Evaluating the relationship between household income and atmospheric pollution: reconsidering the Environmental Kuznets Curve in region of Haute Normandie

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ABSTRACT

This paper estimates the effect of income on environmental quality. For treating this issue, we use a panel data from 2000 to 2004 related to region of Haute-Normandie. We apply the reduced-form regression approach commonly used in environmental Kuznets curve literature. The analysis is based on the ambient concentrations of three pollutants (SO_2, PM_{10} and O_3). The results indicate that there is an inverted U-shaped relationship between mean household income and atmospheric concentration of PM_{10} only. For SO_2 and O_3, this hypothesis is not verificated. We obtain a declining relationship between these two pollutants and income. Based on these results, our findings conclude that the increasing of income can be at the benefit of the environment.

Keywords: environmental quality, inverted U-shaped relation, income, Haute Normandie

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1. Introduction

The academic debate on the relationship between household income and atmospheric pollution has taken a preponderant place in environment economics. To this subject, arise two important question: what are the effects of the increasing income on environment? Is this increase responsible of environmental degradation, or in other words, the environmental quality can be ameliorated by increasing income levels?

The environmental Kuznets curve hypothesis postulates that there is an inverted-U shape relationship between per capita income and measures of environmental quality (Grossman and Krueger, 1991-1995; Panayotou, 1993-2000; Selden et Song, 1994; Shafik and Bandyopadhyay, 1992; Stern, 2004).

Several American studies tried to answer to this question. They suppose that there is a relationship between the indicators of environmental quality and the levels of income. This assumption is analyzed by estimating this relation. Their results indicate that generally this relationship is positive or negative according to the various levels of income. For low levels of income the concentrations or emissions of pollutants rise with the increase of income (negative effect on environment) and decrease respectively with income for high levels of income (positive effect on environment). That generates an inverted U-shape relationship between environment and income. This relationship as known environmental Kuznets curve.

The Environmental Kuznets Curve concept emerged in the early 1990s with the study of Grossman and Krueger (1991) on the effect of the North Atlantic Free Trade Agreement (NAFTA) on environmental quality. They estimates reduced-form regression models relating three indicators of urban air pollution to characteristics of the site and city where pollution is monitored and to the national income of the country in which the city is located. Selden and Song (1992) and Holtz-Eakin and Selden (1995) have used similar methods to relate estimated rates of emission of several air pollutants to the national income level of the emitting country. The evidence on the relationship between environmental quality and levels of national GDP has been also noticed by the report of the World Bank Development (1992).

Generally all these studies do not lead to the same results. What returns to sceptics the researchers as for the global existence of the environmental Kuznets curve? According to the sample size one can lead to discussed results. Stern and Common (2001) in using a global sample of countries obtain a monotonically increasing relationship between the emissions per capita and per capita income. But when the data set is restricted to high-income countries, they obtain an inverted U-shape relationship. Dijkgraaf and Vollebergh (1998) in their analysis on carbon dioxide emissions for a panel of countries, determine that they exists an inverted U-shape relationship. However, when the relationship is estimating separately for each of the countries, they lead to different results. In a more recent study (Maddison, 2004), the results show a monotonically decreasing relationship between the GDP per capita and the SO2 and NOx emissions. According to the author, the reduction in sulphur emissions is due to technological progress. For several authors the shape of the environmental Kuznets curve is the consequence of high-income countries in effect exporting their pollution to lower-income countries (Rothman, 1998; Stern, Common and Barbier, 1996). Moreover although it is the first time that this type of data was used for the estimate of the EKC, the conclusions are not contradictory with the obviousness.

This inverted U relationship is known as « Environmental Kuznets Curve ». It depends of the scale effects, of composition and technological[2]. The starting point is the theory of the distribution of income developed by Kuznets (1955) where the author show an inverted U-shape relationship between the indicators of inequality and level of income.

Although the economic growth involves an environmental degradation at the first stage of development process, followed by an improvement, it remains nevertheless the solution to the environmental problems. That imply that the only way for the countries to attain a better environmental quality is to become rich (Beckerman, 1992).

Indeed, several recent empirical researches integrated other explanatory variables than the income (de Bruyn, 2000 and Panayotou, 2000).

Generally, the income is perceived like one of the main factor generating the environmental inequalities. The exhaustible natural resources and the inexhaustible natural resources are used as input for the production of goods and services. If the combination of the output and the techniques of production was immutable, then the deterioration of the environmental quality would be inevitably related to the global economic activity.

The objective of this paper is to apply to regional level standard model relating income to environmental quality. To inspire by the literature we formulated an equation of pollution which integrates the average household income of Haute-Normandie and the sociodemographic variables. The empirical research carried in the early 1990s shows that for

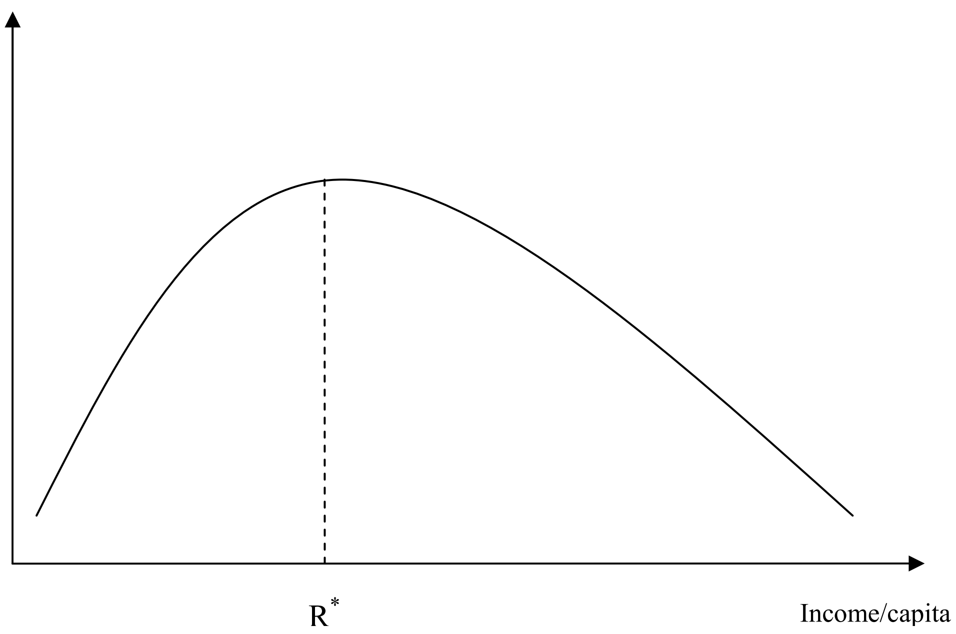
[2] For more details, see also Grossman and Krueger (1995).

certain pollutants local in particular, the emissions would decrease beyond a certain threshold of income. Indeed, will the Haute-Normandy region reach this stage? This study will enable us to answer to this issue.
The empirical estimates achieved for the majority in United States showed that the improvement of the environment depends not only on the increase in the income, but also on the socio-demographic factors (Brooks and *al*. 1997).
The paper is organized as present follows: a theoretical and empirical analysis of the results of the studies on the environmental Kuznets curve and their main criticism. The section 3 details the construction of the sample, the description of data base and the econometric model. The results of our estimations and their analysis are presented in section 4. Section 5 contains the comments and interpretation of the results. The final section concludes.

2. Theoretical approach of the environmental Kuznets curve (EKC): a review of the literature

Kuznets (1955) notices an inverted U-shape relationship between the level of income per capita and the social inequalities.
Several empirical studies attest a similar path for the evolutions of both pollution and national level of wealth. This path is known in the specific literature as *environmental Kuznets curve*.

Figure1. Environmental Kuznets curve



The EKC literature shows that the inverted-U shape may be determined by a series of concurring factors such as: economies of scale in pollution abatement; changes in the industry mix; evolution from physical capital intensive toward more human capital intensive activities; changes in input mix; changes in income elasticity to the marginal damage generated by environmental degradation; changes in environmental regulation (Stern, 2004; Copeland and Taylor, 2004).

This theory constitutes a significant instrument to determine the effects of income increasing on environment.

Despite the diversity of the results of the empirical studies on environmental Kuznets curve, there is an optimist feeling that the economic growth allows the improvement of the environment. But this link between the income and pollution is not inevitable (Grossman et Krueger, 1992 and 1995; World Bank, 1992).

The obvious existence of a Kuznets curve is based on a reduced-form model representing the link between pollution and the income per capita. However, the fundamental mechanism is not explained. Moreover, degradation or the improvement of environmental quality is not automatic when income increases of. According to Grossman and Krueger (1995), the strongest relation between the two indicators is obtained by the stringent environmental regulation due to the public pressure. If the EKC hypothesis were true, then rather than being a threat to the environment, economic growth would be the means to eventual environmental improvement (Stern 2004).

The nature of the data used is also significant in the analysis of the results. In most of the studies the turning point where emissions or the concentrations starts to diminish is in conformity with the levels of income, as the results of the study of Stern and Common (2001) for sulphur dioxide show it, the relation is monotonous.

The evaluating of the relation between the income and pollution must be based on data relating to the city or region (area) where the stations of monitoring are localised. Because the variations of the air quality and the specific localization of the city or region (area) cannot be representative of the national level.

2.1. The diversity of the results of studies on environmental Kuznets curve

The environmental Kuznets curve translates the reduced form relationship in which pollution is expressed according to the income per capita without specifying the link between the two variables.

The general form of the regression estimated is as follows:

$$P_{it} = \alpha_{it} + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + \beta_4 X_{it} + \varepsilon_{it} \qquad (1)$$

Where P_{it} is the indicator of the environmental quality of the locality *I* at the period *t*, Y_{it} is the income per capita, and X_{it} is a demographic vector and other control variables, ε_{it} is the normally distributed error term. The parameters β_1 and β_2 represent respectively the scale effect and the composition and technological effects. They allows to determine the nature of the relationship between the income and pollution:

1-) If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, that reveals a quadratic relationship, representing the environmental Kuznets curve. The turning point of this representation of the inverted-U shape curve is obtained by setting the derivative of *(1)* equal to zero, whch yields:

$$y = -\beta_1 / 2\beta_2 \qquad (2)$$

When the cubic term (β_3) is positive the relationship between the two variables gives the N-shape curve, meaning that beyond a certain threshold of income the curve becomes again increasing[3] (H. Hettigue, M. Mani and D. Wheeler, 1998; E. Barbier, 1997).

If this coefficient is significant, this characteristic makes possible to avoid the teoritical aspect of a curve representing a null pollution or negative for a very high level of income and to detect the more complex shapes of curve.

2-) If $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, then we have a monotonically increasing linear relationship, indicates that rising incomes are associated with rising levels of emissions;

3-) If $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, in this case we have a monotonically decreasing relationship, indicating that rising of incomes results in a reduction in the emissions or concentrations of the pollutants.

[3] According to Stern (2004) that is due to a polynomial approximation of a logarithmic curve.

2.1.1. Review of the literature of the principal results of empirical work of reference.

Grossman and Krueger (1993-1995) estimate for the first time in their study on the environmental probable impacts of a North American Free Trade Agreement (NAFTA) the empirical relation between the national income and of environmental quality. They consider the reduced-form regression (as described in equation 1) relating three indicators of the urban air quality (dioxide sulphur, suspended particles and it smoked black) to characteristics of the site and city where pollution was monitored and to the national income of the country are localised in which the city is localised. The authors use a panel of data of the GEMS (Glogal Environmental Monitoring System' S).

Selden and Song (1992) and Holtz-Eakin and Selden (1995) use similar methods to estimate the relation between the rates of emissions of several air pollutants and the national income level of the emitting country. A study of the World Bank of the Development (1992) also examines the obviousness of the relation between indicators of environmental quality and the levels of the GDP. The results of these studies conclude that there are inverted U-shape relationships between income and environmental quality, witch testify the existence of an environmental Kuznets curves. Despite the consistency among analyses, this consensus is clouded by several methodological issues. These issues include the measure of environmental degradation, the meaning of higher income and proper use of econometric techniques (Stern and al., 1996). This relation implies that the increase in the level of income per capita is accompanied initially by an increase in the pollutant emissions on low levels of income. But thereafter, the relationship between the indicator of wealth (income) and the indicator of environmental quality evolve/move in an opposite direction (see figure 1). This situation is observed starting from a certain threshold of income and also depends on the nature of the pollutant, its characteristics and the atmospheric conditions.

In the study of Grossman and Krueger (1995) this threshold corresponds to R* and it lies between 4000 and 5000 USD. It is the threshold from which the emissions began to decrease. However, this threshold of reversal of the curve is not the same one for all the pollutants. Shafik and Bandyopadhyay (1992) study the same relation and obtain to the same results with points of reversal in the neighbourhoods of 4000 USD. In addition, the study of Harbaugh and al (2002) using the data base GEMS gave results completely different from the precedents. The signs of the coefficients change making unforeseeable the analysis of the curve.

Other studies, in particular those of Selden and Song (1994), use particular a data base relating to the emissions of pollutants in the developed countries. Their results convergent with the precedents, but they obtain the turning point largely higher than those obtained by Grossman and Krueger: 8700 USD for the sulphur dioxide, 11200 USD for nitrogen oxides and 10300 USD for the suspended particles. According to them, it appears more obvious to lower the level of the concentrations in urban centres (where the measuring sites of the levels of concentration are located).

Lopez (1994) and Munasinghe (1998) respectively analyze the influence of the income on the willingness to pay for a good or environmental service and nonrespect of the principle polluter-payer. They main the idea is that an increase in the production will lead invariably to an increase in the level of pollution. However, when the same polluters pay the social marginal cost of depollution, then the relation between the emissions of pollutants and the income depends directly on technology and the preferences. It is more probable to obtain an environmental curve of Kuznets between the local income and pollutants rather than with the total pollutants (Lopez 1994). This idea corroborates with the economic theory of the environment which says that the local impacts are easily internalisables at the local level or regional and cause policies of internalisation of the externalities before applying them within a total framework.

The socio-economic characteristics also tend to affect the results of the studies on the environmental curve of Kuznets. List and Gallet (1999) contrary to the results of Carson et al. (1997) showing a strong fall of the levels of pollution in the United States, obtain a cubic relation statistically significant for the SO2 and NOx emissions on higher levels of distribution of income.

To test the role of the structural changes and the environmental policy in the reduction of the dioxide sulphur emissions, de Bryun (1997) uses the method of decomposition of the emissions. It obtains a reduction of about 50% to 60% of SO2 emissions. Its analysis approves that of Grossman and Krueger who stipulates that the environmental policy due to a great demand of environmental improvement on raised levels of income was a significant factor for the reduction of emissions.

A similar analysis is carried out by de Bryun et al. (1998) for the emissions of CO2, SO2 and NOx, by using the data for United Kingdom, the United States and Holland. Their results show the significant role of the structural changes for explaining the reduction in the emissions. According to them, these significant falls observed can be due entirely to reinforcement in the environmental regulation. In the sometime, the income per capita was by 37% the principal cause for the increase in the carbon dioxide emissions in the OECD countries and the increase in the population of 12%. Moreover the fall of the energy intensity was the factor of reduction of the emissions (Hamilton and Turton, 2002).

2.1.2. Principal critics of the empirical studies

The major critics carried being studied empirical which rests on the environmental curve of Kuznets is that those are often based on the small-scale models. Moreover, it does not appear a retroactive effect of the environment on the increase in the income or on the economic growth. The economic activity and the process of the development are not disturbed by environmental pollutions. Environmental quality is thus perceived like the result of the economic growth (Arrow and *al.*, 1995; Pearson 1994; Stern and *al.*, 1996 and Borghesi, 1999). But according to Stern (2004)[4], engaging a fast growth of the economic activity at the initial stage of the development, with an increase in environmental degradations can thus appear unproductive and untenable. The atmospheric pollution has impact only on the wellbeing of the individuals. The results of the studies on the environmental Kuznets curve showed that this one is checked only for certain pollutants and not for all. It is clear that many developed countries saw their pollutant emissions dropping with a rigorous increase in the environmental regulation and technological innovations.

For example, Shafik (1994), Holtz-Eakin and Selden (1995), Roberts and Grimes (1997) find that the emissions of carbon do not follow an inverted U-shape. Others studies find that the inclusion of the alternative variables in the estimate of the environmental Kuznets curve decreases the level of significativity of the estimated coefficients or do not adhere any more to the inverted U relationship (Kaufmann and *al.* 1998; Torras and Boyce 1998).

The advantage of the using the reduced model is that it allows to directly estimating the influence of income on environment. But this approach has a disadvantage as noticed by Grossman and Krueger (1995); it does not clearly explain the reason of the existence of the relation estimated between the two indicators and particularly does not provide the type of interpretation which one will be able to give on the coefficients of the model. Consequently

[4] See also Stern and al (1996).

the model is very descriptive and does not answer to the question if the reduction of pollutants is carried out by more ambitious environmental policies or by technological and structural changes. Moreover, the approach does not allow to explicitly determine the influence of the growth on the models of emissions. This last point is of particular importance, because it can involve a confusion on the interpretation of the results of regression obtained starting from the data for fixed-effects used by Shafik and Bandyopadhyay (1992), Selden and Song (1994) and Grossman and Krueger (1995). To this end, the time index is significant, because the results of these three studies show that time have a negative effect for the majority of pollutants.

Moreover, these studies for the majority have been carried most of then in developed countries. That can be explained by the fact that the improvement of environmental quality is endogenous with the process of the economic development. Ekins (1997) and Munasinghe (1998) stipulate that this improvement results from an increase in the demand for a better of the environmental quality. The latter increases with the increase in income and stresses the implication of the public authorities for more regulation and investment at environmental ends.

3. Sample description and structure of the econometric model

Before beginning to work out our model, we initially will present our sample and the data the component.

3.1. Construction of the sample and data source

Haute-Normandie is an area equipped with an industrial economic structure very large, with a strong representation of the oil and chemical sector. The transport and industry sector constitute the main principal source of air pollution. The data used are obtained starting from the statements of the annual mean levels of pollution for each station of monitoring of air quality in Haute-Normandie. The indicators of pollution selected are the sulphur dioxide, the suspended particles which are of industrial origin and ozone[5].

The number of observation varies with the pollutants and communes. For the sulphur dioxide the sample contains 139 observations for 28 communes. It is polluting which comes primarily from the combustion of fossil fuels (coal and fuel), with for principal sources industries in

[5] The emissions of these pollutants are measured in µg/m3.

particular the thermal exchange and the large installations of combustion. The industrial reject represent more than 90% of regional emissions, with an average day of 206 tons in 2003. In the Haute-Normandie area, the principal sources of SO_2 are the refineries, the stations of thermal production, the boiler rooms industrial, the petrochemical sites and the workshops sulphuric acid.

Concerning the suspended particles we have 42 observations for 12 communes. It is polluting of varied origin, primarily of the combustion of fossil fuels and automobile transport. The industrial sources are mainly the large industries of combustion and the incineration plant.

Lastly, the concentration of ozone constitutes a photochemical indicator of pollution. It is a summer pollutant, because its formation is done starting from other ambient pollutants, automobile, industrial pollutants and servants under the heat and sunning effect. Its sample is composed of 124 observations in 28 communes. The period considered is five years meaning from 2000 to 2004.

Table 1. Descriptive statistics

Variable	Mean (SD)	Minimum	Maximum
Sulfur dioxide	13.35 (8.52)	2	45
Suspended particles	21.94 (3.46)	17	31
Ozone	44.01 (8.10)	20	55
Income	15054.49 (4942.95)	9531	33128

These variables of the air quality are generally among the most used indicators for atmospheric pollution of the communes. The sulphur dioxide and the suspended particles are in great quantity in the atmosphere and their effects on human health and the natural environment were recognized a long time. These two pollutants are responsible for serious respiratory diseases[6].

Other pollutants contributing to environmental pollution can be analyzed this study does not consider them for lack of data. They are carbon monoxide and toxic metals. However, most significant it is the omission of the pollutants which have a total effect on the atmosphere and which contribute in particular to the destruction of ozone layer. It is about the carbon dioxide, methane and chlorofluorocarbon (CFC). Thus, our sample does not cover all dimensions of the environmental quality. Moreover no many equipped with measuring sites of air quality.

[6] For example, Lava and Seskin (1970) find a variation of the sulphur dioxide and density of the population explaining together the 2/3 of the variation of mortality by bronchitis in a sample of the cities of theplain ones.

We retained only the cities in which are localized the measuring sites of Air Normand[7] for which we have information.

For each city, we associated the household incomes with the density of the population of the area. The equations of pollution relating to each one of these indicators of the environmental quality are thus functions of the income and the density of the population.

The data relating to the density of the population are provided by INSEE[8]. The data collected to estimate the household income by city result from the statistical results of the principal declarations of income tax. These results gather all the cities[9] of the direction of tax services of the departments of Haute-Normandie. These data are available on Internet site of the general direction of taxes[10].

3.2 The structure of the econometric model

To analyze the relation between the indicators of environmental quality and the indicator of wealth, we estimate several reduced form equations which connect the concentration level of pollutants in a locality with the income level and with the density of the population.

An alternative to this reduced approach tightened a model of structural equations connecting the environmental regulation, technology and the industrial composition with the GDP (Grossman and Krueger, 1994). According to these authors, this reduced-form model has two principal advantages: initially, it allows the direct estimate of the nets effects of the national income on pollution. Then, the reduced form of the model enables us to avoid the data on the environmental regulation and the technological level. Because this type of data are not easily available and do not have an unquestionable validity. However, the limit of this approach is that it does not explain the reason of existence of the relationship estimated between pollution and the income. Nevertheless, it is a first significant stage to estimate the relation between pollution and income.

The structure of our regression is inspired by the model of Stern (2004):

[7] Air Normand, the station of monitoring of the quality of the air in Haute Normandie (Observatory of air quality/ALPA-REMAPPA).

[8] They are the data resulting from the census of the population from 1999.

[9] These data are not provided for the cities having less than 11 imposed tax hearths, or those for which one only imposition exceeds the threshold of 85% of the taxable product or the tax of the commune.

[10] http://www.impot.gouv.fr

$$\mathrm{Ln}P_{it} = C_i + \lambda_1 \mathrm{Ln}Y_{it} + \lambda_2 (\mathrm{Ln}Y_{it})^2 + \lambda_3 Z_{it} + \lambda_4 t + \varepsilon_{it} \quad (3)$$

P_{it} represents the concentrations of pollutant of the locality (city) i in the year t, Y_{it} it is the households tax income and Z_{it} another control variable (such as the density of the population), ε_{it} is the random term and C_i indicates the specific constants to each city and allow taking into account the nonmeasurable variables.

If we obtain a positive sign for λ_1 and negative sign for λ_2, then the assumption of an environmental Kuznets curve is verified. In the contrary case, we have either a U-shaped curve or a monotonically increasing or decreasing curve. The turning point of the curve where the concentrations of pollutants reach their maximum is:

$$\mathrm{Y}_{\max} = \exp[-\lambda_1/2\lambda_2] \quad (4)$$

Where λ_1 *and* λ_2 are the parameters of levels and square of household income in equation *(3)*. $\mathrm{Y}_{\max}$ corresponds to the maximum value of the income obtained by the derivative compared to Y of the equation of pollution *(dLnP/dY=0)*.

Two different models are often used for this kind of studies: the fixed effects model or the random effects model. When the random terms are correlated with the explanatory variables, then the random effects model is not appropriate to the study. The econometric justification of the choice between the two models is done by the Hausman test still called test of specification of the variables or test of difference in coefficients. It allows testing the null assumption of exogeneity of the variables (Ho). When the probabilities of the test are lower than 10%, there is a reject of Ho and the difference in coefficients. That implies the endogeneity of the explanatory variables with specific effects. In this case we use the fixed-effects estimator.

If the income is the only explanatory variable of pollution, it directly influences the fact pollution in a direct way. The rise of the level of income is often accompanied by a demand for improvement of environmental quality. But the explanatory capacity of the income as only explanatory variable of environmental degradation is weak. The richer one becomes, the more one requires a better environmental quality. These factors can appear either by changes in the spending patterns while being directed towards less polluting products, or by the displacement of the rich populations towards more respectful. The environmental Kuznets curve allows to detect the principal role and of increasing of income on the atmospheric pollution.

4. Estimation of the model and analysis of results

We have estimated the equation *(3)* for each of the three pollutants (sulphur dioxide, the particles and ozone) and also the explanatory variables described in the preceding section. For comparative goals, we initially estimated the equations with the income only. Then we included thereafter a demographic variable, namely the density of the population, in order to observe the impact of its evolution on environment. The results of our regressions are presented in tables 1 and 2 below.

Table 2. Results of the regression with sulphur dioxide and the suspended particles

	Fixed-effects SO2		Fixed-effects PM10		Random-effects PM10	
	1	2	1	2	1	2
Income	-28.572	-29.614	202.833	403.359	151.791	168.906
	(2.50)*	(3.92)**	(2.58)*	(2.64)*	(3.55)**	(2.53)*
Income squared	1.340	1.430	-10.657	-21.168	-7.963	-8.807
	(2.28)*	(3.70)**	(2.56)*	(2.63)*	(3.53)**	(2.51)*
Density of Pop		0.010		-3.613		0.101
		(1.75)		(0.11)		(1.68)
Years		-0.060		-0.038		-0.030
		(4.53)**		(2.00)		(1.89)
Constants	153.090	260.155	-962.023	-1,813.652	-720.251	-748.263
	(2.76)**	(5.01)**	(2.59)*	(2.91)**	(3.55)**	(2.43)*
Observations	139	111	42	40	42	40
Identifs	28	27	12	11	12	11
R-squared	0.31	0.63	0.40	0.38	0.40	0.44
T-Hausman (1)	28.05(0.00)	14.67(0.00)	2.09(0.35)	3.92(0.27)		
T-Breusch.P(1)					23.5(0.00)	16.2(0.00)
Turning points	42667		13581		13780	

t and *z* statistics are in parentheses
* denotes significance at 5%; ** significance at 1%
(1)The probability values of Hausman test and Breusch Pagan test are in parentheses

Before estimating we indeed carried out the Hausman test as previously indicated. The results (table 1) clearly show the reject of the random-effects model with the profit of the fixed-effects model in particular for sulphur dioxide. For the particles and ozone the results of the test are not significant meaning higher than 10%. The test does not allow differentiating the two models. To avoid the difficulties which emerge in the choice of the model we used the two estimators (fixed-effects and random-effects estimators) to estimate our model (table 2).

We also carried out the Breusch Pagan test to test the significativity of the random effects in the model. The results indicate overall a significativity of the random effects to a threshold of 1%. Lastly, in comparison of variability inter individual and variability intra individual, we notice that the variation inter individual is stronger than variability intra individual. The results of these tests allow concluding that the random effects model is preferable with the fixed effects model for the particles and ozone.

Table 2. Results of the regression with ozone

	Fixed-effects		Random-effects	
	O3		O3	
	1	2	1	2
Income	-8.226	-9.420	-8.151	-10.110
	(2.45)*	(2.73)**	(2.45)*	(3.04)**
Income squared	0.372	0.443	0.370	0.477
	(2.16)*	(2.51)*	(2.17)*	(2.80)**
Density		0.003		0.000
		(1.09)		(0.11)
Years		-0.030		-0.032
		(4.83)**		(5.73)**
Constants	48.105	108.523	47.494	121.404
	(2.95)**	(4.52)**	(2.94)**	(5.87)**
Observations	124	109	124	109
Identifs	28	27	28	27
R-squared	0.45	0.60	0.45	0.59
T-Hausman (1)	2.49(0.28)	1.44(0.83)		
T-Breusch P(1)			176.9(0.00)	158.14(0.00)
Turning point			60770.8	40033.9

t and *z* statistics are in parentheses
* denotes significance at 5%; ** significance at 1%
(1)The probability values of Hausman test and Breusch Pagan test are in parentheses

We have estimated equation 3 for each pollutant described previously. For each pollutant we estimated two equations, the first with the income alone and in the second we included the population density and the time index (years). In all the cases the coefficients of regressions estimated with the fixed effects and random effects models are generally significant as their *t*-statistics indicate it (*z*-statistics for the random-effects model). It thus appears generally that the household income is significant determining local pollution.

For the first estimating of the sulphur dioxide, the relationship to the income is negative, because the estimated coefficients are negative and statistically significant to 5% as their *t*-statistics indicate it. That means that on all the income levels of the sample, meaning between 9531 euros and 33128 euros, we obtain a decreasing relation between the level of SO_2 and the household income. That thus translated the negative influence of the income on the pollutant (figure 2). However, the coefficient (λ_2) between the income quadratic expression and sulphur dioxide being positive and significant means that beyond 33128 euros this relation is not always decreasing. The income increasing can be associated with increasing level of SO_2. Thus, the relation becomes rising and takes the shape "U". The point from which the level of pollutant starts to increase corresponds to income level approximately equal to 42667 euros.
We have estimated the same equation by including the time index and population density. We notice that this inclusion changes the level of significativity of the results meaning a reduction of 5% to 1% for dioxide sulphur.
Regarding the particles the Hausman test doesn't allows to use the estimator within. We then used the two estimators for a comparison of results. The two models give us significant results.
In comparison with the results of test we notice that the random effects estimator provides more significant results compared to fixed effects model for regressions with the income alone. Contrary to the sulphur dioxide the inclusion of the density decline the significativity level from 1% to 5% for the random effects model and remains unchanged for the fixed effects model. Thus, the results obtained starting from the model for random effects appear more significant for our estimates. The coefficients of correlation λ_1 and λ_2 are respectively positive and negative and very significant to 1%. That means that for low income levels one observes an environmental degradation (increasing in the level of the particles) followed by a reduction for high income levels. That indicates an inverted U-shape relationship between the households income and the particles (figure 3). The turning point is approximately equal to

13780 euros. This income level is roughly equal at the average income level of households of the commune of Rouen and Lillebonne in 2000.

Table 2 present us the results of the regressions for ozone. As for the suspended particles the Hausman test indicates that the results obtained by the fixed effects model are not consistent being studied. Our analysis is then based on the results generated by the random effects model. Nevertheless, we notice that the results deferred in table 2 are almost similar for the two estimators. The difference is that the level of significativity becomes 1% between the quadratic term of the income and the pollutant, in particular for the second regressions. The negative coefficient between the income and ozone illustrates the nature of the influence and of the relation between the two variables.
As for the sulphur dioxide, the results of the regressions indicate a decreasing relationship between the household income and ozone in interval between 9531 euros and 33128 euros (figure 4). The turning point calculated is higher to the maximum (60770.8). That means that starting from this point the relation between the two variables becomes increasing.

5. Interpretation of results

The results obtained show that the relation between the two atmospheric pollutants (the sulphur dioxide and ozone) and the household income is decreasing between 9531euros with 33128 euros and beyond this interval it is transformed in "U" (figure 1a in appendix). This relationship is very significant for the two types of pollutants. The turning points 42667 euros and 60770.8 euros respectively for sulphur dioxide and ozone are largely higher to the maximum of our sample. Thus, for the two pollutants above-mentioned, our study leads to opposite results with the assumption of the environmental Kuznets curve at regional level. In considering only the sulphur dioxide, then the results obtained allows to conclude to the nonevidence from the assumption from the environmental Kuznets curve as for the empirical results from Grossman and Krueger (1995) and Torras and Boyce (1998).

Indeed, for all income levels of sample (between 9531 euros and 33128 euros), the estimating of the equation of SO2 gives the results which corresponds with those obtained by Carson and *al.* (1997). Meaning a monotonically decreasing relationship between household income and pollutants. But, these results go against those of certain studies quoted before (Panayotou, 1993 and 1995; Selden and Song, 1994; Shafik and Bandhopadhyay, 1992; Stern and

Common, 2001). That can be due to the fact that the sample size is not the same and the difference of the size of the fields of analysis. For we use data to a very restricted level of area and the majority of these studies use the data on global and national levels.

Theoretically, the considering of income levels higher than 33128 euros can give consistent results with those obtained by Kaufmann and *al.* (1998).

The fact that the income increasing involves an increase of pollution can be due to the change of the type of energy used by households for lighting and the heating (Sathaye and Meyers, 1987). In the case of dioxide sulphur this change results in the use of energies with low content sulphur rather than those with strong sulphur concentration.

In the region Haute-Normandie (Assess of measurements of Air-Normand) more precisely for the agglomeration of Rouen no major episode was recorded during the three last years. The fall of the concentrations levels seems to be due to the reduction of the industrial emissions, accompanied by a diffusion of recommendations to sensitive people for the commune of Petit-Couronne. It is a clear improvement for this commune of industrial proximity with a fall from 20 to 30%. This situation extends on the unit from Rouen agglomeration with in average a fall of 20% from emissions. With the exception of the sensor of Val de la Hay which undergoes an increase of +36% in 2003 because of the proportion of east wind stronger than the last years. Concerning the suspended particles, their evolution remains rather stable. One notes a light increase in 2003. With for source the refinery Total and power station EDF, the emissions of sulphur dioxide know an increase on the Havre agglomeration from 18% to 57%. In particular on the sensors of the centre town and Sainte-Adresse. However, the peaks of pollution are less frequent and less intense, which results of number of information intended for categories of population sensitive slightly in fall. One notices a reduction on the site of Gonfreville l'Orcher which remains despite everything one of the most exposed sites agglomeration of Le Havre. In a general, this improvement is partly due to a regulation more and more severe. However, certain limiting thresholds remain still violated in particular for sulphur dioxide.

The studies which use ozone to test the influence of the income on pollution are rare even non-existent. The only estimating of the model which gives the awaited and statistically significant coefficients to 1% is that of the equation of particles. The results show an inverted U-shape relationship between household income and the atmospheric concentrations of the particles. This relation adheres thus to the assumption of the environmental Kuznets curve.

Starting from income level equal to 9531 euros we observe an increase of particles when the income increases followed by a fall of levels of pollutant up to a income level equal to 33128 euros. There is initially a phase of deterioration of environmental quality at the low levels of income then a phase of improvement. For this same pollutant, the authors like Selden and Song (1994), Shafik and Bandhopadhyay (1992) and Cole and *al.* (1997) obtained the similar results. This phase of improvement began starting from a threshold of income equal to 13780 euros. This value is including in interval of income. The characteristics of each pollutant explain these results mainly.

There is a particular interest for the coefficients estimated with the time index. These coefficients indicates the point to which the environmental problems worsen or improve with time. Environmental quality can worsen with time if the concentrations of pollutants accumulate or if the consumers use the strongly polluting goods. Contrary, the environmental quality can improve if the technological innovations allow it with costs of less expensive reduction (Grossman and Krueger, 1994).

The econometric results for time index (years) show that the signs of coefficients are negative and statistically significant with a threshold of 1% for the two pollutants only (the sulphur dioxide and ozone). The results of the study state indeed that the tendency is with the fall of the levels of pollutants in time.

To recapitulate, we obviously do not find on the fact that environmental quality strongly worsens with income increasing. We find rather than at all income levels of the sample, the increase household income involve an improvement of environmental quality (for sulphur dioxide and ozone concentrations). For particles the income increasing leads initially to a phase of deterioration of the environment followed by a phase of improvement. According to Grossman and Krueger (1994), this possible improvement of the environment reflects in partly a demand increased of the environmental protection on high levels of the national income.

The figures 2, 3, and 4 translate the curves relating to the form of the relation estimated between the tax incomes of the households and each one of these pollutants. They indicate the sensitivity of various pollutants to the changes of income. These are the graphic representation of econometric results of model. They thus illustrate a negative relation between the income of households and the air pollution. Obviously, we observe a downward trend of the emissions of pollutant when there is the increase of income levels. This explains why the demand of improvement of environmental quality increases with household income.

Figure 2. *Relationship between income and SO_2*

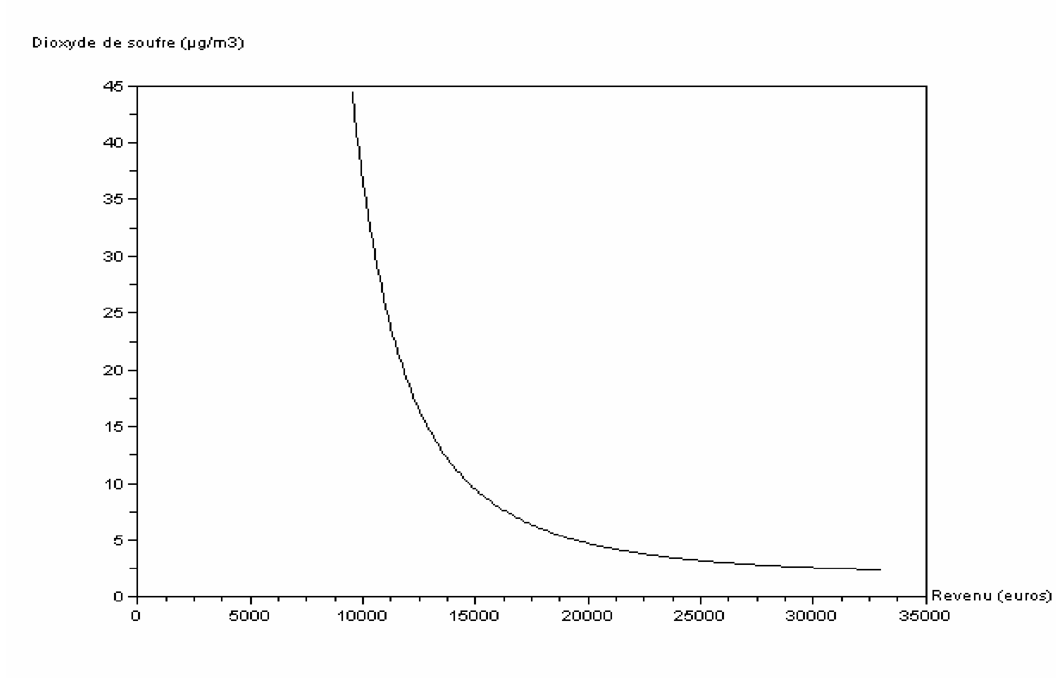


Figure 3. *Relationship between income and PM_{10}*

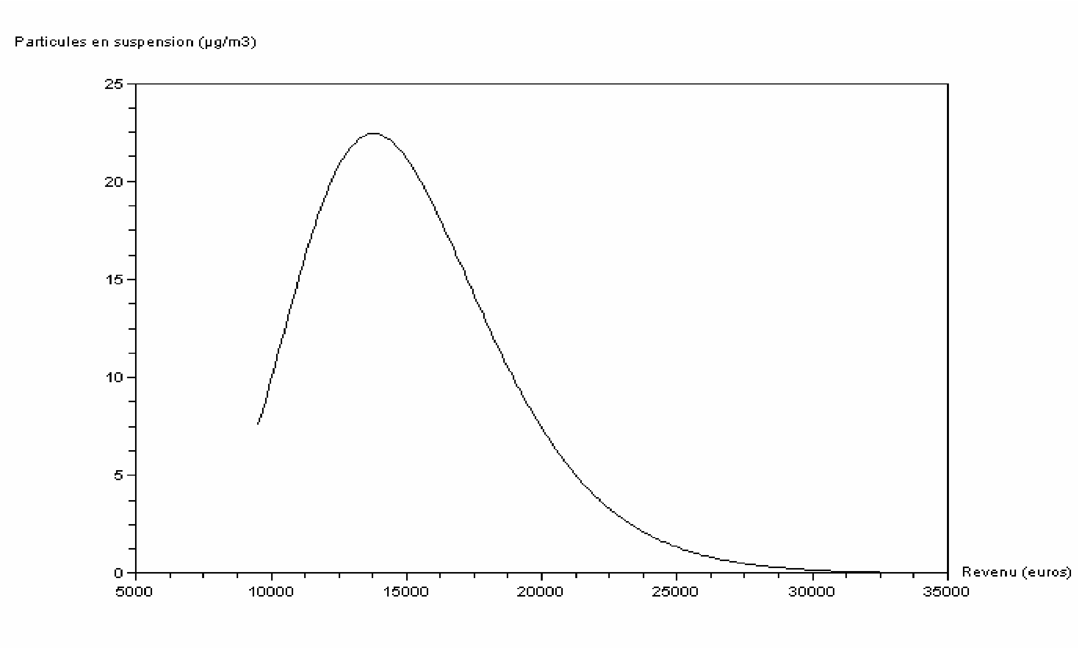
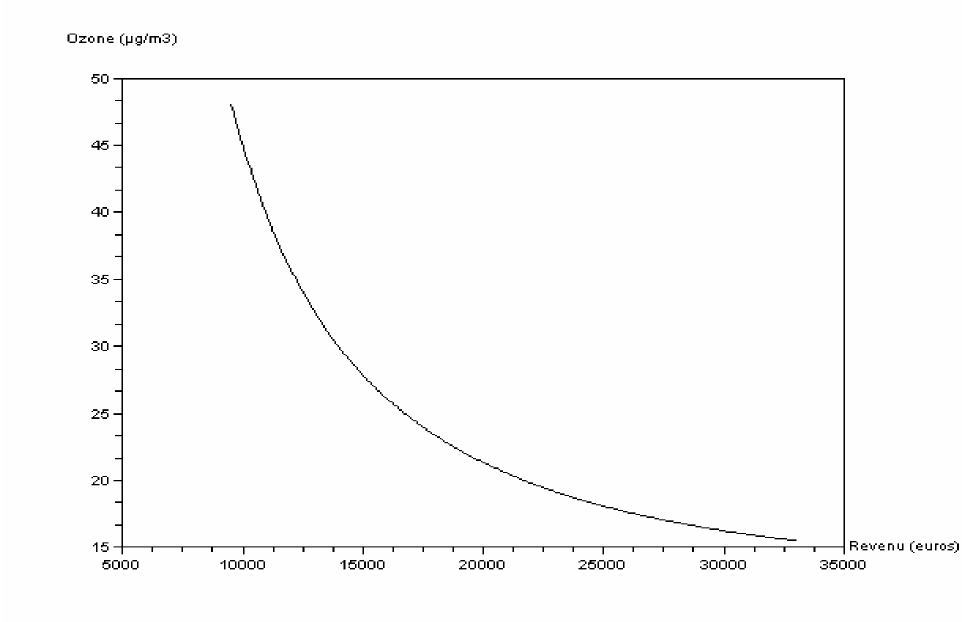


Figure 4. *Relationship between income and O_3*



At moment where the income increase constitutes a determining element of the socio-environmental inequalities, certain authors think that a developed economy has capacities to finance the antipollution fight programs. Conversely, the priority of the poor economies is turned towards the fight against poverty, much more than towards the environmental concerns. Although the economic growth is at the origin of the environmental externalities, it remains nevertheless one of the principal factors of the development and thus one of the only possibilities of finding a better environmental quality (Beckerman, 1992).

If empirical realities show that beyond a certain threshold, the increase in income goes from pair with the improvement of environmental quality, it is indeed necessary to set up more adapted policies environmental making it possible all the social categories to profit from it. This indeed makes it possible to reduce, even slow down, the increase in the social and environmental inequalities.

6. Conclusion

The more recent surveys on the theoretical and empirical literature on the EKC emphasize that the only considered variable affecting environmental degradation is the per capita income (Stern, 2004)

We have estimated the reduced form of the relationship between household income and the local indicators of the atmospheric pollution (dioxide sulphur, particles and ozone) by using a panel data on the area of the Haute-Normandie. This study allows estimating income effects on the atmospheric pollution. The analysis is based on the ambient concentrations of these three types of pollutants.

With many regards, the evaluation results of income effects on environmental quality seem all to converge towards the following conclusion: the income have a positive influence on environment. That indicates that increasing income constitutes a determining factor for environmental improvement

Generally, the atmospheric pollution seems to draw benefit from this increase once that a certain income level is reached. The turning points vary according to various pollutants. The atmospheric dioxide sulphur concentrations can thus decrease more quickly, without passing by a stage of increase in the concentrations as for the particles when the income increases. However, the analyses of the preceding studies (Selden and Song, 1994; Stern and *al.,* 1996) indicate that the concentrations or the emissions increase with the first stages of the increase in income. Our findings show obviousness that the sulphur dioxide concentrations drop with an increase in the income between 9531euros and 33128 euros.

The assumption according to which the increase in income can be related to a deterioration of the environment is rejected on a level of 5% of significativity between 9531 euros and 33128 euros for the sulphur dioxide and ozone. Indeed, we observe a reduction in the levels of concentration of SO_2 and O_3 inside this interval. This reduction is due to an increase in income households. However, this assumption is checked for the particles, because there is well increase in their levels between 9531 euros and 13780 euros. Thus, in Haute-Normandie the assumption of the environmental curve of Kuznets is checked with the concentrations of the suspended particles.

Some remarks can be made in connection with these results. Initially, concerning the dimension of environmental quality where the increasing income seems a solution with the environmental problems, there are no reasons to believe only the process is done in an automatic way. The environmental quality can improve if there is substitution of the clean technologies to polluting technologies.

The methodology used for this work does not allow to us to study the means by which the increase or the reduction in the level of income influences the environmental results.

Then, the *sine qua non* condition to have an environmental quality relatively healthy is to set up more rigorous environmental standards and to have very strict measurements on the application of the environmental laws.

The diversity of these results on the various pollutants allows raising questions about the obviousness of the relation between the income and pollution. According to Ekins (1997) the major part of the world population is in the ascending part of the environmental curve of Kuznets. That implies that in the future the increasing income will lead to degradation rather than with improvement of total environment. Selden and Song (1994) find that in the case of sulphur dioxide, the particles, oxides of nitrogen and carbon monoxide, the emissions will continue to increase quickly in the years to come. Stern et *al*. (1996) obtain a similar result for the total SO_2 emissions. Lastly, the validity of the environmental Kuznets curve must allow the awakening of the environmental matter countries to prevent that the first stages of the economic growth always result in a deterioration of environmental quality.

Two principal limits emerge from our study: first relates to the low number of observations for the particles. What returns the validity of the statistical test very limited? Second relates to methodology. The latter does not enable us to study the means by which the changes of incomes affect the environmental results.

Finally, the econometric results of the estimates of certain pollutants do not seem to confirm the assumption of the environmental curve of Kuznets.

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Annexe 1 : Courbes de la relation avec des niveaux de revenu supérieurs à 33128 euros.

Figure 1a. Relation entre le revenu et les concentrations de SO_2

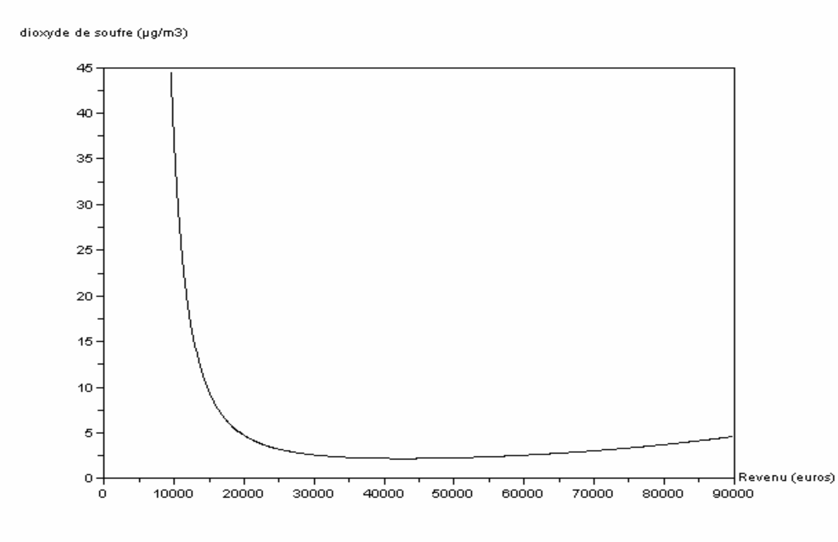
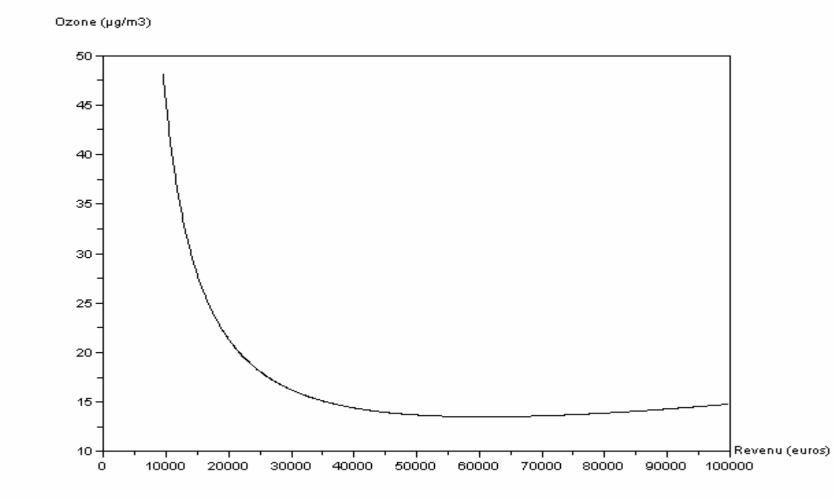


Figure 2a. Relation entre le revenu et les concentrations d’ozone



Annexe 2: Description des variables

Variables	Description	Moyenne (écart-type) (objectif de qualité)	Source
SO_2	Dioxyde de soufre	13.89 (8,69) (50µg/m^3 en moy. annuelle)	Air Normand, Observatoire de la qualité de l'air / ALPA-REMAPPA Bilan des mesures (2000-2004)
PM_{10}	Particules en suspension	21.94 (3.46) (30µg/m^3 en moy. Annuelle)	Air Normand Observatoire de la qualité de l'air / ALPA-REMAPPA Bilan des mesures (2000-2004)
O_3	Ozone	35.87 (14,41) (110µg/m^3 en moy. annuelle)	Air Normand Observatoire de la qualité de l'air / ALPA-REMAPPA Bilan des mesures (2000-2004)
Densité de la Pop.	Densité de la population (personnes/km^2)	1391.17 (1356)	INSEE : Recensement de la population 1999
Y	Revenus fiscaux des ménages (milliers d'euros)	15054,49 (4942,95)	INSEE-DGI : revenus fiscaux des ménages, exploitation des déclarations de revenu (2000-2004)