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Does Air Pollution Affect the Impact of Economic Development on Cancer Mortality? The Case of OECD Countries

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Abstract

This paper's principle aim is to investigate if the level of fine particular matter (PM_{10}) affects the impact of economic development on cancer mortality. At this scope, we consider a polynomial model with the number of cancer deaths as dependent variable for a panel of 26 Organization for Economic Cooperation and Development Countries (OECD) during the 1990-2013 time span. The covariates are PM_{10}, income, public health-expenditure, the share of urban population, the number of daily sold cigarettes and alcohol daily consumption. For the scope of our investigation, we implement a quartile division of covariates using the level of PM_{10} as reference variable in order to estimate the effect of the same variable for each subgroup. Technically, we first use PM_{10} values to construct quartiles. Then, we use cancer-mortality rates by PM_{10} quartile to run separate regressions for each quartile. We also calculate the social costs arising from cancer deaths caused by PM_{10} emissions. According to our results, increasing pollution levels weaken the moderating effect of income and health expenditure on cancer-deaths. As far as PM_{10} is concerned, it seems that it increasingly affects cancer-deaths until it reaches a threshold level, then its influence on the number of deaths lowers down. Finally, we simulate that a 1% increase in PM_{10} emissions leads to an increase of 0.205 cancer-deaths every 100.000 inhabitants. In terms of social costs, these deaths amount to 881.500 US$.

Keywords

Cancer Deaths, PM10, Economic Development

1. Introduction

Nowadays, the relationship between cancer mortality and air pollution is at the center of a multidisciplinary debate involving researchers from many fields of studies. The theoretical contribution given by economists to this debate is noteworthy. In particular, after the seminal paper of Grossman [1], a common approach to interpreting the impact of environmental quality on human wellbeing is the health production function model (HPFM) in which health status depends on different types of input. Not surprisingly, among these inputs, economists place particular emphasis on environmental quality and on the process of economic growth (cf. also [2] [3]).

From this point of view, however, the context defined by the HPFM turns out only partial and, therefore, other complementary theories are needed for a full understanding of the complex relationships between human health, environmental quality and economic growth. For instance, growth and human capital accumulation theories allow the growth process to be influenced by both human health and environmental quality. At the same time, as proposed by the Environmental Kuznets Curve Model (EKCM), environmental quality can be a function of the level of development. All in all, it seems that, in principle, potential circular causality relationships between each pair of variables and among the three variables taken all together cannot be excluded.

This theoretical complexity is probably one of the main reasons why the number of empirical contributions on the relationships between environmental quality, economic development and public health is quite low. Among them, it is common to find that health, often measured by mortality rates, is affected positively by growth and negatively by environmental degradation (Cf. inter al, [4] [5]). However, given the scant empirical literature, more research is strongly needed, especially to provide investigations on important issues that are still open. For instance, in terms of policy implications, it is very important to know whether the level of pollution exposure, besides pushing the number of deaths, also affects the response of mortality to its determinants. Is economic growth effective in reducing mortality rates, regardless of the level of pollution exposure? Is the response of mortality to pollution itself affected by the current level of emissions? Can we measure the social costs attributable to a certain type of pollution? These and other questions are still waiting for further empirical investigation.

The aim of this paper is to contribute to the literature by investigating the impact of pollution level on the vulnerability of cancer mortality to pollution, income and some other selected determinants. As dependent variable we consider the number of cancer deaths, whereas fine particulate matter, PM_{10}, and per capita GDP are among the determinants. Other covariates included in the model are the ratio between public health-expenditure on total GDP, the share of urban population, the number of daily sold cigarettes and alcohol daily consumption. The choice of these variables is based on the extant economic and epidemiological literatures (Cf., inter al., [5] [6] [7] [8] [9]). The analysis is performed for a panel of 26 OECD countries during the 1990-2012 time span. To validate the hypothesis under investigation, we divide the panel into quartile sub-samples using the level of PM_{10} as reference variable. Then, we run separate regressions for each quartile so that we can estimate if the effect of the same variable differs across subgroups. As estimation technique, we opt for a panel fixed effect model in log form.

To complete the investigation, we proceed with the calculation of the social costs arising from cancer deaths attributable to PM_{10} in our sample. There is increasing interest on this issue because it is strictly connected with the possibility to give an economic value to a negative externality that otherwise would remain uncalculated. In terms of policy implication, this value can also be used to measure the social benefits of public resources destined to reduce polluting emissions. In this paper, we calculate social costs based on the Value of Statistical Life index, proposed by World Health Organization [10] and developed, among others, by Biasque [11] and Braathen [12].

The main results seem to suggest that increasing pollution levels weaken the moderating effect of income and health expenditure on cancer-deaths. As far as the effect of PM_{10} is concerned, it seems that this pollutant is increasingly affecting cancer-deaths until it reaches a threshold level, then its influence on the number of deaths lowers down. In any case, pollution above the turning point would be environmentally inefficient.

2. Empirical Model

The present analysis aims to investigate whether the level of exposure to PM_{10} emissions affects the vulnerability of cancer deaths to pollution itself, to income, to health expenditure, to cigarettes and alcool consumption, and, finale, to a measure of urbanization. The investigation is performed for a panel (unbalanced) of 26 OECD countries during the 1990-2012 time span.

The empirical strategy consists in defining a single polynomial equation model in log-log form so that all the estimated parameters represent elasticities. Then, we introduce a quartile subsampling of the panel using PM_{10} as reference variable in order to run separate regressions for each quartile. This strategy allows us to estimate the parameters of the model for each quartile and, therefore, to test whether the differences in environment conditions affect the vulnerability of mortality rate to our covariates. Moreover, this strategy also allows us to control for the heterogeneity between the units of the panel.

As econometric technique, we use a panel Fixed Effects (FE) model. FE assumes that observed units (countries) have time-invariant characteristics and removes the effect of these characteristics on the estimation outcome. Moreover, FE model assumes that these time-invariant characteristics are unique to the individual and should not be correlated with other individual characteristics.

The model[1] is defined as follows:

[1]The variables in Equation (1) are taken from the OECD STAT dataset, with the exception of the share of urban population and cigarettes consumption that are delivered by World Bank and Our World Bank, respectively. The main descriptive statistics are calculated and available upon request.

$$\ln D_{s,t} = \alpha_s + \beta \ln PM_{10s,t} + \gamma \ln Y_{s,t} + \delta \ln H_{s,t-n} + \theta \ln A_{s,t} + \rho \ln C_{s,t} + \pi \ln U_{s,t} + \varepsilon_{s,t} \quad (1)$$

where $\ln D$ is cancer mortality rate, $\ln PM_{10}$ is the particulate matter, $\ln Y$ is GDP per capita at constant price; $\ln H$ is health expenditure on total GDP, $\ln U$ is the share of urban population, $\ln C$ is the number of cigarettes per adult per day and $\ln A$ is alcohol daily consumption in liter per capita. In Equation (1) the subscripts s and t indicate countries and years, α_s is the unobservable time-invariant individual (country) effect and $\varepsilon_{s,t}$ is the error term. As we can see, the variable $\ln H$ is lagged in order to correct for potential endogenity due to bidirectional causality between cancer deaths and health expenditure.

3. Results

Table 1 reports the main findings of the proposed investigation. In general terms, the picture appears very interesting. With the exception of $\ln U$ for which we did not have an a priori definite belief, all coefficients, when statistically significant, report the expected signs. More in details, $\ln PM_{10}$, $\ln A$ and $\ln C$ increase the number of deaths, whereas $\ln Y$ and $\ln H$ contribute to reduce cancer mortality.

Turning the attention to the comparison between quartiles, as reported in Table 1, the picture shows a high degree of heterogeneity. The case of the 4th Quartile is where our model demonstrates its best fit.

Table 1. Results by PM_{10} quartiles: $\ln D$ dependent variable.

Variables	1th Quartile		2nd Quartile		3rd Quartile		4th Quartile	
$\ln PM_{10}$	0.129	***	−0.016		0.147	***	0.072	***
	0.024		**0.067**		**0.031**		**0.025**	
$\ln Y$	−0.433	***	−0.264	***	−0.219	***	−0.075	*
	0.043		**0.074**		**0.036**		**0.038**	
$\ln H(-3)$	−0.072		−0.201	**	0.012		−0.173	***
	0.052		**0.091**		**0.044**		**0.045**	
$\ln A$	0.296	***	0.1		0.06		0.102	*
	0.034		**0.066**		**0.053**		**0.055**	
$\ln C$	0.009		0.106	***	0.039	*	0.067	***
	0.013		**0.034**		**0.023**		**0.017**	
$\ln U$	0.621	***	−0.004		−0.006		−1.11	***
	0.109		**0.88**		**0.148**		**0.292**	
Const	6.597	***	8.25	**	7.211	***	10.77	***
	0.532		**3.674**		**0.62**		**1.129**	
Obs.	88		90		110		97	
rho	0.987		0.918		0.965		0.985	

*, **, *** indicate 10%, 5% and 1% levels of significance.

In more detail, let us first consider the estimated effect of $\ln PM_{10}$. We can observe that this effect starts with an elasticity of 0.129 in the 1st Quartile, it is not significant for the 2nd Quartile, it reaches its peak for the 3rd Quartile and then it goes down to 0.72 for the 4th Quartile. It seems that $\ln PM_{10}$ is increasingly affecting cancer deaths until it reaches a threshold level, then its influence lowers down. However, for countries belonging to the 4th Quartile this is not to be interpreted as a good sign. It means that the greatest damage has already been produced and that the level of pollution reached is environmentally inefficient.

Turning the attention to $\ln Y$, it seems that the moderating income effect on cancer-death decreases the more countries becomes polluted. In fact, as we can see, absolute values of estimated coefficients decrease moving from the left to the right hand side of the distribution (from 0.433 to 0.075). This result bears important consequences because it means that the impact of pollution (+0.072) almost entirely cancels out the beneficial income effect (−0.075).

It is also interesting to observe the estimated elasticities that measure the impact of public health expenditures. As we can see, estimated parameters are statistically significant only for the 2nd and 4th quartiles. As with income, comparing the magnitudes of these coefficients, it seems that the moderating effect of health expenditure on cancer deaths is negatively affected by increasing pollution levels.

As for the other covariates, it is worth noting that the two bad-habit variables report expected signs, but magnitudes that are difficult to interpret. For both variables, it seems that the incidence on cancer death decreases among the most polluted countries. Finally, we find that for countries with lower value of PM_{10} (1st Quartile), the urban index reports a positive coefficient (0.621), while for the more polluted countries (4th Quartile) the effect is negative (−1.11%). Again, this result is difficult to interpret. The explanation could be the presence of possible non-linearities.

All in all, according to our findings it seems reasonable to conclude that PM_{10} emissions exert a double negative effect on health: a direct impact on mortality rates and an indirect impact by contrasting the beneficial effects arising from income and health expenditure. This evidence compares with the extant literature, and at the same time it pushes current knowledge to an interesting step ahead.

4. Social Costs of Cancer Mortality Associated to PM_{10} Emissions

The analysis provided in the previous section demonstrates that, for the countries in our panel, the negative impact of PM_{10} emissions on cancer death is noteworthy. Based upon this main result, we propose now an exercise to calculate the social costs that might be attributable to cancer deaths caused by PM_{10} emissions.

For this scope, we consider a standard method based on the concept of Value of Statistical Life (*VSL*) that is the willingness to pay (*WTP*) to have a marginal reduction in the risk of premature death. According to World Health Organization [10], this method is interesting because, in spite of its simplicity, it relies on robust microeconomic principles. Namely, let us define U_y^e the expected individual utility function of consumption over a given period. Taking into consideration the risk r of dying during the same period, the expected utility can take the following form:

$$U_{y,r}^e = (1-r)U_y \tag{2}$$

Starting from the previous equation, it is possible to define the individual's WTP as the amount of money he/she will be willing to pay to maintain the same expected utility if the level of risk lowers from r to r':

$$U_{y,r}^e = U_{y-wtp,r'}^e \tag{3}$$

According to the previous formula, VSL is defined as the marginal rate of substitution between consumption and risk of mortality:

$$VSL = \frac{\delta WTP}{\delta r} \tag{4}$$

Based on this theoretical assumption, OECD developed a survey in order to ask individuals their WTP. The values provided range between 15 US$ and 45 US$, with an average WTP of 30 US$. More technically, these values express the WTP for reducing the annual risk of dying from air pollution from 3 to 2 in 100.000 individuals. Taking the average WTP of 30 US$, and summing it over 100.000 people, gives a VSL of 3 million US$ (with 2005 as reference year).

According to the OECD's guidelines (Cf. Braathen, 2012 for details), for the calculation of the VSL for a specific country C and different years, two adjustments are in order, one related to income growth and the other to price inflation. These adjustments correspond to the following formula:

$$VSL_{C(2018)} = VSL_{\text{OECD}(2005)} \times \left(\frac{Y_{C(2005)}}{Y_{\text{OECD}(2005)}}\right)^{\beta} \times (1+\%\Delta P + \%\Delta Y)^{\beta} \tag{5}$$

where β is the income elasticity estimated by the OECD between the 0.7 and 0.9, Y_{OECD} is the aggregated value of the GDP for the OECD area, ΔP is the variation of the price index between the reference year (2005) and the 2018, while ΔY is the variation of the GDP for the OECD countries.

The approach suggested by OECD to calculate the VSL is, fundamentally, a very simple method to evaluate the economic cost of an externality that, easily, can be extended to different contexts. In what follows, we will use this method to approximate the current economic effects of cancer-deaths due to PM_{10} pollution in OECD countries.

First of all, since the VSL_{OECD} available regards the year 2005, we need to update this value using the 2018 as reference year. In this case, the previous formula collapses to the following simplest version:

$$VSL_{\text{OECD}(2018)} = VSL_{\text{OECD}(2005)} \times (1+\%\Delta P + \%\Delta Y)^{\beta} \tag{6}$$

According to OECD data the ΔP for the time span 2005-2018 is about 0.294, whereas ΔY is about 0.278. Taking these values and $\beta = 0.8$ (average), the aggregated value of $VSL_{\text{OECD(2018)}}$ corresponds to 4.3 million US$.

Now, to complete our simulation, we should multiply $VSL_{\text{OECD(2018)}}$ by the number of cancer-deaths due to PM_{10} exposure. Since the latter is a very difficult information to obtain, we exploit our empirical setting to obtain the information we need. First of all, we transform the model in *lin-log* form and then we run the model at full sample level. In this way, given the definition of our dependent variable, the estimated coefficient for the variable $\ln PM_{10}$, divided by 100, corresponds to the impact of 1% increase of PM_{10} to the number of deaths for every 100.000 inhabitants.

As reported in **Table 2**, the estimation suggests that a 1% increase in PM_{10} emissions is related to an increase of 0.205 cancer-deaths every 100.000 inhabitants. So, given VSL = 4.3 million, we approximate at about 881.500 US$ (785,120 ˚€) the social costs of this negative externality. This is a reasonable value, if compared with the rest of the literature. For the Metropolitan Area of Skopje, Sanchez Martinez *et al.* [13] estimate that, in the year 2012, social cost for the estimated premature mortality attributable to $PM_{2.5}$ has been between 570 M€ and 1470 M€. On the same issue, the contribution of Croituru and Sarraf [14] reports new evidence for the case of Morocco.

5. Concluding Remarks

The relation between long-term exposure to particular matter air pollution PM_{10} and mortality is increasing concern worldwide. Unfortunately, quantitative estimates of mortality attributable to this pollutant are very critical to obtain because they should be based on complex disease-specific hazard ratio models that need to consider a lot of data uneasy to obtain.

However, economists are willing to contribute, with their instruments, at increasing the knowledge on the relationship between exposure to environmental pollution, human health and the level of development. In this vein, this paper proposed an investigation aimed to understand to what extent the increasing level of pollution might affect the vulnerability of cancer deaths to the level of economic development and to pollution itself. At this scope, we considered a panel of 26 OECD countries that we divide into four quartiles using PM_{10} as reference variable. This strategy allows us to separate countries according to their

Table 2. Estimates at full sample level.

	Const	$\ln PM_{10}$	$\ln Y$	$\ln H(-3)$	$\ln A$	$\ln C$	$\ln U$
D	607.1***	20.52***	−45.55***	−23.2***	19.01***	10.49***	10.26
Obs.	385						
rho	0.93						

*, **, *** indicate 10%, 5% and 1% levels of significance.

different levels of pollution exposure. Then, we define a model in which cancer mortality rate depends on fine particulate matter, per capita income, health expenditure, the share of urban population, cigarettes and alcohol consumption.

In general terms, our empirical analysis confirms previous literature. We find that particular matter air pollution, together with alcohol and cigarettes consumption, increases the number of cancer deaths. Conversely, income and public health expenditure exert a moderating effect on cancer mortality. In this respect, the most interesting finding of the analysis emerges when comparing quartile results. It emerges that the moderating effect of these two variables is negatively influenced by the level of pollution.

These findings on the whole suggest the presence of two mechanisms that can explain the impact of PM_{10} on cancer mortality. On the one hand, there is a direct impact on the number of deaths. On the other, PM_{10} reduces the beneficial effects that increasing level of development and health expenditure might have on mortality. Considering the social costs associated with this negative externality, our results undoubtedly recall the interest on this topic and on the need to dedicate further research to it.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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