The Journal of Socio-Economics 44 (2013) 27–36

Contents lists available at SciVerse ScienceDirect

The Journal of Socio-Economics

journal homepage: www.elsevier.com/locate/soceco

The indirect effect of fine particulate matter on health through individuals' life-style

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ARTICLE INFO

Article history:
Received 25 June 2012
Received in revised form 17 January 2013
Accepted 2 February 2013

JEL classification:
I12
C31
D13
D81
Q25

Keywords:
Health production
Multivariate probit
Spline
Life-style
Fine particulate
Asthma

ABSTRACT

Limited literature has been published on the association between environmental health indicators, life-style habits and ambient air pollution. We have examined the association of asthma prevalence and the amount of health investment with daily mean concentrations of particulate matter (PM) with a mass median aerodynamic diameter less than 2.5 mm ($PM_{2.5}$) in 16 metropolitan areas in U.S. using the Behavioral Risk Factor Surveillance System (2001) data in conjunction with the Air Quality System data collected by the Environmental Protection Agency. A multivariate probit approach has been used to estimate recursive systems of equations for environmental health outcome and life-styles. A piece-wise linear relationship has been postulated to describe the association between health outcome, health investment and pollution. We have assumed one change point at AQI value of 100 which corresponds to the US national air quality standard. The most interesting result concerns the influence of pollution on health-improving life-style choices: below a specified threshold concentration (AQI = 100) a positive linear association exists between exposure to $PM_{2.5}$ and health investments; above the threshold the association becomes negative. Hence, only if ambient pollution is in the 'satisfactory range' (AQI level at or below 100), individuals will have incentive to invest in health.

1. Introduction

Under the 1970 Clean Air Act and subsequent amendments, introduced by the Environmental Protection Agency to limit the amount of air pollution, ambient air quality in the United States has improved dramatically. However, despite regulatory effort, fine particulate continues to be a matter for concern despite its falling level. The situation has been further aggravated by the fact that protection of public health is constrained by the inability of scientists to establish a safe level of $PM_{2.5}$ below which it poses little or no risks for human health. In fact, fine particulate even at much lower concentrations (below current US regulatory levels), has been associated with increased rates of mortality and morbidity in several cities in the United States (in Europe and other developed countries, too) (Dume et al., 1998; Daniels et al., 2000; Bolin and Lindgren, 2002; Brunekreef and Holgate, 2002). Furthermore, the effect of particulate on health may be complex, as it may vary from one individual to another: scientists have to consider that individuals and groups are not equally vulnerable to air pollution health effects. Susceptibility factors could be strictly linked to fixed individual characteristics such as genetics, gender, age and race or to variable individual characteristics caused by the realities of life. Low socioeconomic classes, for instance, tend to be more susceptible to the adverse effects of air pollution because of other factors related to their life-styles: they are more likely to be uninformed over environmental health issues, to have an unhealthy diet, to smoke and drink alcohol, and in general to lead less healthy lives, with associated effects on their health (Grassman, 1996; Sexton, 1997). Hence, analysts must calculate changes in health outcomes by taking into account that the effect of pollution could easily be correlated with other factors that may be just as influential (Schwartz and Weiss, 1994a,b).

While, on the one hand, epidemiological studies have shown that pollution acts synergistically with tobacco smoking, alcohol consumption and unhealthy diet to induce respiratory illness such as asthma, lung cancer and cardiovascular diseases (Valavanidis et al., 2009) on the other hand there is little information on the extent to which quality of the environment may influence choices of life-style. This is an issue that has, in our view, received too little attention (see Cropper, 1981; Erbsland et al., 1994). An important contribution in this area was Cropper (1981), who explored the consequences of introducing pollution variables into the health

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http://dx.doi.org/10.1016/j.socec.2013.02.002

production function. She considered changes in environmental conditions to influence the amount of health investments through the rate at which an individual's stock of health depreciates: Cropper assumes that when pollution increases, it becomes more costly to reduce the probability of a health shock. Individuals feel less healthy because they perceive the health depreciation rate to be higher. Hence, they may choose to invest less in their health and maintain lower health stock because of the higher net investment costs. In this sense, a higher pollution concentration may have two effects on health: a direct effect which consists of an increase of the health depreciation rate and an indirect effect, described by Cropper (1981), by which individuals will invest less in health and display a higher probability of suffering from bad health.

The purpose of this study is to examine the influence that the quality of the environment, captured by the $PM_{2.5}$ level, may have on health investment decisions. The paper divides into two parts. The first part provides theoretical framework built on the basic concepts and ideas of the demand for health by Grossman (1972) and the subsequent contribution by Cropper (1981). In its second part the paper provides empirical support to the theoretical assumptions.

In the empirical part of the paper, in order to introduce a measure of health stock, a dichotomous measure of asthma prevalence has been used. We choose asthma since it simultaneously represents a health outcome and an "environmental health indicator" (see WHO, 1999). Since we have included life-style variables as regressors in the health equations, a problem of simultaneity may arise. Hence, we try to correct the potential endogeneity of the behavioral variables by using a recursive multivariate probit model which is available in the literature although not so frequently. A piecewise linear function has been employed to describe the relationship between health, health investments and pollution. We assume one change point at AQI value of 100 which corresponds to the U.S. national air quality standard.

The model is estimated using data from the 2001 Behavioral Risk Factor Surveillance System (BRFSS). BRFSS does not measure environmental quality but it can be used in conjunction with the 2001 Environmental Protection Agency's (EPA) Air Quality System (AQS) database. We merged data from the AQS with BRFSS data using the metropolitan area information. The EPA's Air Quality System (AQS) database contains measurement of six criteria pollutants: ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO), and particulate matter ($PM_{2.5}$, PM_{10}). Because our study focused on $PM_{2.5}$ we used the daily AQI which reported daily air quality based on the concentration levels of $PM_{2.5}$. The daily $PM_{2.5}$ AQI represented the highest concentrations of $PM_{2.5}$ for that day. Ambient air measurements collected from a network of national, state, and local air monitoring stations were used to calculate the $PM_{2.5}$ AQI.

The most interesting – and possibly surprising – result is the effect that pollution appears to have on health-improving life-style choices. This result partly contradicts what one should expect from Cropper's model, where pollution makes the investments in health more costly. In order to rationalize the empirical result obtained, one should refer to the relationship between pollution and the investments in health as an inverse-V-shaped emission-health investments relationship with a threshold pollution point: only if air pollution is concentrated above this point individuals will no longer have incentives to invest in health-improving activities. This result may have an important policy implication: an intervention that reduces air pollution below the threshold pollution level, may have not only a direct effect on individuals' health status, but also an indirect health effect through a healthier life-style which seems to be one of the driving factors for good health.

The rest of the paper is organized as follows: Section 2 introduces a model of health production. Section 3 describes the data and the variables for the analysis. Section 4 presents the empirical approach and the econometric results. Section 5 concludes with a discussion. The definition of the variables, descriptive statistics and tables with estimation coefficients are in Appendix A.

2. A model of health production

We assume that each individual is endowed with a stock of health capital H_t that evolves according to:

$$\Delta H = H_{t+1} - H_t = f(\Lambda(E), t) - \delta_t H_t - \vartheta_t \tag{1}$$

where $\delta_t \in (0, 1)$ is the natural rate at which health deteriorates. ϑ_t is a random shock. We assume that the shock could be any injury which causes a reduction in the current state of health. Moreover, we assume that ϑ_t can take a value of zero when the shock does not occur and a positive value $\vartheta_t > 0$ when it does occur. The transition probability of having a shock next period is assumed to be inversely related to the stock of health. Then, the size of health is important since it affects the probability for an individual of enjoying good or bad health. Individuals can affect the probability of bad or good health next period by "investing" or "disinvesting" in health. The investments/disinvestments in health are captured by a household production function $f(\Lambda(E), t)$. Where Λ indicates the individuals behavior. We distinguish between healthy and unhealthy behavior. A proxy for healthy behavior consists, for instance, in a healthy diet (fruits and vegetables consumption etc.) or in sport activities practice, while a proxy for unhealthy behavior includes consumption of hazardous goods like alcohol consumption or cigarettes smoking. E is the exogenous education level that is assumed to affect the productivity of producing health. Schooling helps people choose healthier life-styles by improving their knowledge of the relationship between health behaviors and health outcomes (Berger and Leigh, 1989; Kenkel, 1991). A more educated person may have more knowledge about the harmful effects of cigarette smoking, pollution exposition, alcohol consumption or about what constitutes an appropriate, healthy diet. Furthermore, schooling increases information about the importance of having regular exams or screening tests to prevent an illness or at least to minimize disease. $f(\Lambda(E), t)$ can increase or fall in individual behavior Λ. In particular $f(\Lambda(E), t)$ is increasing in a healthy behavior and decreases if individuals disinvest in their health by consuming, for instance, hazardous goods. It follows that while a healthy life-style increases the stock of health capital, actions detrimental to health such as cigarette smoking and excessive alcohol consumption lower the stock of health capital.

In order to introduce the impacts of the environment, our analysis takes changes in environmental conditions to influence the rate at which an individual's stock of health depreciates:

$$\delta_t = \delta_0(1+\tilde{\delta})\Psi_t^{\phi} \tag{2}$$

Following Grossman (1972) and subsequent contribution by Cropper (1981) we assume that health depreciates over time at an increasing rate with age ($\tilde{\delta}$) and with the ambient air pollution to which an individual is exposed (Ψ). Pollution enters directly the rate of decay and physically alters the state of a person's health; its effect is measured by ϕ.

As in Cropper's (1981) model, we assume that the individual behavior is influenced by environmental pollution. We assume that there is an optimal pollution level Ψ^* to maximize health investments and healthy behaviors. An increasing level of pollution encourages health investments if it does not exceed a certain threshold. But if pollution level exceed the optimal threshold, a decrease of ambient air quality may lead individuals to invest less in health. Individuals may have no incentives to invest in health since they feel less healthy because they perceive δ to be higher. Hence, they may choose to invest less in their health and maintain lower