POLICY OR INCOME TO AFFECT THE GENERATION OF MEDICAL WASTES: AN APPLICATION OF ENVIRONMENTAL KUZNETS CURVE

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Abstract - Since the implementation of National Health Insurance in Taiwan, the provision of medical services has risen dramatically, which results in the generation of medical waste increases over time and thus makes a negative influence on the environment as well as the public safety. Therefore, it is urgent to solve the threat from the medical waste by effective management of the generation of medical waste. In order to overcome the problems, this paper attempts to examine whether the reduction in medical wastes can spontaneously happen along with economic growth in society and to investigate the factors of affecting the generation of medical wastes by six models proposed in this paper. The six models employ the concept of the environmental Kuznets Curve to investigate the causal relationship between incomes and the generation of medical wastes. A regression analysis is conducted to test the hypothesis of the environmental Kuznets Curve for the generation of medical wastes and illegal disposal. The results find no evidence to support the environmental Kuznets Curve phenomenon for the generation of general medical wastes, but the generation of medical wastes is positively related with incomes and medical capacity, but negatively with the medical policy. By contrast, the results identify the existence of the environmental Kuznets Curve phenomenon for illegal disposal. In addition, illegal disposal is positively affected by medical capacity but negatively by the medical policy. This implies that the medical policy is an effective instrument of reducing both the generation of medical wastes and illegal disposal. The medical policy may play an important role in reducing the impact of medical waste disposal at source and the government also can provide some incentives for the research and development of medical equipment and supplies to reduce the generation of medical wastes. Moreover, the government should treat the policy as a tool to control the generation of medical waste more actively.

Index Terms - Medical waste, public safety, illegal disposal, environmental Kuznets Curve, medical policy.

I. INTRODUCTION

Due to the progression of civilisation and increase in the quantity of medical waste, the importance of medical waste management becomes a critical issue. Because of the potential of medical waste, which produces a negative effect and harm on environment, the government establishes the environmental regulation to encourage the public's awareness and education that may reduce the pollution. However, the problem of medical waste is still growing rapidly throughout the world because of the fast economic growth that results in the urbanization and population growth and thus promotes the medical service [1]. Above all, the implementation of National Health Insurance in Taiwan promotes the provision of medical service growth dramatically, which results in the generation of medical waste. As to the consequence, it may make an influence on the environmental pollution and degradation because of the improper medical waste management that can spread the diseases in society.

Generally speaking, medical wastes containing infectious wastes and radioactive wastes are considered more dangerous than municipal solid wastes. The disposal of medical wastes represents a significant risk or certain injury to the healthcare personnel and general public [2]. If medical wastes are not treated properly due to illegal disposal, they may threat the biological health. The illegal disposal may cause the potential crisis of the living environment by making a negative influence on the environment as well as the public safety. Komilis et al. [1] point out that the negligence of the improper treatment of medical wastes might result in the global safety crisis. The issue of medical waste management has become an increasing concern [3]. Therefore, it is urgent to solve the threat from the medical waste by an effective management of the generation of medical waste.

Basically, the technique of the treatment of medical wastes is rather complicated. Almost all the treatment methods including incineration, autoclave treatments, etc. more or less have drawbacks. The incineration method may create the secondary pollution with undesirable atmospheric emissions and the autoclave treatment cannot handle all types of wastes. Many researchers suggest that reduction, reuse and recycling are the major strategies to mitigate the negative impacts of pollution. The prevention at source may be the best way to control the negative impact resulting from medical wastes. And thus, reducing the demand for medical care and avoiding the consumption of medical supplies may lead to the reduction in the generation of medical wastes. Generally speaking, the economic development may drive up the utilization of medical service [4], then it may result in the

generation of medical waste (MW). The general waste also produces the same consequence that the generation of general waste will rise with the company of the economic development. Undoubtedly, the economic growth in general results in environmental degradation in the early stage but the pollution may be slowed down and reach the peak after a certain point of economic incomes is attained because of the perception of environmental protection. After the turning point, the pollution is reduced gradually when the economy develops continuously. Such an inverted U-shaped relationship between environmental pollution and national incomes is termed as environmental Kuznets Curve (EKC). The EKC phenomenon mainly explains the relation between incomes and environmental pollution during the process of economic growth. However, the application of the EKC concept to medical wastes is very few and almost cannot be found. A key word "EKC" or "environmental Kuznets Curve" is applied to the database of Elsevier SDOS (source: http://sdos.ejournal.ascc.net/) for the searching of relevant articles. The searching result yields 371 articles in association with the EKC, but no article focuses on the issue of medical wastes. Therefore, the purpose of this paper is to examine the existence of the EKC for the generation of medical wastes and illegal disposal by using EKC to construct six models that at the same time also incorporate some socio-economic variables into the model to analyze their impacts on the EKC. We also treat the implementation of the DRG (Diagnosis Related Groups) as a policy variable that is incorporated into the models to analyze the policy effect.

II. RESEARCH METHODS

A. Environmental Kuznets Model

The medical wastes generated in hospital should be sorted at first, and then should be transported, stored, cleared and treated according to the operation standard regulated by the government. The clearing and treatment can be handled either by the hospital itself or the clearing/treatment agencies entrusted by the hospital to handle the waste treatment and disposal. A cooperating contract can be signed among some interested parties (hospitals) to form a common department of clearing/treatment to do the job. Finally, the category code, property, quantity, and the clearing/treatment method of waste generated should be reported to Taiwan EPA by Internet systems. The treatment and disposal of medical waste generated (MWG) which do not meet the legislative regulation is defined as illegal disposal measured in terms of MWIT. The EKC model in many studies basically incorporates some additional explanatory variables rather than incomes to explain the factor affecting the pollution. Wang [5] points out that incomes and educational levels make a significant influence on the demand for medical services. In practice, the rise of the education level makes people pay more attention to environmental resources and awaken people's environmental consciousness. In addition, some researchers consider the production capacity may affect the level of pollution. For example, Merlevede et al. [6] incorporate the size of the manufacturing company as an explanatory variable of examining the existence of EKC. A firm with larger production scale may own more capacity and ability to manage the problem of wastes generated. Many scholars argue that the amount of MWG depends on the number of beds, and the number of medical staff [7]. On the other hand, the policy of Diagnosis Related Groups (DRG) was announced in 2002 and started to be implemented in 2010. According to the statistical data released by National Health Insurance [8], the number of days in the hospital was reduced from 4.39 days in 2014 to 4.23 days in 2015, with reduction rates by approximately 3.7%. This means that the implementation of DRG may affect the generation of medical wastes due to the change in the days of hospitalization. And thus, the implementation of the DGR policy is seen as an explanatory variable to explain the generation of medical wastes. Eventually, this paper adopts incomes, education levels, capacity, and medical policy as the explanatory variables for the regression model as shown below:

$$E_{1t} = \alpha_0 + \alpha_1 I_t + \alpha_2 I_t^2 + \alpha_3 edu_t + \alpha_4 bed_t + \alpha_5 Y_t + \varepsilon_t \quad (1)$$

where E_{1t} represents medical wastes generated, measured by tons per capita per year ; I_t represents GDP per capita; edu_t represents the education level, measured by the proportion of college graduates in the total population; bed_t refers to the capacity for medical care, measured by the number of beds per capita; Y_t is the implementation of the DRG policy, and ε_t is the residual. In Eq. (1), Y_t is a dummy variable, where $Y_t = 1$ represents the implementation of the DRG policy, $Y_t = 0$ represents the traditional policy.In addition, hospitals are required to take responsibility for the disposal of MWG to safeguard human health and prevent cross infection. The management practice of medical wastes in Taiwan shows that most hospitals entrust the disposal of medical wastes to waste disposal agencies licensed by the government in order to save costs, while very few hospitals own their treatment systems. Medical wastes in general have to be sorted into color-coded bins or bags by medical staff or collecting workers in the

hospitals. Considering the impact of illegal disposal measured in terms of MWIT on the environment, this paper also examines whether illegal disposal has the EKC phenomenon or not. This model is shown in Eq. (2).

$$E_{2t} = \beta_0 + \beta_1 I_t + \beta_2 I_t^2 + \beta_3 edu_t + \beta_4 bed_t + \beta_5 Y_t + \sigma_t \quad (2)$$

where E_{2t} refers to MWIT measured by tons per capita per year and σ_t is the residual.

B. Data Collection

In the past decade, Taiwan experienced a rapid economic development (see Figure 1). National incomes increased from NT$ 454,687 in 2001 to NT$ 714,277 in 2015 with an annual growth rate of 3.81%. The increase in incomes leads to the change of lifestyle and stimulates the demand for medical services. In Taiwan, the capacity of medical services increases stably as a great number of new clinics enter the market and large-sized hospitals expand the number of medical beds. As a consequence, the number of beds increases from 127,357 beds in 2001 to 161,741 beds in 2015 see Figure 1).

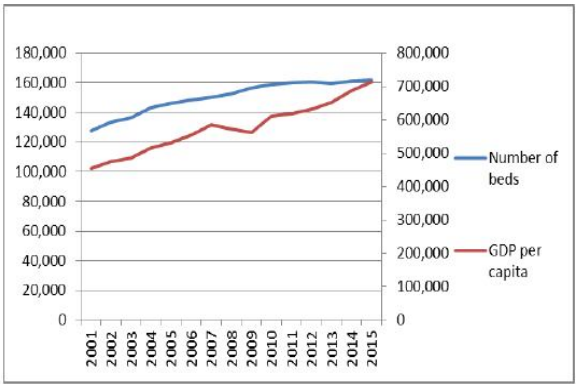


Figure 1. GDP per capita and the number of bed

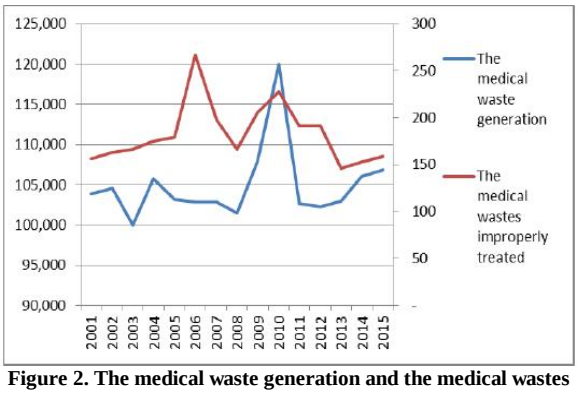


Figure 2. The medical waste generation and the medical wastes improperly treated

Figure 2 indicates that MWG increased from 103,877 tonnes in 2001 to 119,935 tonnes in 2010. After 2010, MWG kept a slightly decreasing tendency and reached as low as 106,883 tonnes in 2015. The data involving the generation of medical wastes is provided by the Environment Protection Administration [9]; the data of "the number of beds" is extracted from the database provided by the Ministry of Health and Welfare [10]; and the educational level and the national income are provided by National Statistics [11] and National Statistics [12], respectively. Due to the availability of data supply, all the data for the variables in Eq. (1) and (2) covers the period of 2001-2015.

III. RESULTS

The regression results are listed in Table 1 for MWG and MWIT, respectively. The reduced-form model in Table 1 considers the explanatory variables of incomes and square incomes only while the full-form model incorporates three additional variables including medical capacity, education level, and the medical policy of DRG. The reduced-form model in Table 1 indicates that no EKC phenomenon exists for the generation of medical wastes as the regression coefficient α_2 is not significant but the full-form model supports the existence of an EKC as the regression coefficient α_2 is -4.338, significantly negative. Furthermore, MWG is positively affected by per capita GDP, and is reduced by the implementation of the DRG policy, but almost is not influenced by the education level and medical capacity.

The comparison between the reduced-form and the full-form model shows that the generation of medical wastes is affected partially by the variable of square income only. These results imply that the rising income may stimulate an increasing demand for medical care and make a major contribution to the generation of medical wastes and in turn yield a stress on current disposal systems. The medical capacity and education level are not found to make any impact on the generation of medical wastes, but the implementation of medical policy DRG is shown to reduce the medical wastes significantly. This paper emphasizes that the implementation of the DRG policy may appear to be the major factor of reducing the provision of medical care and thus to affect the change in MWG. By contrast, the regression result by the linear model indicates that the generation of medical wastes is positively affected by the income, the medical capacity and the DRG policy. The positive relationship between MWG and incomes, illustrated by the linear model in Table 1, fully coincides with the empirical result of Windfeld and Brooks [13]. Some researchers argue that economic growth plays the main role in affecting the provision of medical services [5] and thus the increased utilization of medical resources would be accompanied with the generation of medical wastes [14]. However, the educational level in the linear and full-form models

has little influence on MWG while previous studies confirm a positive relationship between the education level and wastes generated [1,5]. The insignificant impact of the education level on MWG in this paper may be explained by the high popularization of education in Taiwan. The education level has been kept constant in the past decade and thus its effect is neglected.

	MGW			MWIT		
coefficient	Linear model	Reduced form model	Full form model	Linear model	Reduced form model	Full form model
Constant	7.2397 (0.027)**	7.875 (0.001)**	11.103 (0.058)*	-34.876 (0.404)	14.320 (0.001)**	-24.255 (0.024)**
I	0.053 (0.073)*	0.096 (0.154)	0.371 (0.063)*	1.333 (0.022)**	0.196 (0.038)**	0.136 (0.056)*
I^2	-	-1.151 (0.131)	-4.338 (0.067)*	-	-2.381 (0.039)**	-2.622 (0.071)*
edu	-0.119 (0.416)		-0.044 (0.763)	-0.921 (0.355)		-0.751 (0.425)
bed	303.415 (0.048)*		693.759 (0.199)	2911.277 (0.050)**		2602.818 (0.065)*
Y	-0.211 (0.091)*		-0.281 (0.022)**	-1.574 (0.065)*		-1.220 (0.053)*
R^2	0.4421	0.2928	0.6269	0.4541	0.3147	0.5684
adj R^2	0.2189	0.1749	0.4197	0.2356	0.2006	0.3287

TABLE 1 The regression results for MGW and MWIT

In Table 1, both the regression coefficients β_1 and β_2 in the reduced-form model for MWIT is found to be significant, valued 0.196 and -2.381, respectively. This means that both the variables incomes and square incomes have a significant impact on MWIT and thus an EKC phenomenon exists. The full-form model in Table 1 also verifies the existence of an EKC relationship for MWIT. The EKC phenomenon for MWIT implies that illegal disposal may be curbed when incomes grow to a certain point. At the turning point, the increased environmental concerns about the highly negative impact of MWIT on human and ecological health may force the government to keep a continual improvement on the medical waste management. The public involvement in monitoring the management practice of medical wastes may deter illegal disposal.

Medical capacity is found to make an influence on MWIT shown in Table 1 but no significant influence on MWG is indicated in Table 1. As the medical capacity is measured in terms of beds per capita, this implies that the medical capacity involves the MWG by inpatients only. By contrast, MWG contain the waste generated by both inpatients and outpatients. And thus, medical capacity loses its impact on MWG. On the other hand, the MWG by the impatient contains more hazardous wastes including infectious wastes, radioactive wastes, and biological wastes, and requires a higher technology level to treat than general medical wastes. And thus, the positive relationship between medical capacity and MWIT in this paper may be explained by the fact that medical wastes generated by inpatients may attract more for illegal disposal. The result is similar to that of Sanida et al. [15], who confirms a positive relationship between infectious medical wastes and number of beds.

IV. DISCUSSIONS

The results obtained from the regression analysis highlights (1) a positive relationship between incomes and MWG, (2) an EKC phenomenon is confirmed for MWIT, and (3) the medical DRG policy makes a great influence on the reduction of both MWG and MWIT. Basically, higher incomes may provide higher living standards and stimulate more demand for medical care. As a consequence, more disposal merchandise such as diapers, sanitary napkins, sanitary pads, bandages, and cotton swabs are consumed and finally more medical wastes are generated. According to Environmental Protection Administration [9], each person in Taiwan generates 4.57 kg of medical wastes, or 1.75 kg/bed/per day. Compared to other countries, the generation of medical wastes in Taiwan is far lower than that of developed countries shown in Table 2, but still higher than other developing countries. For developed countries, every bed in the US and Italy produces 5-7 kg and 3-5 kg medical wastes per day while medical wastes is generated much less in the developing countries. For example, Thailand only produces 1 kg per day per bed and other developing

countries such as Jordan, Greece, etc. generates less than 1 kg per day per bed.

Country	Amount kg/bed/per day	References
Thailand	1	Kerdsuwan [16]
Portugal	3.8	Ferraz et al. [17]
Korea	0.14-0.49	Jang et al. (2006)
The U.S.	5-7	Medical Waste Committee [18]
Jordan	0.61	Abdulla et al. [19]
Turkey	0.63	Birpinar et al. [20]
Greece	0.58-0.85	Sanida et al. [15]
Greece	0.24-0.27	Komilis et al. [21]
Taiwan	1.75	Environmental Protection Administration [9]

Table 2. The amount of production of medical waste in different countries

Patwary et al. [22] estimates the generation of medical wastes and finds that the amount of MWG in Dhaka is 37 ± 5 ton per day. Among the medical wastes, hazardous wastes accounts for 21% of medical wastes. The amount of medical wastes and the proportion of hazardous wastes are dependent on the size and type of Health Care Establishments. The rising level of medical technique is also an important way to reduce MWG. This paper suggests that reducing the pollution at source can be realized by improving medical techniques and the operation management in hospitals to reduce the consumption of medical articles. In order to avoid the continual increase in MWG linked with incomes, an incentive mechanism of technology policy may be implemented to encourage the research and development for medical techniques that can consume less medical supplies to reduce the amount of medical wastes generated by each patient in the future.

The existence of the EKC phenomenon for MWIT implies that illegal disposal is limited and blocked when the income reaches the turning point. Basically, and the illegal disposal may be caused by the management practice in hospitals, treatment methods and final disposal. A majority of MWG by hospitals are categorized as general medical waste, which can be treated through municipal waste management systems or recycling programs. A small portion of medical wastes are sorted as hazardous wastes including infectious wastes, radioactive wastes etc. and require more complicated technology to treat and dispose. The cost for the disposal of infectious wastes is much higher than general medical wastes. In the US, it costs $0.79 per kilogram to dispose typical infectious wastes disposal costs but only $0.12 per kilogram for non-infectious medical wastes [23]. The gap of cost may encourage the management authorities in hospitals to neglect the correct sorting.The awareness of the public's environmental consciousness may drive the public to serve as an effective tool of monitoring illegal disposal. More public involvement in monitoring the medical waste management system may force the waste disposal agencies and the medical institutions to comply with the legal regulations. This paper suggests that the government needs to provide a transparent environment that the public is involved into monitor the treatment of medical wastes.

The medical staff and the disposal agencies are major stakeholders in affecting MWIT, involved in the recycling of medical wastes. Some previous studies find that the improvement in management practice in hospitals may reduce MWG [24] and thus the incentive mechanism to encourage correct sorting for hospitals is suggested. Among the various treatment methods for medical wastes, incineration is the most popular. The incineration of medical wastes in Taiwan was 96,306 metric tons in 2015, accounting for 90.88% of the total MWG. By contrast, the recycling and reuse of medical wastes increased from 1,433 tons in 2007 to 5,779 metric tons in 2015, accounting for 5.45% of MWG. Compared to the recycling rate 48.82% for municipal solid wastes, the recycling of medical wastes is not as good as municipal solid wastes and thus a large room exists for improvements. Due to technology limit, more and more people are concerned about the negative impacts from the treatment system of medical wastes that generally contain very high toxic substance. Even by use of the incineration process, the treatment of medical wastes still may release undesirable pollution into the atmosphere. Eventually, the treatment cost for medical wastes rises up and discourages the proper treatment rate of medical wastes.

The comparison of the result demonstrates that the DRG policy is an effective policy to reduce both the generation of medical wastes and MWIT. The goal of the DRG policy aims to reduce the unnecessary medical services and regulates the appropriate consumption of drugs to avoid the harms of drug abuse and medical treatment. In corresponding with the implementation of the DRG policy, the hospitals management may attempt to reduce the consumption of medical services and consequently MWG and MWIT is reduced. This implies that a medical policy aiming to reduce the unnecessary medical care may play a more important role than the environmental policy in reducing MWG. In fact, the increased income and life expectancy may result in more concern about health and increase the demand for medical care. The violation of the medical policy on the public demand for medical care may bring about some arguments in the society and thus the medical policy leading to reduced demand may be criticized by politicians and get hindered.Among the various treatment methods for medical wastes, incineration is the most popular. The incineration of medical wastes

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CONCLUSION

Considering the high health and environmental impact of the treatment and disposal for medical wastes, the issue involving the reduction in the generation of medical wastes and the increase in correct sorting to reduce illegal disposal is worthy of our attention. This paper highlights the important role of the DRG medical policy to prevent the continual increase in both MWG and MWIT and confirms the existence of the EKC for MWIT. The reduction in illegal disposal happens when incomes reaches a turning point. This paper suggests that the best instrument of reducing the generation of medical wastes is to reduce the medical care. The medical policy may play a more important role than the environmental policy in reducing the impact of medical waste disposal at source. The environmental policy may focus on the reduction of improper treatment rate and MWG by providing regulations or financial incentives to hospitals. The rising level of medical technique is also an important way to reduce MWG. The government also can help hospitals by providing some incentives for the research and development of medical equipment and supplies to reduce the amount of medical wastes generated by each patient. This paper also presents a brief discussion about the management practice to reduce MWIT including on-job training and incentive mechanism for medical staff and workers.

The data used in this paper is drawn from the database released by Taiwan governments based on the macroscopic perspective. And thus, the result obtained in this paper cannot apply to the level of medical institutions. In practice, the generation of medical wastes including infectious medical wastes varies across wards and departments. For example, the infectious wastes generated vary from 0.26 to 0.89 kg/bed/day or 0.51 to 1.22 kg/patient/day calculated based on the data released by 12 public hospitals of Central Macedonia, Northern Greece [15]. Due to the insufficiency of literature in association with the EKC phenomenon for medical wastes, the comparisons with the previous studies are few . Furthermore, the examination on the EKC phenomenon of various medical wastes can be extended to other countries in the future.

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