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Air Pollution Causes Health Effects and Net National Product of a Country Decreases: A Theoretical Framework

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Abstract: *The paper deals with green accounting and accounts the health effects of air pollution. It shows that due to air pollution human capital can not be utilized properly and net national product of a country decreases. The willing to pay system among workers is beneficial to the government, factory owners and workers of a country. The marginal cost-benefit rule for an optimal level of air pollution creates negative health effects. The air pollution cause both direct disutility and indirect welfare effects by negatively affecting the productivity of labor. The paper also deals the health benefits from reduced pollution may sufficiently affect labor supply to create benefit-side tax interactions which, in turn, may be of the same magnitude as cost-side ones.*

Keywords: Air pollution, net national product, WPT, green accounting.

Introduction

Healthy and efficient human capital is an important asset for economic development and social welfare. Air pollutions effect seriously on human capital. Healthy human capital gives optimal product in the society and decreases all kinds of medical expenditures related with air pollutions. As a result society gains rich economy. In the study about human capital in macroeconomics shows that not only education but also good health has a significant positive effect on aggregate output (Bloom et al. 2001, Nordhaus 2002). In developing countries (e.g., Bangladesh) the health situation is comparatively worse than developed countries (e.g., Japan). Again net national product (NNP) of less air polluted countries (e.g., Norway) is comparatively better than that of dense air polluted countries (e.g., the USA).

Densely populated and industrial areas, where more vehicles move and a majority of people smoke, the air remains in pollution dangerously. As a result most of the people of that area suffer from various respiratory diseases such as sinus congestion, fever, headache, asthma etc. Such respiratory sick people can not work properly and economic growth damages. If willing to pay (WTP) system is implemented in the society then every worker will pay per annum a fixed amount of their income to the government or to the owner of the factory. By paying this amount of money the workers will get free medical service and will find full wages in the period of illness, so that their family members will not suffer from financial crisis. In this process the workers will pay together a large amount of money to the government or factory authority and the authority can provide medical services easily, and the workers will be cure very quickly and do their jobs efficiently. In the WTP method the country will find healthy and efficient workers. As a result the local or national production will increase and the country will develop economically.

After cyclone, earth quake and other natural calamities, diarrhea/cholera other contagious diseases broke out epidemically in the effected areas. If the workers of those areas are under the WTP system, they can find immediate medical services and financial aids from their company. These workers will save partially the country from immediate famine or from serious economic crisis. In Bangladesh 2008 after cyclone SIDOR, diarrhea broke out dangerously. In 2010 after earthquake in Haiti about a million of people had died due to cholera. In 2011 the attack of tsunami in Japan decreased the rapid growing economic progress. If these countries would have WTP system then the workers of these countries would find all the facilities according to the commitment and would avoid economic crisis. The healthy human capital of these countries could recover the NNP of these countries. Japan is a developed country and the government of Japan takes immediate steps to recover the economic deficiency but other two countries mentioned above could not do so. At present very few countries have the WTP system in labor sector. We hope in future all the countries of the world will establish WTP rule in the society. All the environment pollutions are harmful but in this paper we give priority to the effects of air pollution and show that NNP must be reduce when air is polluted seriously. Labors can not be utilized in works properly if they suffer with various respiratory diseases due to air pollution. WTP is very important and beneficial both for the workers and the government of the country. The aim of this paper is to introduce a theoretical framework by keeping into account the health effects of air pollution in national accounting. When identifying the most relevant components of environmentally adjusted national accounts for health impacts, then the applicability of the Hamiltonian framework is obvious, because without such a consistent framework the adjustments and their interpretation become more or less arbitrary. The paper emphasize on several important policy issues such as: (i) the regulation of air pollution impairing health, (ii) the interpretation of mitigation costs, (iii) the defensive expenditures in conventional national accounts, (iv) the basis for determining an optimal tax on harmful emissions and (v) the extent to which the total social costs of health impacts of air pollution can be approximated at the aggregate national level in environmentally extended accounts.

Medical expenditures to cure diseases due to air pollution should not be subtracted from NNP but hamper of production due to pollution related illness should be subtracted from NNP (Dasgupta and Mäler 2000). A rule must be imposed for determining an optimal tax on harmful emission. Mohajan (2011) has described optimal environmental tax following Williums (2003) and Caffet (2005). In this paper we have considered green accounting and economic effects following Huhtala and Samakovlis (2003).

In our mode we should emphasize health impacts as disutility from illness but not as utility from health. Of course we find positive utility from health but measurement and valuation of human health is not taken here. Rather we stress on negative health due to illness. We have included a production externality in the form of a flow of air pollutants which cause both direct disutility and indirect welfare effects by negative affecting the productivity of labor.

The paper is organized as follows: In the model we introduce an optimal control structure to account adjustments with a special emphasis on the health impacts due to air pollution. Then we discuss that defensive expenditures must subtract from the national accounts which reflect welfare changes. Finally we show the theoretical calculations of the marginal physical product in detail.

The Model

Social welfare is maximized when producers and consumers maximized their utility in a healthy way. A person is uncertain about her future health condition. She can not surely demand that her sickness is of course due to pollution; even she does not know when she will die. But scientifically it is proved that the cause of some diseases such as asthma is due to air pollution. It is of course true that where air pollution is very high symptom of respiratory diseases and patients increase there. Green accounting research project (GARP II) found that morbidity impacts in terms of symptom days and restricted activity days to make up to 30% of the total health impacts from air pollution (EC DG XII 1996). Some water borne diseases like cholera, diarrhea and some other stomach lose diseases break out where water is polluted. Our social environment is polluted in different ways mainly by air and water which create different diseases, and we need to invest an extra amount in health sector due to this pollution.

In practical life it is difficult to measure all the possible risk factors accurately, so that in our model we take a weight which captures the proportion of the output of the healthcare sector generated in treating illness related to air pollution. In green accounting a model is prepared for the optimal welfare of the society, where a fixed amount of labor is allocated between production of a composite commodity and the health sector. Assume utility $U(C)$ is obtained from consumption of good C, inputs (labor) in health sector and mitigation is L_2, air pollution is P and disutility is $D(P,L_2)$ such that $D_P > 0$ and $D_{L_2} < 0$, where $D_P = \frac{\partial D}{\partial P}$ is partial derivative of D with respect to P and similar expression for D_{L_2}. Such notations will be used for partial derivatives throughout the paper. We use in our theoretical model a weight that captures the proportion of the output of the health care sector generated in treating illness related to environment pollution. Let the weight is $i(q)$, where i is a function of personal characteristic q. The additional demand for services of healthcare sector $h(L_2)$ due to air pollution is modeled by $j(P)$, where $h_l > 0$ and $j_P > 0$, so that $j(P)i(q)h(L_2)$ constitutes the unnecessary consumption of health care services due to pollution (Huhtala and Samakovlis 2003).

The net utility in the presence of pollution is, $NU = U(C) - D(P,L_2)$. Therefore, the aggregated net utility, discounted by a constant interest rate r, is maximized (Huhtala and Samakovlis 2003)

$$\max \int_0^\infty NUe^{-rt}dt = \max \int_0^\infty [U(C) - D(P,L_2)]e^{-rt}dt$$

subject to

$$K = f(K,L_1,P) - C - j(P)i(q)h(L_2) - \delta K \quad (1)$$

where $K(0) = K_0$ is given initial level of capital,

$$n(P)L' = L_1 + L_2.$$

Here,

K = stock of capital,

δ = depreciation rate of capital stock,

L' = total labor available in the economy,

L_1 = labor input used in producing the consumption commodity C,

L_2 = labor input used in healthcare sector,

f = production function for the composite commodity, where $f_K, f_{L_1}, f_P > 0$, and

$n(P)$ = the effect of air pollutants on the productivity of labor, where $n_P < 0$.

Without air pollution there is no additional demand for healthcare i.e., $j(0)=1$ and if air pollution exists then, $j(P)>1$. Similarly without pollution, there is no productivity adjustment that is, $n(P)=n(0)=1$ and if air pollution found then $0<n(P)<1$ for $P>0$.

The Lagrangian for the optimal control problem, (i.e., the current value Hamiltonian plus the constraint on the total amount of labor inputs) is (Huhtala and Samakovlis 2003),

$$\overline{L}=U(C)-D(P,L_2)+\lambda K+\omega(n(P)L'-L_1-L_2) \text{ i.e.,}$$

$$\overline{L}=U(C)-D(P,L_2)+\lambda[f(K,L_1,P)-C-j(P)i(q)h(L_2)-\delta K]+\omega(n(P)L'-L_1-L_2) \quad (2)$$

where λ and ω denoting the shadow price of capital and the Lagrangian multiplier for the labor input constraint, in utility terms, respectively.

Taking partial derivatives of (2) for optimization we get;

$$\overline{L}_C=U_C-\lambda=0, \quad (3)$$

$$\overline{L}_{L_1}=\lambda f_{L_1}-\omega=0, \quad (4)$$

$$\overline{L}_{L_2}=-D_{L_2}-\lambda\, j(P)i(q)h_{L_2}-\omega=0, \quad (5)$$

$$\overline{L}_P=-D_P+\lambda f_P-\lambda\, i(q)h(L_2)j_P+\omega L' n_P=0. \quad (6)$$

From (3) we can write, $\lambda=U_C$, which indicates the marginal utility of consumption. From (4) we get $\lambda=\frac{\omega}{f_{L_1}}$, which indicates the marginal cost of producing the composite commodity. From (5) we obtain $\lambda=\frac{-D_{L_2}-\omega}{j(P)i(q)h_{L_2}}$, which indicates the net marginal benefit from health care sector. Therefore, the marginal utility of consumption, the marginal cost of producing the composite and the net marginal benefit from health care are all equal.

Again the shadow price of the capital stock is defined by (Huhtala and Samakovlis 2003),

$$\frac{d\lambda}{dt}=\dot{\lambda}=(r+\delta-f_K)\lambda \quad (7)$$

where $\dot{\lambda}$ is the time derivative of λ. For optimal steady state investment $\dot{\lambda}=0$, so that from (7) we get $f_K=\delta+r$ that is, the marginal product of capital equals sum of depreciation and interest rate.

The objective function of the economy i.e., the maximized Hamiltonian is interpreted as a measure of the Hicsian income (Dasgupta and Mäler 2000, Heal and Kristrom 2001). In utility terms the current value Hamiltonian is interpretable as NNP. Rewriting the Hamiltonian with a linearized utility function we get (Huhtala and Samakovlis 2003),

$$\overline{H}=U_C C-D_P P-D_{L_2}L_2+\lambda\dot{K} \quad (8)$$

Dividing $\overline{H}$ by the marginal utility of consumption, $U_C=\lambda$, we obtain a linearized measure for partially environmentally adjusted NNP as follows:

$$\overline{NNP}=(C+\dot{K})-\frac{D_P}{U_C}P-\frac{D_{L_2}}{U_C}L_2. \quad (9)$$

Here $(C+\dot{K})$ is the sum of consumption and investments in the conventional accounts and the term, $-\frac{D_P}{U_C}P$ is disutility due to pollution. Again, since $D_{L_2}<0$, so that the term,

$-\frac{D_{L_2}}{U_C}L_2$ is positive, which measures the avoidance of the disutility arising in the health care sector from mitigating problems and symptoms associated with pollution related illness. As healthy people can reduce product cost so that the third term of (9) should not be subtracted from the NNP to reflect the welfare effects of pollution. Due to sick leave labor inputs decrease as a result it affects NNP. The output in the health care sector is measured by the production costs, so that it will not effect in the NNP. Because the output of the health care sector increases due to air pollution which has no contribution to the NNP. To optimize the economy decrease of health situation due to air pollution has taken into account.

The marginal physical product function, f_P can be written from (6) as follows:

$$f_P = \frac{D_P}{U_C} - \omega L' \frac{n_P}{U_C} + i(q)\,h(L_2)\,j_P\,.$$

By the use of (3) and (4) we can write the above function as follows:

$$f_P = \frac{D_P}{U_C} - L' n_P f_{L_2} + i(q)\,h(L_2)\,j_P \qquad (10)$$

which provides a guideline for a cost-benefit rule for an optimal level of pollution.

The first term of (10) is the marginal disutility of pollution, the second term is the impaired marginal productivity of labor and the third term is the marginal increase in the output of the health care sector. We do not know the actual value of marginal product of pollution so that the value of the right hand side of (10) expresses how valuable the marginal product of pollution should be in order to justify the externality costs to the society. A welfare-maximizing society will pollute up to the point where the benefit from an additional pollution unit just equals the social cost of that unit. To impose an optimal emission of tax on a unit of pollution in practice the right side of (10) should be assigned monetary values.

The people who suffer due to respiratory illness are divided into three classes. The first one is for minor episode, and the second and third portions for major episode:

(i) Minor episode which lasts for one day with respiratory phlegmy cough, lightly sinus congestion, some tightness in the chest with some breathing difficulties. This day the patient can not engage in strenuous activity, but capable of doing ordinary works.

(ii) The first one is **bed**; which is described as 3 days with flu-like symptoms including persistent phlegmy cough with occasional sinus congestion, headache, fever, eye irritation and fatigue. Symptoms are serious enough so that patient must stay home in bed for the three days.

(iii) The second one is **hospital**; which is so severe that it includes admission to a hospital for treatment of respiratory distress. Symptoms include persistent phlegmy cough, with serious sinus congestion, gasping breath, fever, headache and tiredness. The patient stays in the hospital, receiving treatment for 3 days, followed by 5 days home in bed.

Theoretical Calculations of the Marginal Physical Product

In this section we express a theoretical calculation of air pollution due to nitrogen dioxide (NO_2). We calculate the three terms of the marginal physical product of equation (10) in the following three steps:

Calculation of the first term of equation (10)

The first term of (10) is the direct disutility of symptoms associated with air pollution. It is basically estimated as willingness to pay (WTP) for avoiding illness episodes with respiratory symptoms related to air pollution. A contingent valuation or benefit transfer study could be applicable here so that we will calculate $\frac{D_P}{U_C}$.

Assume that one unit microgram/cubic meter, $\left(1\mu g/m^3\right)$ increase of NO_2 leads on average to increase of $\alpha\%$ in respiratory-related restricted active days (RRADs) in a country. Let share of people with RRADs in a sample of a survey in a country be $\beta\%$, and annual RRADs be x days and total population of the country whose ages are in 19-60 years be y. So that total annual RRADs of the country per year due to average 1 unit increase of NO_2 be $xy\times\beta\% = \beta xy\%$. Therefore the total number of additional RRADs per year be $\beta xy\%\times \alpha\% = 0.0001\times \alpha\beta xy$. Among them let X % of the workers suffer in minor RRADs, so that the total additional minor RRADs be $0.0001\times\alpha\beta xy\times X\% = 0.000001\times\alpha\beta xyX$ and total additional major RRADs be $0.000001\times(100-X)\alpha\beta xy$. The WTP to avoid one minor RRAD be \$ a and WTP to avoid one major RRAD be \$ b (a WTP of a major restricted activity day is the sum of the valuations of **bed** and **hospital** episodes divided by the number of days i.e., if $\$b_1$ be the WTP by the total patients (labors) of **bed** and $\$b_2$ be the WTP by the total patients (labors) of **hospital**, then a WTP by the major restricted activity day will be, $\$\frac{b_1+b_2}{11}=\$b$). Therefore the disutility value of additional RRADs per year of the country be \$ $(aX+(100-X)b)\times 0.000001\times\alpha\beta xy$ which is the first term of (10), hence marginal disutility be,

$$\frac{D_P}{U_C} = \$\ (aX+(100-X)b)\times 0.000001\times\alpha\beta xy.$$

$$= \$\ (aX+(100-X)b)\times 10^{-6}\times\alpha\beta xy. \qquad (11)$$

Calculation of the second term of equation (10)

For the second term of (10) we need to calculate the impacts of pollution on the productivity of labor input by the use of a estimated dose-response relationship n_P, the total amount of labor available in the economy L' and the productivity of labor, or wage rate, f_{L_2}. We have estimated the dose-response relationship $n_P = \alpha\%$. Let average daily wage of a labor be \$ p (the average daily wage of a labor, p = an average monthly wage ÷ 30), so that loss per minor RRAD ($w\%$ of daily wage, say) be \$ $wp\%$ and loss per major RRAD be \$ p. Again let $L' = Y\%$ of the working age (19-60 years) people be labor. Therefore productivity loss of additional RRADs per year be $(Xxy\times Y\%\times wp\%+(100-X)\ Y\%\times\ xy\times wp\%) = 0.0001\times xywpY$. Finally the share of minor and major RRADs in the employed population is proportional to the total population, the productivity loss for one unit increase of NO_2 be

\${(aX +(100-X) b)×0.000001×$\alpha\beta$ xy +0.0001×$xywpY$ } which is second term of (10), that is the impaired marginal productivity of labor be,

$$\bar{L}n_P f_{L_2} = \$\{(a\,X + (100-X)\,b)\times 0.000001\times\alpha\beta\,xy + 0.0001\times xywpY\}.$$

$$=\$\{(a\,X + (100-X)\,b)\times 10^{-6}\times\alpha\beta\,xy + 10^{-4}\times xywpY\}. \qquad (12)$$

Calculation of the third term of equation (10)

The third term of (10) is the pollution related medical care costs, including hospital and prescription drug expenditures, $i(q)\,h(L_2)\,j_P$. To calculate the optimal tax, medical expenses related to a 1 unit increase in NO_2 (third term of (10)) should also be taken into account. We are dealing with respiratory type diseases which are caused by NO_2. Let in a country θ_1 tons of NO_2 are produced (which is the sum of production in factories and emissions for domestic purposes), θ_2 tons are exported and θ_3 tons are imported. So that annual deposition is, $\theta = (\theta_1 + \theta_2 - \theta_3)$ tons. Let annual average concentration level be θ' $\mu g/m^3$ of NO_2 in dose-response study of a country. If 1 $\mu g/m^3$ increases of emission creates ξ tons of NO_2 then, $\xi = \frac{\theta}{\theta'}$ tons.

We have the disutility and productivity loss associated with 1 $\mu g/m^3$ increases of NO_2 is estimated to be \${(a X +(100-X) b)×0.000001×$\alpha\beta$ xy +0.001×$xywpY$ }. Therefore, the total marginal health damage for increasing per kilogram of NO_2 could be;

$$i(q)\,h(L_2)\,j_P = \$\frac{\{(a\,X + (100-X)\,b)\times 0.000001\times\alpha\beta xy + 0.0001 xywpY\}}{\xi\times 1000}$$

$$= \$\frac{\{(a\,X + (100-X)\,b)\times 10^{-2}\times\alpha\beta xy + xywpY\}}{\xi\times 10^{7}}.$$

We assume that in a country about *R%* of the working age (19-60 years) populations have respiratory problems. Hence the total marginal health damage for increasing per kilogram of NO_2 could be;

$$\$\frac{\{(a\,X + (100-X)\,b)\times 10^{-2}\times\alpha\beta xy + xywpY\}R}{\xi\times 10^{9}}.$$

Let total cost of medical services of respiratory related diseases for increasing per kilogram of NO_2 be \$ φ. This cost consists of the sum of consultation visits with doctors \$ π_1, cost for purchasing medicine \$$\pi_2$ and cost for admission in hospitals \$$\pi_3$ i.e., total medical expenditure would be, \$ φ = \$ (π_1 + π_2 + π_3) for increasing per kilogram of NO_2. So that,

$$\$\frac{\{(a\,X + (100-X)\,b)\times 10^{-2}\times\alpha\beta xy + xywpY\}R}{\xi\times 10^{9}} = \$\,\varphi. \qquad (13)$$

Again if we consider the emission of all the nitrogen oxides then this figure would be about 3.5 times of the original marginal health damage cost for an industrialized country which implies that the total medical expenditure would be \$3.5φ for increasing 3.5 kilogram of all the nitrogen oxides for that country. Again total cost estimate amounts to \$3.5$\varphi\times\theta$. NNP should be adjusted for the disutility part of the total cost.

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Although there is scientific evidence of increased respiratory related hospital admissions on high air pollution days, it is difficult, if not impossible, to estimate how much of these costs should be attributed to air pollution in general and to an increase in the NO_2 concentration in particular (Bellander et al. 1999, Thurston et al. 1997). Therefore we have decided to exclude these costs and consider our approximation of social marginal health damage, in terms of disutility and productivity loss, as a conservative estimate. The productivity of polluting input must equal the direct disutility of pollution, the decreased productivity of labor and the additional healthcare costs due to pollution. It is true that the optimization rule is based on marginal social costs; we have tried for the derivation of the total costs of health impacts of air pollution.

Concluding Remarks

In this paper we have shown that environmental pollution effects economic development. We have expressed a theoretical structure for comprehensive national accounting, which takes into account health effects of air pollution. A marginal cost-benefit rule is established for an optimal level of pollution to give its negative health effects which can be used to find taxes on harmful emissions. WTP will be beneficial both for labors, factory owners and government, and an attempt has been taken to calculate and adjust it with the model.

References

Bellander, T.; Svartengren, M.; Berglind, N.; Staxler, L. and Järup, L. (1999), *The Stockholm Study on Health Effects of Air Pollution and their Economic Consequences*, Part II, Department of Environmental Health, Karolinska Hospital.

Bloom, D.E.; Canning, D. and Sevilla, J. (2001), The Effect of Health on Economic Growth: Theory and Evidence, *NBER Working Paper* 8587.

Caffet, J.C. (2005), Health Effects and Optimal Environmental Taxes in Welfare State Countries: *EUREQua Working paper*-49.

Dasgupta, P. and Mäler, K-G. (2000), Net National Product,Wealth and Social Well-Being: Environment and Development Economics, 5, pp 69-93.

EC DG XII. (1996), *Green Accounting in Europe. The Role of Damage Estimation. Four Case Studies. Green Accounting Research Project (GARP I).* European Comission, Directorate General XII - Science, Research and Development. Draft February 1996. Will be published as an edited volume (eds: Anil Markandya and Marcella Pavan) in the Fondazione Eni Enrico Mattei/Kluwer Academic Publishers Series on *Environment, Energy and Environment.*

GARP II (1999), 'Final Report of the Green Accounting Research Project II to the European Commission – DG XII, RTD Programme "Environment and Climate" ',contract ENV4-CT96-0285, November.

Heal, G. and Kristrom, B. (2002), Green Accounting: in Mäler K-G. and Vincent J. (eds), Handbook of Environmental Economics, North Holland, Amsterdam.

Huhtala, A. and Samakovlis, E. (2003), Green Accounting, Air Pollution and Health: *The National Institute of Economic Research*, Stockholm; Working Paper No. 82.

Mohajan, H.K. (2011), Optimal Environmental Taxes Due to Health Effect: *KASBIT Business Journal,* 4(1):1-19.

Mohajan, H.K. (2012), Air Pollution Causes Health Effects and Net National Product of a Country Decreases: A Theoretical Framework, *International Journal of Development Research and Quantitative Techniques*, 2(2): 3–10.

Nordhaus, W. D. (2002), The Health of Nations: The Contribution of Improved Health to Living Standards, *NBER Working Paper* 8818.

Thurston, G. D.; Lippman, M.; Scott, M. B. and Fine, J. M. (1997), Summertime Haze Air Pollution and Children with Asthma, *American Journal of Respiratory and Critical Care Medicine*, 155, pp 654-60.

Williums III, R. C. (2003), Health Effects and Environmental Taxes: *Journal of Public Economics*, 87, pp 323-335.