1999) that justifies its inclusion in the sensitivity analysis. Note that, in the U.S. the discount rate used by public agencies for benefit-cost analyses of public investments is 7% (set by Office of Management and Budget), while in the EU a rate between 2 and 7 % is recommended (EC 1999a and 1999b). In other developing countries, as for example Chile, they use higher rates (in Chile, 12%). Argentina at some point had also established (resolution 110/96) 12% as the social discount rate but nowadays there is no official figure (resolution 100/97).

[18] This is in the same order of magnitude than the Argentine Labor Risks Act (law 24.557 of 1996) figure, which establishes a maximum value for compensations of 180.000 pesos (decree278/00).

### IV.1. 2. WTP Transfer Values

### Value of a Statistical Life (VSL)

As explained above, WTP for mortality or morbidity are not available for Argentina at all. This is a common issue in other developing countries[19]. Transfer of WTP values can be made in two ways: 1) by transferring average WTP estimates from a given study to a policy site, or 2) transferring a WTP function based on a meta-analysis of existing similar WTP studies. As shown by Brouwer (2000), the latter is a better option. However, to do so, we would need to have available a WTP function (which in fact we do not have) and even if we had such a function we would need all the variables which determine WTP (age, health status, income, etc.) in order to use as an input. Finally, an intermediate option and the one adopted here, given the information available for BAMA, is to transfer the average WTP at the study site adjusted by the relative income between both sites according to the following formula:

$$WTP_{ijp} = WTP_{ijs} \cdot \left( \frac{Income_p}{Income_s} \right)^{\varepsilon} \tag{7}$$

where i = pollutant, j = health effect, p = policy site, to which the WTP is transferred, s = study site, where the WTP is transferred to, and, , is the WTP income elasticity (which is assumed constant in time).

Relative income among countries is the ratio of 2000 PPP GDP per capita as calculated by the World Bank (http://www.worldbank.org/data/). We calculate this ratio for Argentina with respect to the U.S. and with respect to the EU.

To define the values of the elasticity is also important because the further its value is from 1 implies that people with less income are willing to pay relatively more for environmental goods than people with higher income. The literature varies in that respect, but because elasticity is found generally to be less than 1 (not a luxury good, as one might think), WTP adjusted down by Income ratio, increase again after the elasticity adjustment. An elasticity value of 0.5 is used here and a lower and upper bound of 0.3 and 0.7 may be included in a later version sensitivity analysis.

Mortality values to be transferred have two main references: EPA (1990 and 1999) use 4.8 millions of 1990 dollars (around 6 millions of 2000 dollars, by adjusting with the U.S. Consumer Price Index), while EC (1999a and 1999b) utilize 3.1 millions of ECU based mainly on UK studies.

Finally, a last issue related to the VSL is the fact that when looking at statistical lives saved for pollution causes, approximately 75% are in the range of people 65 years of age or older (Krupnick et al, 2000), while WTP studies for the VSL are in the 35-45 ages band. Hence, based on variation in VSL by age, it is possible to adjust the VSL. Intuition would say that older people value less their life because they have a lower life expectancy, but it may also be the case that because they have fewer years to live they fear the end and so assign higher values. The main

[19] This is the case of Mexico according to Cesar et al (2000) and Brazil (Seroa da Motta and Fernandes Mendes 1996), but not of Chile where a preliminary figure of WTP for mortality based on CVM is available (Cifuentes et al 2000c).

reference on this issue is Jones-Lee et al (1985). Hence, an extra adjustment is made according to the following formula (in a similar way as in Conte Grand, 1997)[20]:

$$0.75 \cdot (0.85 \cdot VSL) + 0.25 \cdot VSL = 0.8875 \cdot VSL \tag{8}$$

So, the VSL adjusted by income (and elasticity) and by age yields a VSL of around 3.2 and 1.8 million dollars if value is transferred from the U.S. or Europe respectively. In our calculations, we take the more conservative value (and so, the VSL using the WTP approach is approximately 28 times larger than using the HC approach for CF, which is quite in line with Viscusi, 1993).

**Value of a Statistical Life Years Losts (VSLY)**

As was seen in the previous subsection, adjustment of VSL by age only is not very significant (less than 12% of the VSL). A more important issue seem to be how many years are lost because of pollution. A rational guess is that air pollution is only one additional factor that determines mortality.

Average VSL year can then be obtained by simply dividing VSL by the mean number of years remaining of life. According to INDEC (1995): Age 40 - Life expectancy of an individual of age 40 = 36.6. Here we use directly mortality actuarial tables and a discount rate in the following formula:

$$VSLY_i = \frac{VSL}{\sum_{j=i}^{99} p(alive)_i^j \cdot \left(\frac{1}{(1+r)}\right)^{j-i}} \tag{9}$$

The VSLY calculated as (9) is used here to approximate a new VSL by assuming as in EC (1999b) that for acute pollution events the loss of life is on of average 0.75 years, and this figure goes up to 5 years for chronic events[21]. Long-term mortality has to do with chronic effects and so the latter is used in calculations (in fact, a value of 6.9 years lost as in Viscusi et al 1997 is the one chosen because its source and way of derivation is clearer)[22]. As a result, the new VSL is U$S 851,054 based on US-based adjusted VSL and ECU 475,753 based on EU-based adjusted VSL. Despite all possible criticisms on the VSLY in the literature, this last number is the one used for valuation here. We do so on purpose to avoid arriving to excessively high mortality monetized benefits, which then become not credible to policy makers. However, for a later version of this work, we project to use the VSL for mortality in a sensitivity analysis.

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[20] In congruence with this, Pearce (2000) recommends to value life for older people from 1/3 to 3/4 of the mean VSL.

[21] Note that this type of estimations could be easily derived for Argentina. In fact, MS (1999) reports percentage of years of life lost by aggregate medical reason by political division.

[22] Note that this is a simplified calculation, which does not take into account explicitly latency period, etc. as in EPA (1999) or Abt (1999 and 2000).

### IV.2. Morbidity valuation

#### IV.2.1. Productivity losses

WLD and MRAD include all of the productivity losses that are due both to hospital admissions, emergency room visits, and symptoms. Hence, one option is to disaggregate what is due to what as in Cesar et al (2000) and EC (1999a and 1999b). In that case, net (only due to symptoms) RAD are obtained by assuming that Respiratory Hospital Admissions last 10 days on average, those admissions due to Congestive Heart Failure and to Cerebrovascular conditions last 7 and 45 days respectively. A similar comment holds for MRAD, which include also Asthma Attacks. These calculations could have been made here[23], but there were discarded because no matter what the origin, WLD and MRAD are productivity losses. So, while very interesting, the only gain of that methodology is to be able to disaggregate productivity losses by type and that is not a goal here.

Hence, WLD are valued according to the average income (median income is not available) in each political division. According to INDEC (1999), the average daily income is $ 39.2 in CF and $ 25.6 in GBA assuming an 8-hour working day. For MRAD, we use the fact that according to Lvovsky et al (1997) for ill days about 40% are bed days and the rest are worked days with some problems. Hence MRAD are valued at 60% of wages. Note that wages correspond to the formal sector, adjustments for informality as in Cesar et al (2000) could be introduced.

#### IV.2.2. Medical costs

Medical costs include treatment, laboratory and medicine costs. So, the relevant items have to be included in relation to Hospital Admissions, Emergency Room Visits and Symptoms. Local information is limited here again. Only 65.9% of BAMA population (18 years and over) contribute to the health system, the rest goes to public hospitals. Of those affiliated to the health system, 70.9% have health systems related to their professional activity ("obras sociales" for construction workers, people working in education, etc.) and 20.7% belong to health firms ("prepagas") which are not linked specially to any activity (MS, 2002). Table 6 reports average expenditure per capita for BAMA for some categories. However, this information does not allow quantification of each item (Hospital Admissions, Emergency Room Visits and Symptoms), but it is a reference for quantification (medical costs cannot be more than $411/person/year)[24].

As a consequence of the lack of information, we have estimated Medical costs based on U.S. EPA (1999) estimates (adjusting by GDP per capita ratio[25]). The results are shown in Table

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[23] While there is no information for length of stay in hospital by cause, there is an average figure for public hospitals for all causes of 15 and 8 days per stay for CF and GBA respectively (MSPBA, 2002 and GCBA, 1998). Note that the first figure is biased up because the average for the Capital includes specialized hospitals as psychiatric ones, which have nothing to do with pollution caused hospitalizations.

[24] An alternative could be to take health costs from the "Nomenclador de Prestaciones Hospitalarias", which has what the public sector pays to "prepagas" when somebody who is affiliated to them goes to a public hospital. But, further work is required to value a Respiratory Admission for example because the Nomenclador includes item by item. A work as in Holz (2002) for Chile is required.

[25] An indirect way to approximate a medical cost estimate for Argentina used in Conte Grand (1997) is to take the US figures and then adjust them by the ratio of the two countries' doctor visits costs (this constitutes the central

7. As expected those values seem to be rather high, because the U.S. is known for its expensive medical system. Best guess estimations think about hospital admissions costs of $200 per day per person (which with an average stay of 10 days -discussed above-) implies costs of $2000. This is also true for medical visits (not emergency), for which expected costs in BAMA are $25[26].

**Table 6. Medical Costs for BAMA**

| Type of expenditure | Average monthly expenditure | |
|---|---|---|
| | $ | % |
| Affiliation | 5.39 | 15.7 |
| Medical Visits | 2.97 | 8.7 |
| Medicines | 12.29 | 35.9 |
| | | |
| TOTAL | 34.26 | |

Source: Table 11 MS (2002).

However, no much discussion will be made on this issue because hospitalization impacts seem really low. There are also minor medical costs which could be assigned to Symptoms impacts (if not included in WTP values) but the lack of data on this issue implies that no account is made from them.

**Table 7. Central Unit Values for Calculations of Benefits (r =7%): $ of 2000**

| | | 1. HC/Prod. Losses | 2. Medical costs | | 3. Adjusted WTP | | |
|---|---|---|---|---|---|---|---|
| | | | For the U.S. | Arg. Equivalent* | For the U.S. | For the EU | Arg. Equivalent* |
| **Long-term mortality** | | | | | 6,327,774 | 3,354,098 | 475,753 |
| | CF | 63,568 | | | | | |
| | GBA | 44,109 | | | | | |
| **Hosp. Adm. Pneumonia** | | | 10,453 | 6,293 | | | |
| **Hosp. Adm. COPD** | | | 10,353 | 6,233 | | | |
| **Hosp. Adm. Asthma** | | | 8,275 | 4,982 | | | |
| **Hosp. Adm. Cardiovascular** | | | 12,252 | 7,377 | | | |
| **Emerg. Room Visits Asthma** | | | 256 | 154 | | | |
| **Chronic Bronchitis** | | | | | 342,754 | | 206,370 |
| **Symptoms Acute Bronchitis** | | | | | 59 | | 36 |
| **Symptoms LRS** | | | | | 16 | | 9 |
| **Symptoms URS** | | | | | 26 | | 16 |
| **Asthma Attacks** | | | | | 43 | | 26 |
| **WLD** | | | | | | | |
| | CF | 39 | | | | | |
| | GBA | 26 | | | | | |
| **MRAD** | | | | | 51 | | 30 |
| | CF | 24 | | | | | |
| | GBA | 15 | | | | | |

Note:* are scarce national data ** are U.S. (or Europe, when available) values adjusted by elasticity (assumed 0.5) and ratio of PPP GDP per capita.
Details of the various sources are explained in the text.

bound for the medical costs estimates) or by the ratio of household expenditures on medical services in both countries. However, this was not done here because even if done in that way uncertainty remains very high.

[26] Personal communication with Dr. Federico Tobar, National Health Ministry.

### IV.2.3. WTP Transfer Values

WTP values have to do with symptoms (for which there is no other way to assess them). It has also to do with WTP for MRAD. Table 7 summarized WTP values, which are also transferred from EPA (1999).

## V. Monetized Benefits: Results obtained

Combining results in Table 5 (Health Impacts) and Table 7 (Unit values) in (5), monetized benefits of health impacts in each scenario are obtained. The present values for the whole period 2000-2012 are summarized in Table 8. Finally, Table 9, aggregates benefits under four options by type of value, as discussed above.

**Table 8. BAMA 2000-2012 Value of Health Impacts according to PM Reductions Different Scenarios (r = 7%, elasticity = 0.5, millions $ 2000)**

| | Base/Mitigation | Base/Integrated |
|---|---|---|
| **Long-term mortality** | | |
| ***HC Approach*** | **491** | **1,436** |
| ***WTP Approach*** | **4,146** | **12,167** |
| ***Medical Costs*** | **11.13** | **12.51** |
| **Hosp. Adm. Pneumonia** | 1.71 | 1.85 |
| **Hosp. Adm. COPD** | 0.66 | 0.69 |
| **Hosp. Adm. Asthma** | 0.45 | 0.49 |
| **Hosp. Adm. Cardiovascular** | 8.18 | 9.35 |
| **Emerg. Room Visits Asthma** | 0.12 | 0.13 |
| ***WTP Approach*** | **1,128** | **3,208** |
| **Chronic Bronchitis** | 1,115 | 3,192 |
| **Symptoms Acute Bronchitis** | 0.66 | 1.86 |
| **Symptoms LRS** | 0.20 | 0.20 |
| **Symptoms URS** | 4.88 | 5.28 |
| **Asthma Attacks** | 7.20 | 8.76 |
| ***Productivity Losses*** | **42.23** | **42.94** |
| **WLD** | 14.02 | 14.40 |
| **MRAD** | 28.21 | 28.54 |
| ***WTP Approach*** | | |
| **MRAD** | **48.08** | **48.73** |

Results confirm the fact in the literature (EPA, 1999), according to which when dealing with WTP estimates, mortality accounts for around 77 to 78% of benefits under the most complete option (Option 4 in Table 9). In general, policy makers know (and believe more) in COI (medical costs and productivity losses) measures than in WTP ones.

But, as Table 9 also shows, results differ very much depending on what type of value is considered. If policy makers do not believe in WTP estimates but would rather choose more direct ways of validating values as HC approach for Mortality and Medical costs plus

Productivity losses for Morbidity, the most conservative Option 1 would reflect the value of local health benefits for BAMA. That value accounts for approximately 500 million pesos of 2000 for the Mitigation Scenario and around 1,500 millions pesos of 2000 for the Integrated Scenario (which in addition to GHG mitigation options includes other local air initiatives). Then, climate change has a rather important role to play in avoiding local health costs.

**Table 9. Value of Health Impacts according to PM Reductions for BAMA 2000-2012 Different Scenarios (r = 7%, elasticity = 0.5, millions $ 2000)**

| | | Base/Mitigation | Base/Integrated |
|---|---|---|---|
| **Option 1** | **Total** | **545** | **1,491** |
| | Mortality (HC) | 491 | 1,436 |
| | Morbidity Hospitalizations (Med.Costs) | 11 | 13 |
| | Morbidity WLD & MRAD (Prod.Lost) | 42 | 43 |
| **Option 2** | **Total** | **1,721** | **4,748** |
| | Mortality (HC) | 491 | 1,436 |
| | Morbidity Hospitalizations (Med.Costs) | 11 | 13 |
| | Morbidity Chronic Symptoms (WTP) | 1,115 | 3,192 |
| | Morbidity Acute Symptoms (WTP) | 13 | 16 |
| | Morbidity WLD & MRAD (Prod.Lost) | 42 | 43 |
| | Morbidity MRAD (WTP) | 48 | 49 |
| **Option 3** | **Total** | **4,200** | **12,222** |
| | Mortality (WTP) | 4,146 | 12,167 |
| | Morbidity Hospitalizations (Med.Costs) | 11 | 13 |
| | Morbidity WLD & MRAD (Prod.Lost) | 42 | 43 |
| **Option 4** | **Total** | **5,376** | **15,479** |
| | Mortality (WTP) | 4,146 | 12,167 |
| | Morbidity Hospitalizations (Med.Costs) | 11 | 13 |
| | Morbidity Chronic Symptoms (WTP) | 1,115 | 3,192 |
| | Morbidity Acute Symptoms (WTP) | 13 | 16 |
| | Morbidity WLD & MRAD (Prod.Lost) | 42 | 43 |
| | Morbidity MRAD (WTP) | 48 | 49 |

Note: It is not clear in all cases which WTP include medical costs and productivity losses.
So, they are treated as if they are excluded because people believe other pays.

Finally, it is important to remember that this work is a preliminary estimation of the co-control benefits of GHG mitigation measures in BAMA. As such, it may suffer from several limitations due mainly to data availability, and the consequent need of realizing extrapolations from other countries where information is more complete. In addition, as provisory, the results here still need to be checked against other co-benefits estimates for other places in terms of their magnitude with respect to carbon abatement costs or to the amount of carbon tons abated. For example, Cifuentes et al 2000a for Chile estimate co-benefits in the period 2000-2020 to be around 1,000 million dollars and there are more countries, which have done so -IPCCC, 2001-, but those costs are different in many aspects because they refer to 4.3 million people and to different policy measures. However, comparisons can be made taking into account those differences.

Further work on this work would include mainly more details in terms of separating air quality impacts of specific mitigation options instead of aggregate scenarios (changes in all the transport fleet and the electricity sector). That, together with better local data on health costs would allow a better use of IES results for policy makers. More precisely, the methodology here employed would allow quantifying the benefits of specific policies as traffic changes or any other with an air quality impact, which could then be weighted against the costs of such regulation. This will be the objective of the second phase of ICAP work in Argentina.

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