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Considerations in Applying the General Equilibrium Approach to Environmental Health Assessment[1]

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There are currently two commonly used approaches to assessing economic impacts of health damage resulting from environmental pollution: human capital approach (HCA) and willingness-to-pay (WTP). WTP can be further divided into averted expenditure approach (AEA), hedonic wage approach (HWA), contingent valuation approach (CVA) and hedonic price approach (HPA). A general review of the principles behind these approaches by the authors indicates that these methods are incapable of unveiling the mechanism of health impact from the point of view of national economy. On a basis of economic system, the shocks brought about by health effects of environmental pollution change the labor supply and medical expenditure, which in turn affects the level of production activity in each sector and the total final consumption pattern of the society. The general equilibrium approach within the framework of macroeconomic theory is able to estimate the health impact on national economy comprehensively and objectively. Its mechanism and applicability are discussed in detail by the authors.

Key words: Human capital approach; Willingness-to-pay; General equilibrium approach

INTRODUCTION

There is no denying that air pollution leads to a severe negative impact on health. The generally observed damages are increases in mortality and morbidity. Although epidemiological studies on dose-response relationship provide the basis to quantify the health effects of air pollution, placing monetary values on health damage generally has been very difficult as health has neither a substitute nor a market price. The attempt therefore in making a tradeoff between currency price and health has been a controversial issue.

Economists have managed to develop various approaches to expressing health effects in monetary value[1-2], each of which has its own features and applicability. Thus, a methodology review is undertaken for judging how to objectively reflect health impact on national economy. In this paper, three types of approaches are reviewed: human capital approach (HCA), willingness-to-pay (WTP) and the general equilibrium approach which is considered as the last one.

HUMAN CAPITAL APPROACH

HCA summarizes the economic loss of health damages arising from three aspects: premature death, workday loss, and excess medical expenditure. The economic loss of a premature death equals the discounted flow of future earnings if the person does not die, with the person's age weight and productivity weight taken into consideration. The economic loss per workday equals the wage per day per worker. Calculation of medical expenditure is based directly on the cost-of-illness.

Compared with other approaches, HCA has a

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Abbreviations: CGE: computable general equilibrium; HCA: human capital approach; WTP: willingness-to-pay approach; AVA: averted expenditure approach; HWA: hedonic wage approach; HPA: hedonic price approach; CVA: contingent valuation approach; FCM: friction cost method; GDP: gross domestic product; VOSL: value of a statistical life; AIM: the Asia Pacific Integrated Model.

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lower cost and is time saving. The required data are easy to collect. However, researchers have pointed out that HCA has obvious shortcomings either in terms of ethics or methodology[3-4].

Firstly, HCA raises the issue of ethics. The value of a child or an adult is easy to be underestimated for it makes use of personal income to measure his contribution to the society. If one's net income (output minus consumption) is adopted as measurement, it implies that some people's living would hider the economic growth. In realistic terms, people's subjective consciousness of life is quite different. Two studies of contingent valuation approach have shown that value of a statistical life (VOSL) does not decline with age[5-6]. One study of hedonic wage approach showed that the eldest and most risk averse workers require significantly higher, but not lower compensation for accepting jobs related to increased fatality risks[7].

Secondly, calculation of VOSL may vary with the selection of age weight, productivity weight and discounting rate.

Thirdly, HCA regards the workday loss as not replaceable. This is unlike the friction cost method (FCM) which puts forward a dissenting view that any absence can be replaced by a new employee[8]. In other words, the economic loss due to long-term absence only occurs during the period spent in searching for and training a new employee. This period is known as the friction period. FCM estimates the value of lost production that only amounts to 18% -44% of HCA[9-10].

Fourthly, according to the definition of health stated by WHO, health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. HCA cannot measure the intangible variables of pain. It is generally thought that HCA provides lower bound estimation[11]. Table 1 gives an example.

WILLINGNESS-TO-PAY

WTP is the amount that an individual is willing to pay to reduce the risk of death or illness. This may be elicited from the stated or revealed preference technology. In this case, WTP can be further categorized into averted expenditure approach (AEA), hedonic wage approach (HWA), hedonic price approach (HPA) and contingent valuation approach (CVA). CVA is elicited from the stated preference approach and the others are the revealed preference approach.

Averted Expenditure Approach

AEA is more suitable when damage avoidance expenditures have actually been, or will actually be made in a small area. For example, when there is deterioration of air, one can try to protect oneself through various expenditures, such as wearing gauze mask or installing air purification gadgets. The expenditure provides an initial figure how an individual values the health of himself.

Although AEA is relatively simple and has the advantage of being based on observed behavior, the final estimation is short of reliability. Firstly, its application is under the assumption that the consumed goods and environmental quality are perfect substitutes. This assumption may or may not be true because of too many alternatives on the market. Secondly, degree of the known risks needs to be identified. Thirdly, the capability of payment is subjected to people's income level. Even among goods offering the same help services, people prefer the cheaper ones. As a result, it is generally thought that AEA provides a lower estimation among the WTP approaches[11] (Table 1).

TABLE 1

Value of a Statistical Life (VOSL) by Different Approaches

	Value of a Life (Million US$, 2001)		
Approach	Low	Median	High
Human Capital Approach[12]	1/10 to 1/5 of CVA		
Averted Expenditure Approach[13]	3.4	4.0	4.7
Hedonic Wage Approach[13]	7.0	8.2	9.7
Contingent Valuation Approach[13]	5.6	6.6	7.8

Hedonic Wage Approach

HWA premises that higher wages induce workers to work in polluted areas or expose themselves to physical risks. The existing labour market provides a good opportunity to observe the trade-off between risk probability and wage/ compensation.

Although most studies relied on official risk data due to their low cost and easier access, it should be noted that little consideration is given to the issue whether the official data can represent the risk affecting worker's decision. For instance, by realizing that workers have their own idea of risk, the American researchers not only use official data, but also execute a face-to-face interview with workers in order to explore their cognition of death risk[14]. It was found that VOSL based on official data is $6-$10 millions, much higher than that based on workers' perception, $1.5 millions.

Wage level depends not only on fatal risk but also on non-fatal risk, work intensity, degree of difficulty, *etc*. These variables should be carefully investigated and controlled for avoiding possible confounding bias in a HWA assessment. A review of HWA studies showed that VOSL has a large standard deviation ($6.68 millions) with the range from 0.37 to 23.45 millions[15].

Contingent Valuation Approach

CVA is a valuation technique which asks people directly how much they are willing to pay/accept for improving/deteriorating environmental quality.

CVA is widely used for its unique technique that permits people to measure all types of economic value on a hypothetic market, especially non-use values that other methods can not carry out. When compared with HWA, VOSL from CVA shows a relative consistence across the samples[14] (Table 2). It is also flexible and cost-saving in that people can separately place monetary values on multi-illness episodes included in one questionnaire. The values are hardly influenced by the order of illness[16].

TABLE 2

Mean VOSL Based on WTP, WTA, and HWA (US$: 1983)

Samples	Mortality	WTP	WTA	HWA
All Workers	2.6	2 558 000	7 404 000	727 000
All Union	3.3	2 789 000	7 384 000	1 753 000
Union White-collar	1.8	2 030 000	7 156 000	5 981 000
Union Blue-collar	4.0	2 952 000	7 480 000	1 495 000
Non-union White-collar	1.6	2 531 000	7 436 000	-
Non-union Blue-collar	3.7	2 544 000	7 342 000	-

Note. Mortality refers to the death per 4000 workers annually.

Interestingly, all these advantages are exactly the source of intense controversy as well. Firstly, people are skeptical of the reliability of CVA because willingness to pay is based on the personal subjective responses rather than actual behavior. A study indicates that responders who are given 1-2 days to think about their willingness to pay give significantly lower bids than those who are not[17]. If a responder thinks that his answer might influence his welfare in the future, he prefers to place the value on willingness to accept (WTA) several times higher than willingness to pay[14] (Table 2). Secondly, individual willingness to pay does not reflect medical expenditures where there is a third party payment or a sick leave payment[18]. Thirdly, there are not so many developing countries that implement CVA to estimate VOSL life for their civilians. A simple approach is to scale VOSL by the ratio of per capita income in a developing country and a developed country. In this way, VOSL of a Chinese person amounts to $100 000[19]. Such a transformation is generally regarded as inappropriate because age, education level, culture background and consumption pattern can not be adjusted proportionally. People's willingness to pay varies with countries as well as cities. A CVA study in Chongqing revealed that people's willingness to pay for preventing a death from air pollution is about $ 26 000[19], while another study in Beijing showed that it is $ 30 000 to $ 200 000 of VOSL[20]. Finally, launching a CVA requires a full comprehension of risk. Investigators should be trained and responders should be well informed. A survey of CVA is quite expensive and time-consuming.

Hedonic Price Approach

So far, all the aforementioned approaches have dealt with life valuation. The monetary standard on a statistical life has not been established yet. Comparatively, HPA is a unique technology that does not need to quantify the health effects of environmental pollution and to value a life.

The price of a market good is related to its characteristics, or the services it provides. The price of a set of furniture reflects its characteristics: such as materials, function, comfort, durability, luxury and style, *etc*. We can therefore evaluate the individual characteristic of the furniture by looking at the price that people are willing to pay when this characteristic changes. HPA introduces the mechanism that environmental situation is bundled into the characteristics of one market good, typically real estate. If non-environmental factors are under the control, any differences in price can be attributed to the difference in environmental quality so that individual's willingness to pay can be revealed by market price. HPA is applied to the estimation of

environmental factors like air, water, and noisy pollution[21-23].

The application of HPA is an arduous task in practice. Firstly, it is quite difficult to correctly and completely collect large amounts of data that probably affect the price of real estate, such as intrinsic variables, neighborhood variables, accessible variables and environmental variables. Secondly, the value of environment can not be reflected in housing price if people do not know the benefits that the environment contributes. Thirdly, carrying out HPA in poorer areas may get small valuation for environmental changes[23]. Under these constraints, relying on HPA to estimate health impact on economy in large scale areas is unrealistic.

GENERAL EQUILIBRIUM APPROACH

Generally, health impact on economy can be observed from the standpoints of the people and the country. In terms of the country, gross domestic product (GDP) is a common indicator that reflects a nation's overall economic situation. GDP refers to value-added index during the production process in a certain period, which includes depreciation of fixed capital, compensation of employees, net taxes on production, and operating surplus. According to the definition, all above-mentioned approaches are inappropriate to estimate health impacts on national economy. Taking HCA for example, there is no relationship between VOSL and actual value-added loss. Actual forfeited income due to absence from work is a partial value-added loss, and medical expenditure comes from income originating from value-added. Likewise, valuation based on willingness to pay cannot reflect the actual value-added loss. The assessment of HCA and WTP should be regarded as the economic burden of disease that people have to endure.

Theoretically speaking, national economic fluctuations are under the constraints of supply and demand, and slight changes can bring shocks to the economic system by spreading from the part to the whole. This is often referred to as chain reactions. From a national point of view, economic study should comprehensively explore the chain reactions and the resulting impacts on national economy. In this case, general equilibrium approach is a good choice because it addresses problems by explicitly recognizing that even when a change has a direct impact on one sector of the economy, there are always indirect impacts on other sectors.

Analysis of general equilibrium approach draws support from a computable general equilibrium (CGE) model. General equilibrium is the theoretical foundation of the CGE model, its structure is based on input-output tables and some assumptions on nonlinear substitution among commodities[24-25]. Currency circulates between the consumer and producer. The consumer provides labor and capital to the producer for income. Under the constraint of income level, the consumer decides the proportion of consumption and investment to maximize the consumer's utility. Under the constraints of capital and labor input, the producer produces commodities to maximize the producer's profits at a certain level of prices. After selling the products on the market, the producer receives income. The operation and stability of the national economic system follow the rule that any adjustment always achieves a balance between supply and demand. The significant difference between general equilibrium approach and other approaches is that the general equilibrium approach addresses the dynamic relationship between the part and the whole. In this regard, the general equilibrium approach is applicable for estimating a country's GDP loss due to health deterioration.

The effects of environmental pollution on health decrease the labor supply and increase the final demand for health services. Any change of the labor supply or heath service demand causes the original economic balance shifting to a new balance in order to maximize the consumer's utility and the producer's profits. The resulting fluctuation of GDP should be attributed to the effects of pollution on health. Theoretically speaking, labor loss has a negative impact on production activity and excess medical expenditure changes only the consumption pattern. To address this issue, the Asia Pacific Integrated Model (AIM) project in Japan has developed a CGE model which constructs the channels for health feedback. This model, named as AIM/Material model, is applicable to the case of China[26]. It takes the actual numerical labor input as an input variable instead of the tradeoff between currency price and life. Within the model, the modified labor supply is reallocated to all sectors based on the input-output relations across sectors. In so doing, the economic impact of labor loss is disaggregated to all production sectors as well. Under the constraints of income, the increase of health service demand translates into the decrease in demand of other commodities. When health service demand increase alone does not lead to an increase of total final consumption, its negative impact on the country's GDP is weak. By applying general equilibrium approach, it was found that China's GDP loss due to the effects of air pollution on health in 2000 is 0.38‰ (0.162‰-0.511‰) in which the attributable GDP loss due to labor loss and medical expenditure is 0.365‰ (0.157‰-0.491‰) and

0.014‰ (0.005‰-0.020‰), respectively. For comparison, HCA was employed in the same study and the economic loss was 1.26‰ (ranging from 0.44‰ to 1.84‰) of China's GDP. The key point needs to be clarified again is what the HCA evaluates is people's economic burden of diseases, not a countries GDP loss.

CGE model was initially developed to emphasize the analysis on external trade and financing policies. Since the 1980s, CGE model has become popular with the issues of environmental policies, such as pollution taxes, pollution abatement subsidies, *etc*.[27]. Until now, although there are more than 600 CGE models in the world[28], few models incorporate health feedbacks. However, if health feedback is not internalized within CGE model, it is a shortcoming of one study attempting to apply CGE model to comprehensive assessment of the impacts of environmental countermeasures on an economic system. Introducing CGE model to the field of environmental health is a new methodology that deserves a deep exploration. An integrated assessment is of great significance to policymakers in making the decision whether priority should go to environmental protection projects and in framing the appropiate environmental policies.

Although CGE model can demonstrate the mechanisms by which exogenous shocks affect the economy with multi-sectoral interactions, it has been criticized in some aspects. Firstly, the general equilibrium approach attempts to simulate the real system of the national economy. However, CGE is idealistic and different from reality because the real economy is always dynamic. Secondly, data selection of a year for benchmark calibration means that whatever stochastic abnormalities are present will unduly influence the model structure. Thirdly, appropriate and systematic sensitivity analysis is crucial for improving the robustness of a model because the limited availability of data forces researchers to arbitrarily specify some of the parameters, such as elasticity of substitution and the very least initial conditions which significantly matter for CGE analysis[29-31]. Finally, the reliability of parameter is by no means the only source. The assumptions about functional form are also the uncertainties in a model[32].

Even so, estimation from CGE model is objective. The CGE model follows the rules of balance between input and output and between supply and demand. These rules are the foundation of any market behavior. Through benchmark calibration, CGE model reproduces a country's economic system. It simulates the trend and effect-size of one or more shocks that have occurred or will occur in a feasible way in order to provide useful information for policymakers in decision making.

CONCLUSION

The economic value of effects of environmental pollution on health can be measured through a variety of sophisticated techniques. Each approach has its limitations because of a number of theoretical and practical drawbacks. Their implementation raises academic, ethical and equitable controversies. Nevertheless, they do provide valuable information for the policymakers. For policymakers, it is always worth undertaking a careful investigation of research approaches before adopting any results of environmental health assessment in order to avoid the possibility of misleading the decision-making process.

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