A STUDY ON THE EFFECT OF DEMOCRACY ON AIR POLUTTION

Economic Theory

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1. Introduction

The environment affects our lives tremendously through many ways from the air we breathe, to the water we drink, to the food we eat. The ecological problems that we encounter today, from air pollution in particular have major implications on health. For instance, many excessive death and hospital admissions were the result of the London Fog of 1952 and Donora Smog of 1948, two of the greatest periods of air pollution that Europe and United States had experienced in the mid-20th century (Cohen et al., 2004). Those environmental factors do not influence developed countries only, but they have similar impact on both poor and rich ones. This makes environmental problems an international subject that seriously deserves our attention.

There have been a lot of debates on what factors affect the environment and influence the decisions to reduce pollution. On one hand, several studies in the literature looked at the relationship between income and environmental quality, based on the idea that income might be considered the major component that can affect the environment (Grossman and Krueger, 1995; Selden and Song, 1994; Shafik, 1994). Some articles suspected an inverted U-shaped curve, suggested first by Simon Kuznets (1955) and named as the Environment Kuznets Curve (EKC), between income and pollution. On the other hand, some authors have found other interesting variables that might be affecting environmental activity in addition to income, for example the political regime variable in the article by Farzin and Bond (2006). It is hypothesized that with democracy, people are allowed to defend their rights of a clean environment, and to protect themselves from health problems.

Urban air pollution, considered nowadays one of the most serious environmental issues due to the health problems that it might be generating, has been suspected to lead to death according to some studies. Cohen et al. (2004, page 1354) state the following: "We estimated that air pollution in urban areas worldwide, in terms of concentrations of PM, causes about 3% of mortality attributable to cardiopulmonary disease in adults, about 5% of mortality attributable to cancers of the trachea, bronchus and lung, and about 1% mortality attributable to acute respiratory infections (ARI) in children". In general, exposure to air pollution has become the main environmental threat to human health in many towns and cities.

Being inspired by the study of Farzin and Bond (2006), I examine the relationship between democracy and environmental quality in order to prove that democracy might affect environmental quality. The latter is represented by the concentration of one of the air pollutants known as particulate matter (PM^{10}) for a cross sectional data covering 3109 cities and national capitals around the world. I also check the well-known relationship between pollution and income, the Environmental Kuznets Curve, if it applies to the data used in this paper.

I look closely at the following two questions: First, are increases in the level of democracy, which is measured by the degree of competitive political participation, guarantee of civil rights and the constraints on executive power, associated with an improvement in environmental quality? Second, does democracy have a bigger impact than income on pollution abatement? More specifically, an econometric model is proposed to evaluate those factors using multiple regression analysis based on robust regression performance. The empirical findings show that environmental quality

decrease with an increase in the level of democracy. In addition, income per capita is proved to be insufficient in explaining pollution abatement where democracy seems to have a bigger influence in explaining that matter.

In this paper, I focus on another objective that has not received much attention from economists. The positive impact of democracy on environmental quality cannot be achieved within a short period of time. Democracy needs time to be implemented and for its results to be concrete. The findings of this paper indicate, by conducting four different regressions representing each a certain period of time, that democracy needs approximately 5 years to give the most effective results on environmental quality.

Finally, I study the impact of education on the relationship between democracy and pollution abatement. The results show that education alone cannot influence the reduction of pollution unless it is combined with democracy.

The remainder of the study is structured in the following way. In section 2, I present previous studies found in the literature, and try to compare them with the contribution and findings of this paper. In section 3, I describe the environmental indicator PM^{10} and the health risks associated with this pollutant. Section 4 outlines the structure of the empirical model and presents the expected signs and predictions. Section 5 reviews the data sources and Section 6 discusses the methodology and the estimation issue that took place. Section 7 presents and discusses the results of the model. Section 8 summarizes the findings and concludes.

2. Literature Review

In the last few years, along with the growing concern over environmental issues, much research has been done in the literature about the major reasons behind environmental degradation.

Some authors like Seldon and Song (1994) and Shafik (1994) conducted studies which concluded that income per capita has one of the biggest effect on environmental quality. Grossman and Krueger (1995) used GDP as their main explanatory variable as well. They study the relationship between income and 14 environmental indicators which are divided in four categories: urban air pollution, the state of oxygen regime in river basins, fecal contamination of river basins, and contamination of river basins by heavy metals. In their results, they find an inverted U-shaped curve between income and environmental quality that is similar to the EKC suggested by Simon Kuznets (1955). Those findings were also supported by the studies of Anderson and Cavendish, Heerink et al., and Panayotou and many others (as cited in Farzin and Bond, 2006, page 214)

The EKC curve, generally, shows a positive relation with pollution at low income levels, a transitional value for middle income ones and then a negative trend for high income levels. It is often interpreted as economic growth increases environmental quality after a certain level of income. In this case, the model suggests that income might be the primary solution for pollution abatement (Torras and Boyce, 1998). Grossman and Krueger (1995) found that the turning points for the inverted U-shaped relationships to be in general less than $8000 (1985 dollars) for GDP per capita for the studied pollutants.

These findings of inverted U-shaped curve were also consistent with the results found by the World Bank Development Report (1992) that found even lower turning points in their study on the relationship between each of sulfur-dioxide and suspended particulates and income per capita. Selden and Song (1992) also found the inverted-U relation but this time with higher turning points, for estimated per capita national emissions of sulfur dioxide, particulates, oxides of nitrogen and carbon monoxide.

However, the inverted U-shaped curve between pollution and income might not be maintained in all occasions. The curve may in fact be linear, where a monotonic relation between those two variables, whether it is negative or positive, can take place instead.

The World Bank Development Report (1992) finds that a negative relationship exits, instead of an inverted-U relation, between increasing level of income and both the percentage of inhabitants who are not able to access clean water and the percentage of citizens who does not have a suitable hygiene. The World Bank development report (1992) also conducted a study on municipal waste and another one on carbon dioxide emissions where for both studies they find that the environmental situation displays a positive correlation with increasing levels of income. This result was not only found to hold for developing or poor countries but it also for the most developed ones.

Several empirical evidences were presented against EKC as well. Stern and Common (2001) state that problems in specification such as omitted variable might be the result of having the hypothesis of EKC sample specific and dependent on estimation methods. Holtz-Eakin and Selden (1995) agree with Stern and Common, and adds that there are potential differences in individual country behavior.

After all, one should keep in mind that, as Torras and Boyce (1998) write, supporting Grossmann and Krueger (1995):

> There is no a priori reason to assume the relation between income and environmental quality to be strictly monotonic. Instead, environmental quality may worsen with income within some ranges of income, but improve over others. Also we should not necessarily expect the same relationship to hold for all dimensions of environmental quality. (Page, 148)

Other authors tried to find supplementary or new key variables responsible for the environmental degradation. Moomaw and Unruh (1997), found that historical events of 1970's oil price shocks and the policies that followed from it are behind the major reason that affects the emissions of CO_2, not income. In addition, Farzin and Bond (2006, page 227) state that "These results support the findings of the previous literature; namely, growth in income per capita is not sufficient for increases in pollution abatement as nations develop." Therefore, as reinforced by those authors and many others, such as Bhattarai and Hammig (2001), income alone cannot totally explain the reduction in pollution. These authors agree that political regime play an important role in explaining the relationship between income and pollution. As cited in Farzin and Bond (2006, page 214), I highlight what Dasgupta and Maeler emphasized in their study about the subject:

> The connection between environmental protection and civil and political rights is a close one. As a general rule, political and civil liberties are instrumentally powerful in protecting the environmental resource-base, at least when compared with the absence of such liberties in countries run by authoritarian regimes.

As found in the literature, democracy appears to influence environmental quality in a positive way, reducing pollution. However many authors do not totally agree with those findings and their studies show quite the opposite.

Heilbroner (1974) believes that democracy might not help in decreasing pollution. He argues that an autocratic regime is needed to preserve the environment from environmental degradation and scarcity of resources.

These mixed results brought up many questions on whether democracy is bad or good for the environment.

However, the approach followed in this paper builds on recent contributions that underline the necessity to account carefully for the role of political institutions in decreasing pollution in order to increase environmental quality. Using a panel from 48 developing countries, Damania et al. (2003) try to explore the relationship between environmental policy corruption and trade liberalization for those countries from 1982 to 1992 in an open economy. They present a theoretical model where one of their predictions was that corruption reduces the rigidity of environmental policies decreasing environmental quality. To build up this analysis, the authors presented a three-stage model following Aidt (1998) and Schleich (1999).

The intuition behind the first stage is to show that the effect of trade liberalization on environmental policy strategy is dependent on how much corruption there is. The second stage predicts a decrease in pollution tax as a result of a decrease in corruption. Finally the third step considers an increase in the level of environmental quality due to less corruption. Indeed, the result of their econometric model supports those predictions. In addition, one of their interesting outcomes was that the relationship between income and environmental quality was not found to be conditional on the level of corruption.

However, Lopez and Mitra (2000) investigate theoretically the effect of corruption and rent seeking on this relationship, but in contrast to the findings of Damania et al. (2003), they argue that corruption and rent seeking can influence this relationship between pollution and income.

Fredriksson et al.(2005) show that an increase in environmental lobbying leads to stricter environmental policies. They prove empirically using cross sectional data set formed by 82 developing countries and 22 OECD countries that an increase in the number of environmental lobby groups or a greater political competition will lead to a decrease in the lead content of gasoline, and they show that democratic participation and political competition are conditional on each others. They even write:

> Democratic participation affects environmental policy stringency only in countries with sufficiently high degree of political competition. Thus democratic participation has no effect in pure dictatorships. (Fredriksson et al., 2005, page 346)

A study by Torras and Boyce (1998) was done to further examine the Kuznets curve relationship between income and pollution. They hypothesize that the distribution of power is essential in this relationship. The idea was brought by Simon Kuznets (1963) but did not receive much attention until the study by Torras and Boyce (1998). By the distribution of power, they mean power inequality represented by political rights and civil liberties, literacy rate and income inequality. They carry out an empirical analysis using a panel data for seven pollution variables from a variety of air and water pollution indicators and estimated the regressions using generalized least squares (GLS). The results support that less power inequality leads to less pollution especially in low-income countries, with literacy rate and rights as better proxies for power inequality than income inequality.

Similarly, Bhattarai and Hammig (2001) use the political rights and civil liberties, measured by the Freedom House Index to account for the role of political institutions in their study for deforestation in Latin America, Africa, and Asia. In particular, they measure the relationship between deforestation in those areas and the type of the regime along with other explanatory variables, using also the GLS to test this relationship. Mixed significant results were established: a negative relationship between democracy and the rate of deforestation was found for Latin America and Africa, yet a positive one was found for Asia.

Once again, it is showed that income might not be the only key for a decrease in pollution. The socio-political regime of the country seems to be one of the major controllers of environmental policy as stated by Rivera-Batiz (2002). Democracy is an important component reflecting the political regime and many studies were carried out to see its impact on pollution abatement.

According to Farzin and Bond (2006), and relying on the studies discussed earlier in this section, they state that the effect of political institutions was studied and explained in the literature, but what was not accounted for is what Farzin and Bond (2006, page 214) has added: "However, these studies did not explicitly decompose the demand for environmental policy based on heterogeneous population characteristics, nor did they address the potential for distortions of the environmental quality preferences by the political regime". Farzin and Bond (2006, page 214) build an econometric model using a panel data on a variety of air pollutants to prove their hypothesis that "Democracy and its associated freedoms provide the conduit through which agents can exercise their preferences for environmental quality more effectively

than under an autocratic regime, thus leading to reduced concentration and/or emissions". They propose first a theoretical model on the relationship between environmental policy, governance and preferences where they predict that since environmental quality is a public good, the government is responsible for providing it and accounting for people preferences in their decisions of environmental policies.

However this depends on the type of political regime of the country that defines how much the government will weight those preferences and on the impact of education, urbanization, income inequality and population under age in shifting those preferences. Urbanization is found unambiguously positively related to pollution; however the results for education were not very clear. Nevertheless, a decrease in the illiteracy rate shows an increase in environmental quality but it happens at a decreasing rate. At the end, they show in their econometric model that increases in the democracy level tend to greatly decrease the level of pollution.

Another interesting theoretical work was presented by Congleton (1992). He shows in his analysis that to reduce pollution a "median voter" will do better than an authoritarian one. Based on his analysis, I emphasize the importance of one of his results that can be highly related to this paper, the idea that the environmental problem are of long-term nature. He states that environmental regulations, given their nature, if they are set in a short time period, they won't be very rigid. Due to the high uncertainty in the position held by an authoritarian regime, the latter has probably a shorter time horizon than a median voter has. Consequently, his environmental regulations will be less stringent, giving more room to a decrease in environmental quality. This study by

Congleton, has put some light on the idea of time horizon when studying the relationship between the type of political regime and environmental policies.

Note that this point of view was not accounted for in the paper by Farzin and Bond (2006). They examined the relationship between income and many pollutants conditional on democracy within the same year. Moreover, the fact that there are no empirical findings done previously to prove the importance of time dimension for democracy or to disregard it, constitutes a contribution to the literature.

Using a cross sectional data in year 1999, for 2929 cities whose population is greater than 100,000 and national capitals, I build my econometric model to test the relationship between PM^{10} and several explanatory variables, emphasizing on per capita GDP and the democracy variable which is represented by the Polity IV index. This model is inspired by the model tested by Farzin and Bond (2006) but not exactly the same. Some of his explanatory variables are not included in my model such as population under age and income inequality, although I tried to run regressions including them as well but they were highly correlated with other explanatory variables leading to specification errors. In addition, there was a lack in the data for Gini coefficient that measures income inequality, which made it also difficult to include this variable.

Many estimation problems were encountered as well, similar to the one encountered by Farzin and Bond (2006) such as multicollinearity, heteroskedacticity and specification errors. Moreover, most of the dependents variables chosen by Farzin and Bond (2006) are measured in terms of emissions rather than concentrations. However, in this paper, testing concentrations was preferred over testing emissions due to

differences in the geographical areas between countries. Measuring the pollutant in terms of emissions may not reflect the real impact of pollution on the economic activity and health. For instance, take the example of Canada and Luxembourg. With the same amount of emissions, people living in Luxembourg will be suffocating from pollution because it is a small country and pollution will be highly concentrated there. However, Canada's residents won't even feel the burden of pollution because it is a very large country, pollution will be easily spread out.

The environmental indicator chosen for this paper will be discussed in details in the next section.

3. The Environmental Indicator

Many studies have been conducted recently on environmental quality to inform nations about which environmental policies best decrease pollution and thus reduce the health impacts. The health risks due to pollution range from eye irritation to death over a range of annual average concentration from $7.5\mu g/m^3$ to $50\mu g/m^3$ (Cohen et al., 2004). In general, researchers face a certain challenge in assessing the impact of air pollution on health due to the limited availability of information on such studies.

I chose to work with an atmospheric air pollutant that can have serious effects on health and whose levels of concentrations have been estimated all over the world. It is the "particulate matter" (PM) pollutant that will be measured as an indicator for environmental quality.

More specifically, I deal with PM^{10} that is a particulate matter with an aerodynamic diameter of less than 10 micrometer that includes coarse particles greater than 1 micro

meter as well as fine and ultra-fine particles. It is produced mostly by a combustion process, penetrates indoor and can be easily inhaled.

This particulate matter, being easily inhaled, causes various health problems. Many studies have shown that particulate matter, in particular, is related to the most severe effects of air pollution in an independent and consistent way, including short and long term average mortality (by Health Effects Institute; WHO, as cited in Cohen et al., 2004, page 1359). Several health problems were found to be associated with long term exposure to the PM air polluter, such as cardiopulmonary and respiratory diseases, coughing, bronchitis, and lung cancer. These health problems, if coupled with very high concentration of PM, can lead unfortunately to death. (Bolt et al., 2006).

According to Krzyzanowski and Schwela (1999), the available measures of PM^{10} fluctuate extensively and that makes it hard for the researchers to estimate its annual average concentration. The World Bank has developed the Global Model of Ambient Particulates (GMAPS) to estimate the PM^{10} concentrations in cities worldwide, as an attempt to bridge the uncertainty found in the exposure of developing countries' residents to PM air pollution (Bolt et al. 2006). GMAPS is based on the available information of PM from the monitoring sites that are only included in residential or mixed residential sites across the cities in the world to reflect the average exposure to PM^{10} in a more accurate way (Bolt et al., 2006). Moreover, monitoring sites that are located in specific sources such as sites where there is heavy vehicular traffic or a local industry, were removed from the data sets as such monitoring sites may cause a deviation from the average levels of population exposure to PM^{10}.

National monitoring systems that collect information on air pollutants system exits worldwide but the access to this information is often restricted. The data in the GMAPS model comes mostly from the World Health Organization (WHO) Air Management Information System (AMIS) that collects the information from those national environmental agencies and air quality authorities following the national approved methods and standards of data quality. Inaccurate measurements take place due to the kind of pollutant distribution. However it is not the case with PM^{10}. For PM^{10}, the errors will be reduced because this kind of pollutant is uniformly distributed and penetrates indoors in an efficient way.

An econometric model is presented in the next section to discuss pollution abatement and the factors that are predicted to influence environmental quality and its policies.

4. A Framework for Discussing Air Pollution Abatement

Several reduced-form equations were estimated in order to relate the level of pollution presented by the indicator PM^{10} to income, and other important variables. According to Grossman and Krueger (1995), having a reduced form approach involves two important advantages. The first benefit of this approach consists of giving the net effect of the national income and the other variables on pollution. The second is to save the researchers the difficulty of collecting the data that might be invalid and not readily available. However, one limitation might be that the reason behind the relationship between income and pollution is unclear.

Other variables apart from income may strongly affect the environmental quality and it is worth taking them into account. These variables include the political regime, urbanization, population density, size of population in each city observed and power inequality such as illiteracy rate (Farzin and Bond ,2006; Torras and Boyce,1998).

Section 4.1

Specifically I estimate the following econometric model:

(1) $$PM^{10}_{i,1999} = \alpha_i + \beta_1 Y_{i,1999} + \beta_2 P_{i,1999} + \beta_3 C_{i,1999} + \beta_4 D_{i,1999} + \beta_5 U_{i,1999} + \beta_6 I_{i,1999} + \varepsilon_{i,1999}$$

Where $PM^{10}_{i,1999}$ represents an air pollutant measure as a proxy for environmental quality for city i at year 1999, $Y_{i,1999}$ is per capita GDP, $P_{i,1999}$ is population density, $C_{i,1999}$ is city population size, $D_{i,1999}$ is the democracy variable, $U_{i,1999}$ is the urbanization measure, and $I_{i,1999}$ is illiteracy rate. The βs are regression parameters; α_i is the intercept accounting for the unobserved heterogeneity across countries in a cross sectional model, and $\varepsilon_{i\,t}$ is an error term.

Using the first equation, two regressions will be conducted. One without the democracy variable for a reassessment of the Kuznets curve allowing for higher order terms in the GDP variable. The other includes the democracy variable in order to capture the effect of democracy and to analyze its effect on PM^{10}.

Section 4.2

Following from Equation (1), I introduce the idea of the time dimension in democracy. Democracy cannot be achieved in few days, it develops with time. Thus, I examine the relationship between environmental quality and a lag in political regime. To this end, I conduct four separate regressions with democracy measured in 1999, 1994, 1989 and 1979 respectively. Since the pollution indicator is measured in 1999, this procedure will tell us whether democracy takes 0, 5, 10 or 20 years to affect pollution.

(2) $$PM^{10}_{i,1999} = \alpha_i + \beta_1 Y_{i,1999} + \beta_2 P_{i,1999} + \beta_3 C_{i,1999} + \beta_4 D_{i,1999-k} + \beta_5 U_{i,1999} + \beta_6 I_{i,1999} + \varepsilon_{i,1999}$$

Where $D_{i,t-k}$ is the democracy variable, allowing now for lags in time.

Section 4.3

Once it is decided which lag has the biggest effect on environmental quality decision and preferences, i.e. which k to be used in the model, the following equation is estimated:

(2) $$PM^{10}_{i,1999} = \alpha_i + \beta_1 Y_{i,1999} + \beta_2 P_{i,1999} + \beta_3 C_{i,1999} + \beta_4 D_{i,1999-k^*} + \beta_5 U_{i,1999} + \beta_6 I_{i,1999} + \beta_7 D_{i,1999-k^*}.I_{i,1999} + \varepsilon_{i,1999}$$

To allow non-constant marginal effects on the pollution measure PM^{10} to take place, democracy is entered additively and multiplicatively in eq. (3) where I interact the democracy variable with the illiteracy variable. The results of this equation will determine whether illiteracy rate can only be exercised through democracy or whether it has its own important impact on pollution.

To make the analysis of the coming econometric results easier, I will discuss the expected relationship between each of the explanatory variables and PM^{10}.

Regarding GDP, people with more income are expected to have more commodities and they are expected to consume more than people with lower income. Thus, they are expected to generate more pollution. One would predict the relation between GDP and pollution to be positively related. On the other hand, people when they get richer, can afford consuming goods that are less harmful to the environment, consequently increasing environmental quality. In this case the relation between pollution and income is negative. This ambiguity in the sign between income and pollution has been clarified by the inverted-U shape of the environmental Kuznets curve. However, there have been many debates on the shape of this curve and whether it can be applied on all pollutants.

The relationship between urbanization and urban air pollution is not easily predicted. Increases in the urban population will drive more people to consume more fuels in the city. This will lead to an increase in the combustions processes that will produce more particulate matter, and thus increase air pollution (Farzin and bond, 2006). However, other authors such as Rivera-Batiz (2002) suggest a negative relation between urbanization and air pollution. When the population becomes more urban,

more people get together and form environmental organizations, which can influence greatly policy makers and politicians in their decisions to look after the environmental issues. According to Rivera Batiz (2002), urbanization reduces transportations and transactions costs of people getting together and helps them to easily form organizations to channel their opinions in protecting their environment.

On the other hand, the education level of the population (the illiteracy rate) is expected to have a positive (negative) relationship with the environmental quality. Several arguments can be given according to Farzin (2006) and Rivera-Batiz (2002) to reinforce the predicted relationship. Educated people are more concerned about the environmental issues and about protecting it and consequently will act in favor of reducing pollution. Moreover, an educated population is able to make its voice heard about its environmental preferences through participating and organizing advocacy groups, by having environmental organizations and giving the chance to democratically-minded policymakers to ensure a safe environment. Similarly, illiterate people won't be aware of the consequences of neglecting the environment and even if they do, they won't have the channels to express their preferences. Therefore, it can be predicted that as illiteracy rate decreases, the concentration of the air polluter PM^{10} decreases, thus promising better environmental quality.

The arguments presented above, either for urbanization or for education emphasize the fact that when citizens are more educated and of great masses, they can influence significantly the environmental policy makers' decisions. But what if the country is autocratic and no weight is given to citizens' preferences? In such cases, urbanization and education are no longer as effective as they are in a democratic country.

Furthermore, it is expected that the more democratic the country is, the more people can express their opinions about environmental issues, and the less the country will be polluted. In brief, democracy is forecasted to be positively related to environmental quality.

To conclude this section, the two remaining independent variables, population density and population city size, are both expected separately to increase the level of pollution, all else equal, as more people will be involved in pollution generating activities.

Note that all the independent variables are foreseen to be correlated between each others to a certain level and may be causing statistical problems that will be discussed, if any, in the section on methodology and estimation problems.

5. Data

The data used in the estimation covers 3109 cities from 141 countries, including all the OECD ones except for Iceland due to missing values for the democracy variable. The 3109 observations are cities and national capitals. It is an unbalanced data set due to the fact that some countries have more cities than others, thus cross-country comparisons should be made with caution. However, in this study, all the regressions are conducted at the city level, giving each observation its own weight.

5.1 The dependent variable:

In this model, PM^{10} measures the concentrations of particulate matter in year 1999 in micro grams per cubic meter in residential areas of cities with populations larger than

100,000 and national capital cities as well (Bolt et al., 2006). The data is taken from a complete set of estimators built up by the World Bank's Development Economics Research Group and Environment Department, "new estimates based on Global Model of Ambient Particulates (GMAPS)". The data of the GMAPS model contains originally 3226 observations representing cities worldwide, in 180 countries. One should note that even within the same city, different concentrations by different monitoring sites may be recorded, and that local meteorological conditions can greatly influence pollutant concentrations. Therefore, the data is only considered to give a general indication of air quality in each city.

5.2 The independent variables:

5.2.1) *Income* is measured by GDP per capita, in Purchasing Power Parity (PPP) that is the total annual output converted into current international dollars, per person.

5.2.2) *Population density* is measured in terms of population per square km at the country level.

5.2.3) *Urbanization* is defined by the urban population as a percent of total population.

The data set for the above three variables is provided by World Bank's World Development Indicators (WDI).

5.2.4) *Illiteracy* measures the adult literacy rate that is defined as the percentage of the population whose age is 15 and above with reading and writing skills that are at a reasonable level in their society. "These estimates reflect the performance of the national education system, as well as the quality of the human resources within a

country in relation to their potential for growth, contribution to development, and quality of life" as stated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO, 2006). The data is available for ranges of years. I chose to work with range 2000-2004 as an approximate for year 1999. The reason UNESCO uses ranges is because "adult literacy rates do not fluctuate significantly over the short term and therefore year-to-year estimates of short-term change can be unreliable in the absence of observed data"(UNESCO, 2006). Some countries' literacy rate was missing. Data from the World Bank's WDI with same measure and similar methodology based on the 1999 Census are used to fill in the missing values as much as possible. Moreover, to enlarge the sample size, interpolation methods were used as well. I ended up, mainly due to the missing values for the literacy variable for some countries, with 141 countries, 3109 cities observations.

5.2.5) As a proxy for *Democracy,* I use 'the political regime characteristics and transitions' variable, measured by the "polity IV" index, provided by the Center of International Development and Conflict Management at the University of Maryland. It has annual values describing the regime and authority of the independent countries with total population greater than 500,000.

The polity IV index is constituted of two main components, the level of democracy as well the level of autocracy (Polity IV Project, 2005).

For determining democracy, the index takes into consideration the level of competitive political participation, the constraints on executive power and the guarantee of civil liberties. However, not all civil liberties manifestations have been used in

measuring the polity IV democracy index. For example, the freedom of press and the rule of law are not included.

As for measuring autocracy, the index makes use of the same sub-indices but weights them differently. For example, an autocratic system suppresses competitive political participation whereas a democratic system encourages it.

There are few institutionalized constraints on the executive power, which is not the case in the democratic regime. The polity autocracy index doesn't include the control of social and economic activity as well as the effects of traditional or revolutionary groups unless it is affecting the central governing structure.

Note that this index measures behaviors and ideas so one should bear in mind that it is a subjective measure, giving rough comparisons between observations, and it is not appropriate for rankings and rigid score comparisons. The data gives a scale from -10 to 0 to measure the autocracy level and from 0 to 10 to measure the democracy level (-10 means strongly autocratic, 0 suggests that no elements of autocracy or democracy are present and 10 means strongly democratic). In this paper, following the paper by Farzin and Bond (2006), I add 10 to the polity variable measure. Therefore I obtain a range from 0 to 20 for this variable.

Note that some problems were encountered with the data set: special codes or "Standardized authority codes" are used for some countries to indicate an interruption in government (-66), an anarchy period (-77), or a transitional state (-88). One of the treatments is to consider the country with -66 values for polity measure as a missing value and remove those countries and their cities, to give the country with -77 a value

of zero, and to estimate for the country with -88, a number depending on both the earlier and the later state of that country, by following the trend.

One other problem I faced with the democracy index data set was the lack of democracy information for countries that had undergone dissolutions such as the Czech Republic, Slovakia, Germany, countries that where under the Soviet Union (USSR), Yugoslavia and many others. The problem was adjusted for these cases by giving them the values of the country they belonged to previously.

Table 1.--Summary Statistics of Primary Explanatory Variables

	Units	Count	Mean	Std. dev.	Min	Max
PM^{10}	Concentration, Micrograms/ cubic meter	2929	46.72	30.38	6.00	187.00
GDP	000 current PPP$	2929	11.29	10.39	0.50	33.03
Popden	0 people/ sq. km	2929	14.35	12.85	0.15	47.22
Demo99	index, 0 (autocratic) 20 (democratic)	2929	15.18	6.20	1	20
Urbaniz	% population	2929	59.09	20.63	8.34	97.04
Pop city	00,000persons in city	2929	4.88	6.23	0.43	105.58
Illiteracy	% population	2929	10.88	13.89	0.10	58.5

5.2.6) *City population*: It should act as a proxy for global economic activity in the city. It is the number of people in the city or metropolitan area as described by national

authorities and reported to the United Nations. The data for city population 1999 is provided by World Bank's Development Economics Research Group and Environment Department, "new estimates based on Global Model of Ambient Particulates (GMAPS)" (Bolt et al., 2006).

Although the measure of the dependent variable PM^{10} is measured at the city level, all the previously mentioned explanatory variables, except for city population, are given at the country level. Grossman and Krueger (1995) argue that it is appropriate to do that, since environmental standards are set at the national level. Moreover, data for cities are not readily available, and they are not much comparable across countries. Table 1 provides the summary statistics after removing outliers (outliers will be discussed in the next section).

6. Methodology and Estimation Problems

I face a problem in attempting to measure the effect of aggregate variables like national GDP per capita, population density and others on the economic behavior of micro units, in this case the PM^{10} measure of cities, by merging macro and micro data in the regression. Moulton (1990) discussed such practices and the pitfalls that a researcher may encounter, such as omitted variable bias, errors in variables, aggregation problems and many others.

In particular, he focuses on the possibility that the random disturbances are correlated within groups, here countries, in the regression. According to Moulton, the levels of correlations, even the smallest ones will drive the OLS standard errors to be drastically biased downward which will cause spurious regressions in estimating the

effect of aggregate variables on micro-units, the t-statistics will be overestimated. One should be careful and sensitive towards the evidence given by the data and its ability to test the desired hypothesis. Pfeffermann (1985) and Moulton (1986) discuss models suitable for grouped structures.

In order to solve for this problem, I introduce the population city size, as a micro-unit explanatory variable, to allow changes in the regression on the right hand side of the equation even within the same country. Note also that due to this trouble, I could not introduce dummy variable to account for region differences.

In addition, a problem of heteroscedasticity was detected using the white's test. This test is probably the most general of all existing tests for testing heteroscedasticity and does not provide any information regarding its cause. To solve for the problem of heteroscedasticity, I use the white'estimator estimator to correct for the variance of the coefficients in the estimation procedure (Greene, 2003).

Furthermore, I check for outliers using the Rstudent test (studentized residuals test). It is suggested that the studentized residuals in excess of 2 in absolute value are indicative of outliers. Indeed, many are found and the results looked very sensitive to outliers. Therefore, to tackle this problem, robust regressions are performed after excluding outliers because these regressions work with less restrictive assumptions compared to the least squares regressions and they provide better regression coefficients in the presence of outliers that violate the assumption of normal residuals. Robust regression techniques are iterative procedures that seek to identify these outliers and minimize their impact on the coefficient estimates. In this model, there are around

180 observations considered as outliers. I ended up with a data of 2929 city observations when correcting for these outliers.

In addition to those problems, mullticolinearity was detected using the condition index (CI) measure when I introduced GDP powers in the specification to check the existence of a square or cubic relationship between income and environmental quality. In addition to the measure provided by the CI, the correlations between the powers of GDP are very high. Simple correlations between the explanatory variables are illustrated by the correlation matrix in table 2. For example, the correlation between GDP and GDP^2 is 0.98. This problem of multicollinearity is not uncommon, and it has been encountered by other authors that have dealt with it, although many authors did not even mention this problem or what they did to get rid of the correlation between GDP and its higher order variables. For example, Boyce and Torras (1998), and Grossman and Krueger (1995) seems to ignore talking about the highly correlated GDP terms in their papers.

On the other hand, Farzin and Bond (2006) do report this issue in their paper:

> Finally, multicollinearity is a problem resulting from the introduction of the power terms in the parametric regressions, interaction terms between the independent variables, and partial collinearity of the explanatory indicators, leading to inflated standard errors on the highly collinear terms. As such, model specification is performed using orthogonalized independent variables with the correlation to lower-order terms removed through auxiliary regression on deviations from means. For hierarchical completeness, insignificant lower order terms are preserved whenever higher order terms prove significant. Once a specification has been chosen, the within model on the original data is estimated and reported in the subsequent tables below. Given these potential statistical issues, the reader is encouraged to be cautious in interpreting the econometric results. (p.226)

Table 2.--Correlation Matrix between Explanatory Variables (after controlling for Outliers)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) pop density	1.00							
(2) democracy 99	0.23	1.00						
(3) urbanization	-0.33	0.51	1.00					
(4) gdp	0.08	0.54	0.63	1.00				
(5) gdp square	0.07	0.50	0.53	0.98	1.00			
(6) gdp cubic	0.02	0.45	0.48	0.94	0.98	1.00		
(7) pop city size	-0.04	-0.23	-0.15	-0.08	-0.06	-0.04	1.00	
(8) illitercay	0.24	-0.16	-0.67	-0.58	-0.49	-0.44	0.03	1.00

Multicollinearity problem does not only involve primarily GDP and its powers. It also involves other explanatory variables. This might lead to inflated standard errors. As a first step, I choose to drop the powers of GDP as a remedy for this problem, therefore I won't be getting the Kuznets curve anymore. For the present paper, It would be probably enough to assume a linear relationship between GDP and PM^{10}.

In addition, a regression was conducted, when checking equation (2) of the econometric model, using the sum of democracy variables at t =1999, t-5, t-10, and t-15 all together. It caused again a problem of multicollinearity. An explanation can be that, for a given country, democracy did not probably change much between those years. Thus, it was preferable to run regressions taking each one separately.

7. Results

The empirical results from estimating equation (1) are reported in table 3 for several specifications with PM^{10} as the dependent variable, and all explanatory variables in year 1999. All specifications are performed using robust regression analysis.

Table 3.-- Model with and without democracy

	Dependent variable (PM^{10})			
	Specif 1	Specif. 2	Specif.3	Specif. 4
GDP	0.61	-0.28*	2.35*	0.073**
	(0.55)	(0.45E-1)	(0.52)	(0.44E-1)
GDP2	-0.06**	–	-0.14*	–
	(0.33E-1)		(0.31E-1)	
GDP3	0.13E-2*	–	0.24E-2*	–
	(0.60E-3)		(0.60E-3)	
Popden	0.78E-1*	0.40E-1	0.28*	0.24*
	(0.35E-1)	(0.30E-1)	(0.34E-1)	(0.29E-1)
Demo99	–	–	-1.80*	-1.75*
			(0.76E-1)	(0.77E-1)
Urbaniz	-0.76 *	-0.75*	-0.45*	-0.39*
	(0.33E-1)	(0.26E-1)	(0.33E-1)	(0.50E-3)
Pop city	0.68*	0.69*	0.45*	0.46*
	(0.50E-1)	(0.50E-1)	(0.50E-1)	(0.50E-1)
Illiteracy	0.30*	0.30*	0.70*	0.66*
	(0.37E-1)	(0.35E-1)	(0.38 E-1)	(0.36E-1)
R^2	0.58	0.58	0.65	0.64
N	2929	2929	2929	2929

* significant at 5% level
** significant at 10 % level

Model specifications 1 and 2 exclude the democracy variable while it is included in specifications 3 and 4. Specifications 1 and 3 allow for a cubic relationship between income and pollution. This is meant as a check for a U-shaped relationship between the air pollutant and GDP, the so-called environmental Kuznets curve. A simple linear relationship between income and pollution is included in specifications 2 and 4.

The estimated coefficients for GDP per capita and population density turn out not to be significant in the absence of the democracy index (specification 1). But once democracy is introduced (specification 3), those coefficients become highly significant. This puzzling result may have been helpful to test the hypothesis of the existence of an inverted-U shaped Kuznets curve conditional on the political regime. However, it may simply be due to the high degree of correlation between powers of GDP in both specifications 1 and 3. As mentioned before, this correlation problem appears to have been eschewed in much of the existing literature. I suspect that this is due to the difficulty in dealing with it from a statistical point of view. For this reason, I have decided to proceed in estimating the equations assuming a simple linear relationship between income and pollution.

In specification 2 and 4, the results are now given assuming a linear relationship between income and pollution, respectively without and with the democracy variable. This yields interesting results. In specification 2, income is found to be negatively related to pollution and significant at 5% level. An increase in GDP by 1000 (1 unit) will decrease the PM^{10} concentration by 0.6% (0.28 unit). This is often interpreted as an indication that pollution decreases as people's income increases. For instance, instead of using charcoal for heating and cooking, people in richer countries may choose to use more expensive but less polluting energy sources such as natural gas and oil. This would take place assuming all else equal, i.e. by controlling for all other relevant factors. But as specification 4 shows, it turns out that controlling for democracy makes a crucial difference.

The estimation of specification 4 indicates that once democracy is introduced, the slope of GDP becomes positive, significant at the 10 % level, and much flatter than with specification 2. Hence, once democracy is controlled for, income levels appear to have a much smaller impact on pollution levels. Democracy, on the other hand, has a very important impact. This suggests that the large and significant effect of income on pollution in specification 2, as well as in many previous studies, is probably due to the fact that richer countries are also generally more democratic than poorer ones. But higher income alone is not sufficient to reduce pollution in a country; it must be accompanied with a more democratic regime. Democracy proves to be essential in reducing pollution. The relation between democracy and pollution turns out to be negative, as expected, and significant at 5% as well. Therefore, this indicates that increases in the level of democracy improve environmental quality as people's demands for a cleaner environment are taken into account by governments.

As for the other covariates, population density, population city size and illiteracy rate, I got the expected signs except for urbanization. The latter is found to negatively affect PM^{10}, in contrast to what is found for population density, population city size and illiteracy rate that display a positive impact. The negative relation between urbanization and pollution reinforces the argument of Rivera-Batiz (2002) that when population becomes more urban, more people get together to influence policy makers in their decisions regarding environmental issues. Furthermore, population density has been found insignificant even at the 10 % level in specification 2 (without democracy) but becomes significant with the democracy variable in specification 4. This additional result shows the importance of the democracy variable being included in the model.

In terms of magnitude, again comparing specification 2 to specification 4, the coefficients of urbanization and GDP variables decrease in absolute value when controlling for democracy. Moreover, GDP's relationship with air pollution becomes even positive (changes in the sign of slope). In specification 4, if democracy increases by 10 units for example, PM^{10} concentration decreases by 37.5% (17.5 units). On the other hand, an increase in GDP by 10 units (10,000) will only increase the dependent variable by 1.6% (0.73 units). Consequently, democracy proves once again to have more impact than GDP on PM^{10}. In addition, the effect of illiteracy rate seems to increase in specification 4 showing that illiteracy variable works better through democracy, in other words it will have a greater effects in reducing pollution when combined with democracy. Moreover, those two points will be revisited later.

I turn now to table 4 that displays the regression results of equation (2) in the econometric model. As it was stated earlier in section 4.2 of this paper, these regressions look for the appropriate time difference needed in order for democracy to have its biggest impact on reducing pollution. Specification 4 presents the results of introducing democracy in 1999 which is the same year taken for all other variables. Specification 5, 6 and 7 present the outcomes for year 1994, 1989 and 1979 respectively which corresponds to 5, 10, and 20 years difference compared to the base year 1999 (specification 4).

In specification 6 and 7, democracy going back to 10 and 20 years ago seems not to have this important influence on environmental quality. First, R^2 in specification 6 and 7 are lower than R^2 in specification 4 and 5. Second, although all the other explanatory variables are significant at the 5% level, GDP was found statistically insignificant for

specification 6 not even at the 10 %level. Third, the demo89 and demo79 coefficients are much smaller in absolute value than for demo99 and demo94. As a result, 10 or 20 years ago for democracy seems to be too long to affect what we see today.

Table 4.—Model with democracy at four different years

	Dependent variable (PM^{10})			
	Specif.4	Specif.5	Specif.6	Specif.7
GDP	0.073**	0.14*	-0.05	0.24*
	(0.44E-1)	(0.43E-1)	(0.51E-1)	(0.63E-1)
Popden	0.24*	0.25*	0.12*	0.09*
	(0.29E-1)	(0.28E-1)	(0.31E-1)	(0.30E-1)
Demo99	-1.75*	–	–	–
	(0.77E-1)			
Demo94	–	-1.87*	–	–
		(0.70E-1)		
Demo89	–	–	-0.65*	–
			(0.74E-1)	
Demo79	–	–	–	-0.78*
				(0.67E-1)
Urbaniz	-0.39*	-0.37*	-0.63*	-0.75*
	(0.5E-3)	(0.27E-1)	(0.29E-1)	(0.25E-1)
Pop city	0.46*	0.47*	0.65*	0.66*
	(0.5E-1)	(0.49E-1)	(0.50E-1)	(0.50E-1)
Illiteracy	0.66*	0.62*	0.50*	0.53*
	(0.36E-1)	(0.35E-1)	(0.40E-1)	(0.39E-1)
R^2	0.64	0.66	0.60	0.60
N	2929	2929	2929	2929

* significant at 5% level
** significant at 10 % level

Comparing specification 4 and 5 will answer the question if it is more significant to have a lagged variable for democracy and if so what should be the difference in time. First, the R^2 in specification 5 is larger than in specification 4, thus the model fits better. Second, even though the two specifications preserve the same signs and approximately the same magnitude for most of the explanatory variables, the democracy variable's coefficient shows a bigger magnitude in absolute value for year 94 than for year 99 and practically this is the variable that really matters in order to verify the hypothesis.

Note a greater change in the slope of urbanization even if it is small but now with a smaller standard error. Note also the change in the slope of GDP along with a change in sign for specification 5 and 4 when compared with specification 2. It seems therefore that it takes approximately five years for democracy to have its main effect on reducing pollution.

Theoretically, it can be said that it is not simple to form organizations and to put people together in a short period of time. Such steps need planning, commitment, mutual interests and most of all it needs time, time to form those groups, time to implement ideas and work on them to be effective in society, time to take decisions, to influence politicians and policy makers and to accomplish goals. If all that time is needed for one single organization, how about the time a society needs? To make it more general, how about the whole country when it undergoes transitions and changes in the political regime? Democracy is not a one day phenomena, it needs a lot of time to be implemented. From the analysis, it can be deduced that democracy needs around 5 years to be the most effective.

Finally, table 5 provides the results of equation 3. In this part, I resume the discussion on education and urbanization with respect to the political regime in more details since it is hypothesized earlier that they both may play an important role in reducing pollution. Specification 2 and 5 are once again included in the analysis to drive the point that education is not important to explain pollution unless it is combined with democracy.

In fact, this is what the results present as well: the effect of illiteracy becomes larger when the democracy variable is introduced in specification 5. To educate people won't have such an important effect on pollution if democracy is not accounted. For this is actually very close to what happened in communist Eastern Europe (a non-democratic area) where people were highly educated but the environment was still much polluted.

To capture more closely the interaction between democracy and illiteracy, I include a new regression with illiteracy rate multiplied by the political regime variable. The related results are displayed in Specification 8. The estimated effect of illiteracy for a country with average democracy is equal to 0.74 (1.5% increase in PM^{10} for a one unit increase in illiteracy) with a 0.08 standard error. For a highly democratic country like Canada, the effect is 0.99 (2.1% change in PM^{10}), as for a highly autocratic country like Iraq, the effect is 0.05 (0.1% change in PM^{10}).This drives the point again that education needs to be combined with democracy for illiteracy to have an effect on pollution.

The other interesting idea now is that once the interaction between democracy and illiteracy is included, the effects of democracy and GDP become larger and the relation between GDP and pollution is now remarkably positive not approximately flat

anymore. This would probably indicate that there is more to democracy than what polity IV measures. Freedom of press and rule of laws, which were not included in calculating the polity IV index, may have a good role in explaining this result.

Table 5.-- The Impact of Education Conditional on Democracy

	Dependent variable (PM^{10})		
	Specif.2	Specif.5	Specif.8
GDP	-0.28*	0.14*	0.33*
	(0.45E-1)	(0.43E-1)	(0.50E-1)
Popden	0.40E-1	0.25*	0.25*
	(0.30E-1)	(0.28E-1)	(0.28E-1)
Demo94	–	-1.87*	-2.68*
		(0.70E-1)	(0.12)
Urbaniz	-0.75*	-0.37*	-0.29*
	(0.26E-1)	(0.27E-1)	(0.29E-1)
Pop city	0.69*	0.47*	0.43*
	(0.50E-1)	(0.49E-1)	(0.50E-1)
Illiteracy	0.30*	0.62*	-0.22E-2
	(0.35E-1)	(0.35E-1)	(0.72E-1)
Illitera*demo94	–	–	0.05*
			(0.53E-2)
R^2	0.58	0.66	0.66
N	2929	2929	2933

* significant at 5% level
** significant at 10 % level

Another covariate already mentioned and discussed previously, is urbanization. The impact of urbanization on pollution abatement diminishes respectively in specification 5 and 8, suggesting that more urbanized societies are both more

democratic and literate. The causation probably goes both ways. However, it is comforting to see that the sign of urbanization is still negative. This means that all else equal, the more people are living in the cities, the lower the pollution level, due to the reasons discussed earlier, such as more power to influence the government which probably will care more to provide the best to its citizens. Nonetheless, one would expect the interaction between democracy and urbanization to be even more important, but a multicollinearity problem was detected and the interaction term appeared to be highly correlated with democracy (0.8) as well.

The effects of GDP and Urbanization, unlike the illiteracy, do not appear to go through democracy; they have their own separate small effect on the dependent variable.

8. Conclusion

Some of this paper's results match with part of Farzin and Bond (2006)'s findings for the majority of their air pollutants. In sum, both empirical works support the positive relationship between democracy and environmental quality and the insufficiency of income in decreasing pollution by its own.

However, according to Grossman and Krueger (1995), one should note that the different relationships that have occurred in the past or in the previous literature on the relationship between income and pollution, whether the EKC curve or just a linear relationship, are not inevitable. Many factors such as the economic and political situations or technology at that time may have played a role.

In this paper, the empirical analysis supports the hypothesis that differences in the level of democracy/autocracy explain the differences in the environmental quality between countries. In particular, the more the country is democratic, the less there is urban air pollution. In addition, according to the findings of this work, democracy seems to have a bigger impact than income on pollution abatement, and the time period needed for it to greatly influence environmental quality seems to be approximately 5 years. However, one can say that the effect of democracy might be immediate and what really takes time can be the changes in PM to be detectable. Therefore, I leave this as an open question for the reader.

Another interesting result that also highlights the importance of democracy, states that education needs to be combined with a democratic regime so the educated people, who are most probably aware of the environmental problems, can express their concerns and their environmental preferences to influence policy makers in their environmental decisions.

Nevertheless, urbanization, unlike the illiteracy variable, needs not to be directly linked to democracy. It is shown that the more the country is urbanized, the less the city is polluted. This suggests that when people get together, they have a bigger influence on the authority in enforcing environmental protection in order to protect themselves as well.

One should note that only one environmental indicator is being considered in this paper. Consequently, its findings cannot be generalized by any means. It should be also emphasized that both democracy and environmental quality are considered to be heterogeneous goods, thus not all environmental indicators show the same results when

controlling for democracy, neither democracy have the same impact across countries. Two countries may have the same democratic level, but may show different democracy characteristics thus lead to different environmental policies. Therefore, one should keep in mind that the results, just mentioned earlier, might not be applicable in every situation but at least gives a broad view on the effect of democracy.

Last but not least, democracy will probably have an impact when a pollutant is expected to be causing serious health problems where the government needs to put stringent environmental policies to limit the concentration of pollution in order to protect its citizens. Therefore, this paper has presented the situation of one of the important urban air pollutants that is the particulate matter PM^{10} which is responsible for causing serious health problems.

Finally, future research may put some light on further variables other than the political regime that can greatly improve environmental quality even more. But until now, democracy proves to be one of the most important factors that can positively influence pollution abatement.

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