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Income growth and pesticide consumption in the future: Applying the Environmental Kuznets Curve hypothesis

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Abstract

Applying the Environmental Kuznets Curve hypothesis, the economic structure of pesticide consumption in the world was examined and its future consumption was predicted. It was found that the hypothesis is applicable and the income level significantly affects the pesticide consumption. Additionally, sustained population per land is also influential. In spite of the applicability of the hypothesis, it was also demonstrated that the great increase of pesticide consumption in developing countries would be predicted. Furthermore, among pesticide categories, the increase of insecticide consumption would be predicted even in developed countries.

Key words: Environmental Kuznets Curve, Income growth, Pesticide, Sustained population of land

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Introduction

Pesticide has contributed to raising productivity during the period of agricultural modernization. However, the reduction of pesticide consumption has recently emerged as an acute problem for agricultural policy makers. Although the pesticide consumption in several developed countries has already been on course towards reduction, in other countries it is still at the stage of increasing. It is concerning that the abuse of pesticide would cause not only the directly hazardous problems such as endangering of food safety, but also the deterioration of the surrounding ecosystem, which in itself does not seem to immediately cause serious damage to human beings. It is necessary to investigate the economic structure of pesticide consumption and emission at a macro level.

With regard to the emission of environmental pollution at a macro level, one of the most controversial arguments recently revolves around the so-called "Environmental Kuznets Curve" (EKC) hypothesis. This argument states the relationship between the environmental indicators and income growth. This is widely used in environmental economics literature, however it is rare for it to be applied to agricultural inputs. Although the applicability of the EKC hypothesis varies with environmental indicators according to previous studies[1], it would be helpful to examine its applicability to the

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[1] Barbier (1997) suggested that generally speaking, the EKC hypothesis tends to hold true on the indicators of air pollution except for CO2, while not holding true on those of water quality pollution.

pesticide case in order to analyze the economic structure of pesticide consumption.

The interpretation of the EKC hypothesis has been of an essential argument even if this curve itself would fit well to observed data. At the first stage, the EKC hypothesis tends to be emphatically interpreted that economic growth and environmental improvement must not necessarily be incompatible aims, as opposed to the pessimistic view which asserts the incompatibility of growth and environment. The most optimistic view went so far as to state that economic growth may spontaneously resolve the environmental problem. Meanwhile, various environmental indicators have been examined as to whether the EKC hypothesis can be properly applied to them. As a result, it has become clear that some environmental indicators can appropriately be explained by the EKC, while others cannot be suitably explained. Recently, the common view has been formed that although economic growth and environmental improvement must not necessarily be incompatible, it is indispensable for us to take proper policy measures to resolve the environmental problem.

The basic stance towards the EKC hypothesis adopted in this paper also follows the common view mentioned above. There is little intention to utilize the outcome of the study of the EKC hypothesis to take an excessively optimistic view that income growth would spontaneously bring with pesticide reduction. On the contrary, the critical point of how to get the increase of pesticide consumption under control will be examined as a

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As a commonly observed fact, some indicators such as the volume of city garbage are said not to be applicable to the hypothesis of EKC. Arrow et al (1995) pointed out that the indicators for short term phenomena, local figure, and flow index are apt to be applicable to the hypothesis of EKC, while the ones for long term phenomena, global figures, and stock index are apt not to be applicable.

central issue of this paper. The EKC hypothesis will be effectively utilized as a tool of analysis.

In this context, the purpose of this paper is to analyze the present situation of pesticide consumption in the world from the viewpoint of the EKC hypothesis, and to apply this result to predict pesticide consumption in the future.

Another methodological feature of this paper is to separately analyze each pesticide category, i.e. insecticide, fungicide and herbicide. As mentioned later, economic linkages with influential factors are different from one another among pesticide categories. A separate analysis will be needed.

Theoretical framework and conceptual model

Theoretical framework

Prior to model building, it is helpful to conceptually consider the linkage between the pesticide consumption and other various socio-economic conditions including the income per capita. In the case of environmental indicators related to heavy industrial wastes such as SOx, the logics of EKC hypothesis, that is, the linkage between economic growth and the index of environmental degradation can easily be recognized with intuition. However, in the case of pesticide, an illustrative causal chain is not apparent. It is necessary to theoretically clarify this chain between the economic growth and pesticide consumption.

Figure 1 shows various influential factors related to pesticide consumption. In previous papers for example, Vijftigschild and Oskam (1994) pointed out that the level of pesticide input is dependent upon the type of farming system, intensity of production and climate. In this paper, from more schematic perspectives, possible factors are shown including socio-economic factors, agronomic factors and natural factors.

With regard to socio-economic factors, the most fundamental factor of influence is how much high yield, especially for staple food crops, is pursued. Such a pursuit is intrinsically linked to population pressure to land. It has historically formed the intensity of farming systems in each region. In order to pursue high yield, intensive input of labor and fertilizer are required. To make farming systems be more intensive means that the gap between the artificial ecosystems in farm land and the natural ecosystems surrounding them becomes larger. This inevitably requires us to input more pesticide in order to maintain highly artificial ecosystems which are vulnerable to attacks by insect, fungi and weed. It is suggested that the population pressure, the pursuit of high yield and pesticide consumption are a closely connected causal chain. Consequently, it is deducted that sustained population per arable land would be one of the important explanatory variables.

Among other socio-economic factors, the shift of food demand structure is also important influential factor. People’s preference of foods has been shifting from satisfying basic nourishment to realizing a higher level requirement such as the variety of the taste and the need for healthier foods with the rising of living standards. Accordingly, food demand for vegetables and fruits tends to increase with income growth instead of staple foods such as grains. Generally speaking, since the intensity of farming system of horticulture is higher than that of crop growing, it requires much more input such as fertilizer and pesticide. Furthermore, if these vegetables are grown in greenhouses, the intensity of farming systems for growing them, and as a result, the input of pesticide would be accelerated. It is reasonable to suppose that the shift of food demand structure with income growth causes an increase in pesticide consumption[2].

With regard to herbicide, and with regard to insecticide to some extent, the condition of the labor market, and as a result, the level of wage is a crucial factor to influence the degree of pesticide consumption. Weeding has been done by hand historically. In addition, it was common that insects were also removed by hand. To use herbicide and insecticide can be regarded as the process of substitution of pesticide for labor. If labor becomes scarcer with economic growth, this substitution process would be accelerated. As a consequence, wage level is regarded as one of the influential factors on the consumption of herbicide and insecticide.

Nowadays, people's higher desire for food quality should also be considered as an influential factor. It should be noted that this can affect both positively and negatively.

The higher desire for food quality with respect to its appearance causes so-called cosmetic use of pesticide. This affects positively to the pesticide consumption, although it is not related in the case of herbicide. According to Babcock et al. (1992), it was reported in the case of apples in North Carolina that 100% of insecticide consumed and 15% of fungicide consumed respectively contributes to cosmetic purpose, not to raising yield. In general, the people with higher living standards tend to require higher food quality in appearance. As a result, it causes cosmetic use of pesticide.

The higher desire for food quality with respect to the anxiety about food safety, and

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[2] Income growth also causes an increase in the demand for meat and dairy products. There is no need for pesticide to grow the grass, however, there is a need to grow feed grain. It may safely be said that the shift of food demand structure with income growth causes an increase in pesticide consumption.

the concern for health and the environment negatively affects pesticide consumption. The anxiety about food safety and the concern for health and environment are said to be highly income-elastic. This holds concretely in the case of pesticide[3]. The anxiety about food safety directly affects its negative influence from the consumers to the producers, while the concern for health and environment indirectly affects its negative influence through the change of policy, such as the strengthening of the regulations concerned with pesticide use restrictions.

Thus, people's higher desire for food quality contains two opposite elements towards pesticide consumption. The controversial point still remains whether or not the segment of those who insist on the quality of food as an appearance, widely overlaps the segment of those who are predominantly concerned about food safety or environmental issues. According to the survey conducted by Baker (1999), it was indicated that these two segments are not completely overlapping. It is suggested that there would be the people who require the appearance of food and do not so much care for safety and environment. The existence of this sub-segment would cause more pesticide consumption even after their income reaches a higher level. Furthermore, even the people who basically attach importance to food safety or environment in their philosophy may not reveal them in practice when they are facing the incompatibility between the appearance and safety of pesticide reduced foods[4].

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[3] For example, Govindasamy and Italia (1998) pointed out that the people in a higher income class have a stronger intention to reduce the risk on pesticide residue.

[4] For example, this is demonstrated by Ott (1990) that 89% of respondents do not permit worm-eaten vegetables even though they support the reduction of pesticide residue.

In the era of globalization nowadays, trade is becoming more important in determining the level of pesticide consumption. If one country exports more and imports less, this will cause the country's ecosystem to have a heavier burden imposed upon it. In the opposite case, this burden will be mitigated.

From the viewpoint of natural science, the argument might be expected that the most decisive factor for pesticide consumption would be climatic conditions such as temperature and humidity. This will be true if it were tested at an experimental level. Insect, fungi and weed will show a high reproduction rate if they are under the experimental conditions of high temperature and high humidity. However, in reality, it does not seem to have strong explanatory power. For instance, it cannot explain why pesticide is used minimally in tropical Africa. In this paper, it is assumed that it would play only a supplementary role to explain pesticide consumption.

In figure 1, several agronomical factors are shown. However, in this paper, these factors are not regarded as independent but derived from economic incentives. Therefore, these are not treated as independent explanatory variables.

Model

Considering the factors mentioned above, a conceptual model is specified as follows:

$E = E(P, S, W, C, FS, H, EP, XM, T^*, R^*)$

E: Environmental indicator of pesticide consumption,

P: Sustained population per land,

S: Structural shift of food demand,

W: Level of wage rate,　　C: Cosmetic use of pesticide, FS: Anxiety about food safety, H: Concern for farmers' and others' health,

EP: Consciousness of ecological preservation,

XM: net export of international trade,

T: Temperature, R: Humidity

Note: * means supplemental explanatory variables.

With regard to each explanatory variable, the following signs would theoretically be expected respectively.

$\partial E/\partial P > 0$, $\partial E/\partial S > 0$, $\partial E/\partial W > 0$, $\partial E/\partial C > 0$, $\partial E/\partial FS < 0$, $\partial E/\partial H < 0$, $\partial E/\partial EP < 0$,

$\partial E/\partial XM > 0$, $\partial E/\partial T > 0$, $\partial E/\partial R > 0$

In order to simplify this conceptual model, let us remember the causal chain mentioned in the previous section. W is straight-forwardly connected to income per capita. S and C can be described as a function of income per capita. The three negative variables, i.e. FS, H, and EP, can also be described as a function of income per capita. These variables are described as follows. I is income per capita.

$S = S(I)$, $W = W(I)$, $C = C(I)$, $FS = FS(I)$, $H = H(I)$, $EP = EP(I)$

As s result, the conceptual model mentioned above is simplified as follows:

$E = F(P, I, XM, T^*, R^*)$

According to Stern (1998), explanatory variables other than income per capita in the EKC model are classified in four categories: i.e. intensity of economic activity, economic structure, trade and political conditions. In this context, sustained population per land can be regarded as representing the intensity of economic activity. Economic structure in this model is represented as food demand shift. It is included in the variable of GDP per capita. The political condition is not included in this model. All explanatory variables are assumed to be exogenous[5].

It is rare that natural conditions are included in the EKC model[6]. In this paper, it is assumed that it will only have a small role in explaining pesticide consumption. Temperature and humidity will be treated only as supplementary variables.

Empirical test of the model

Empirical model

Based upon the conceptual model in previous section, the empirical model to be tested is presented as follows:

$$\mathrm{Ln}E_i = \beta 0 + \beta 1 \mathrm{Ln}I_i + \beta 2(\mathrm{Ln}I_i)^2 \; (+\beta 3(\mathrm{Ln}I_i)^3) + \beta 4 \mathrm{Ln}P_i + \beta 5 \mathrm{Ln}XM_i + \beta 6 \mathrm{Ln}T^*_i + \beta 7 \mathrm{Ln}R^*_i + \varepsilon_i$$

E_i : Environmental indicator of pesticide consumption in i country

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[5] As Stern et al. (1996) mentioned, in order to apply the EKC hypothesis, it is a theoretically necessary condition that the burden of pollution to the environment should not affect production functions, even if economic activity affects the environment. With regard to pesticide, there are the cases that this necessary condition is not satisfied. For example, as Antle and Pingali (1994) reported, there is the case in which the abuse of pesticide affected the health of farmers and deteriorated their productivity. Nonetheless, it is inconceivable that these cases happen frequently. It is reasonable to suppose that we assume these reciprocal effects do not exist.

[6] It is not usual but sometimes adopted. Exceptional cases are Grossman and Krueger (1995) in which the temperature of water was adopted in the analysis of water quality indicators such as BOD and COD and Panayoutou (1995) in which the difference between tropical areas and non-tropical areas was adopted as a dummy variable in the analysis of deforestation.

I_i : GDP per capita (PPP) of i country,

P_i : Sustained population per arable land in i country,

XM_i : Trade Index in i country,

T_i : Average temperature in i country, R_i : Rainfall in i country,

ε_i : Disturbance in i country

With regard to functional forms, different types can be possible according to previous studies[7] if they are consistent with theoretical logics. In this paper, it is theoretically valid that the double-log form should be adopted. The reason is that each explanatory variable must interact in the manner of multiplying each other.

With regard to explanatory variables, considering data availability, several variables are substituted as more practical and proxy indicators. For example, rainfall is used instead of humidity. As for Income per capita, GDP per capita PPP base is adopted as followed in previous studies[8]. The index of net export is transformed as follows:

$XM = \{1 + |(EXa\text{-}IMa)/GDPa|\}^{\delta}$ $\delta = +1$: if $(EXa\text{-}IMa) > 0$

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[7] For example, simple linear form is adopted in Selden (1994), de Bruyn (1997) and Koop and Tole (1999), while semi-log form is adopted in Shafik (1994), and double-log form is adopted in Panayoutou (1995) and Hettige et al (2000).

[8] Several previous studies include not only the level of GDP per capita but also the growth rate of it. It might be rational to include the latter if environmental pollution would reflect the fact that environmental carrying capacity could not dispose of the increment of environmental burden which is caused by rapid economic growth. However, in the case of pesticide, this argument is not appropriate.

$$\delta = -1: \text{if } (EXa-IMa) < 0$$

EXa: Export value of agricultural product[9], IMa: Import value of agricultural product, GDPa: GDP of agricultural sector

It is the most critical point in the EKC hypothesis whether the terms related to income per capita can take a quadratic or cubic form. If neither quadratic nor cubic holds true but only a singular term of income per capita were significant, it would mean that a monotonic increase of pesticide consumption with the rise of income level should be justified. This would also mean that the EKC hypothesis is rejected. In this paper, the significance of a quadratic and cubic form will be tested and the validity of omitting a quadratic term will be tested.

Data

In this paper, the level of pesticide consumption is dealt with as the same meaning as the environmental indicator of the emission to the ecosystem. Principally, the data examined in the study of the EKC should be the one as an emission base, not the one as consumption base. If we follow this principle precisely, the data for pesticide will be those which represent the amount scattering toward the ecosystem. Nevertheless, as Falconer (1998) mentioned, it is practically impossible for us to take emission base data in the case of pesticide. Therefore, as an approximate indicator, consumption base data will be used.

Examined data is cross section data, not panel data. Available data for world

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9 The values of commodities which are not related to pesticide, such as livestock products, wool and silk, are extracted.

pesticide consumption is only the statistics in FAOSTAT. Furthermore, the problem is that the statistics really cover only about fifty countries for each year’s data, since many countries seem to report the data irregularly. In order to obtain a statistically sufficient size of samples, it is necessary to build up the data by increasing the number of countries. Although it is not desirable for a statistically rigorous comparison, it can be allowed in practice to regard the data during several years as cross section data under the assumption that there has been little change in the basic structure of pesticide consumption in the world within the period. In this paper, the latest seven years of data is collated[10].

Principally, a three year moving average is used. Besides, it is omitted in the case that rationally continued statistic figures cannot be obtained. The data of pesticide in FAOSTAT includes many unreliable figures which are doubtful to rational continuity as statistic data[11]. Therefore, doubtful figures are eliminated from the database. Besides, in order to mitigate the disturbance, a moving average is used. As a result, available data is more restricted but this process cannot but be indispensable for accurate analysis.

In the prediction, cross section data is used. It is difficult to obtain regularly

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[10] Additionally, in this paper, the data for Japan was originally estimated. There is no official data for Japan related to pesticide consumption in terms of active ingredients. Nonetheless, the data of Japan is indispensable because it is said to be one of the most typical pesticide-abusing countries. This is the first attempt to estimate the pesticide consumption in terms of active ingredients in Japan.

[11] The reason seems to be partly that the unit of consumption is calculated in terms of active ingredients not by a real volume or weight term. The figure in terms of active ingredients is a proper index of an environmental indicator. Nevertheless, in practice, it is difficult to calculate it precisely.

ordered time-series data for each country in order that the panel database can be well organized. Because of this, for prediction, it is impossible to aggregate each countries predicted figures which is estimated by extrapolating each countries time series data. Therefore, the prediction will be carried out by the cross section data with relatively a naïve method.

As an indicator of environmental degradation, per person index is mainly used in the case of air pollution. However, in this paper, since the influence to ecosystems rather than to human health is of primary importance, per area index will be adopted. More concretely, pesticide consumption per arable land and permanent crop land will be adopted as an indicator of environmental burden.

Results

Table 1 shows the results of regression analysis. Basically, normal OLS was employed. However, in the case of fungicide and herbicide, since strong heteroskedasticity was observed, "White heteroskedasticity consistent standard error" was employed respectively[12]. In cubic function form, strong multicollinearity was found because the 2nd power and the 3rd power of log GDP per capita are heavily correlated with each other. Nevertheless, no specific remedy was applied because this fact in itself does not cause a serious problem other than lowering the t-value.

According to the results of empirical tests, either quadratic or cubic function form

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[12] Stern et al (1996) pointed out that there tends to be heteroskedasticity in the cross section analysis for the EKC. Although most of the previous papers dealt with this problem without any remedy, in this paper, standard error was adjusted.

of the log of GDP per capita significantly explains the dependent variable, while the null hypothesis of omitting the quadratic term is highly rejected in each pesticide category. Consequently, it is obvious that the monotonic increasing pattern does not hold true and the EKC hypothesis can basically be applicable to each pesticide category.

It is also demonstrated that sustained population per land and trade index both significantly affect the level of pesticide consumption. These results are highly robust among different function forms.

With regard to temperature and rainfall, mostly as expected, these do not significantly explain the dependent variable. In some cases, the signs themselves contradict the one theoretically expected. An exceptional case is the temperature in case of insecticide.

Consequently, in the case of insecticide, the quadratic with the temperature term is adopted, while in the case of fungicide and herbicide, the cubic without natural condition terms are adopted as statistically significant results. With each adopted regression, the turning point is calculated as follows.

Insecticide: 25,094 $(PPP), Fungicide: 15,434 $(PPP), Herbicide: 15,985 $(PPP)

In the case of insecticide, the turning point is reached at the highest income level.

Prediction of consumption in the future

Method of prediction

Let us examine the implications of the models obtained in the previous section for future pesticide consumption. The method adopted here is not an econometrically sophisticated forecasting method but a naïve prediction by using a simple calculation[13]. Nevertheless, it is helpful to understand the implication of the estimated model. The prediction period is twenty years.

There is the residual which is obtained by subtracting the fitted figure in the model from the actual figure in each country's data. These residuals mean the effects of so called "site specific factors" in the EKC literature. In this prediction, this effect to each country will be assumed to be unchanged even in the future. Therefore, the figure of the residual of each country plus the theoretically calculated fitted figure which is obtained by substituting the GDP per capita and the population in the future[14] for these figures at present will be regarded as predicted figures.

There will be several scenarios in the prediction of each pesticide category. Control variables are the GDP per capita and the population. With regard to GDP per capita, three cases, that is, standard case, high growth case and low growth case, are set. In each case, the growth rate is assumed to be common among the world, 2.0%, 2.5% and

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[13] If the panel data were obtained, it would be the best way to predict that each country's future level is predicted based upon the time series data of each country and then these predicted figures are aggregated. However, in this paper, it cannot but use cross section data. Additionally, the purpose of this prediction is not to acquire accurate figures but to understand the implication of the model. Under such a circumstance, a simple and naïve method is a satisfactory way to adopt.

[14] It is possible that trade index will be dealt with as a changeable variable in the prediction. However, in this paper, in order to simplify the scenario setting, it is regarded as an unchangeable variable. With regard to the prediction of insecticide, it is natural that temperature should be regarded as one of the site specific variables and be assumed to be unchanged in the future.

1.5%. It is possible to assume that each country will have a different growth rate based upon the extrapolation of each country's present figure. Nevertheless, in this paper, scenarios with common growth rate will be adopted. The reason is partly that since the period of this prediction is considerably long, i.e. twenty years, it is inconceivable that the economic growth rate may continue at the present situation.

With regard to the population, also three cases, that is, standard case, high growth case and low growth case, are set. In the standard case, the growth rate is assumed to be set differently among countries based upon the extrapolation method. The reason is that this figure is relatively stable and individual to each country. The average of the figures in the last five years is adopted. In the high growth case, the growth rate is set as the figure of the standard case plus 0.5%, while in the low growth case, it is set as that of minus 0.5%. Additionally, the figure of arable land and permanent crop land is also relevant to the prediction. As for this figure, as same as the population, the extrapolation method is adopted. However, in some cases, since it would become an unrealistic figure if the simple extrapolation method were adopted, there will be an upper and lower limit set to the growth rate of arable land in the future. One and a half times during twenty years is the upper limit and two third is the lower limit.

The most critical point in the prediction is whether or not the relationship between GDP per capita and pesticide consumption can simply extrapolate to a higher income level than the level at present. It seems to be too optimistic that developed countries will be able to reduce the pesticide consumption at the same rate continuously in the future. Therefore, in this paper, two cases will be set. One is a simple prediction while the other is the case in which there will be set upper limits to the reduction rate in the pesticide consumption per land. In this case, it will be assumed that developed countries cannot reduce the pesticide consumption per arable land more than 30% compared with the level at present. The implication of the upper limits setting will be addressed later.

Results

The results of prediction are shown in table 2. First of all, according to the results of three categories' aggregated figures, the world pesticide consumption as a whole is predicted to increase moderately even if developed countries will be able to continue to reduce the pesticide consumption at the present rate during the next twenty years. In the case of scenarios when the upper limits to the reduction of pesticide in developed countries are set at 30%, the increase rate would become higher. Let us look at the results of each pesticide category in detail.

First, among three categories, only in the case of insecticide, the increase of consumption will be predicted even if the upper limits to the reduction in developed countries would not be set. This means that developed countries as a whole cannot restrain the increase of insecticide. This prediction is inferred by the fact that the turning point of insecticide is highest among three pesticide categories. It is almost equal to the level of GDP per capita of a majority of developed countries.

Secondly, comparing the change of income growth rate with the change of population growth rate, the latter is more strongly influential in the change of pesticide consumption in the future. This is mainly because in the case of the change of income growth rate, the effect to increase the consumption in developing countries will mostly be mitigated by the effect to decrease the consumption in developed countries, irrespective of the level of growth rate. In contrast, in the case of the change of the population growth rate, the effect will be toward the same direction both in developing countries and developed countries.

Discussion

In the argument revolving around the EKC hypothesis, where the turning point is located is another crucial point. Even if the EKC hypothesis were distinctively observed, but the turning point were located higher, it is expected that it would not be easy to reduce the environmental pollution in the world as a whole. The reason is that if a majority of the countries in the world have yet to pass the turning points, the reduction brought by developed countries' efforts would easily be wiped out. Furthermore, in some cases it is predicted that the increase in developing countries would exceed the decrease in developed countries and then world environment as a whole would deteriorate further.

In the case of pesticide, especially insecticide, the turning point was estimated at a relatively higher income per capita. This fact is inferred by the general tendency mentioned by Grossman and Krueger (1996). They point out that the pollutions which cause acute environmental damages and locally occur tend to have the turning points at an early stage, while the ones which cause chronic damages and globally occur tend to have them at a later stage. Pesticide problem as an emission to the ecosystem is relatively classified as chronic pollution. Besides, since it is featured as non-point pollution, its damage may not occur locally but be widely spread. This characteristic also holds true when it is compared with the problem within pesticide. Endangering food safety and damages to farmers' health derived from pesticide are both acute and locally occur. Because of this, the turning points of these problems probably are revealed at a comparatively lower income stage. Compared with the turning points of these problems, it seems quite probable that of macro level pesticide consumption as an emission to the ecosystems would be revealed at a higher income stage.

In comparison between three pesticide categories, the fact that the turning point is reached at the highest income level in the case of insecticide, it should be considered more carefully in the context mentioned above[15]. It may be presumed that the negative influential factors such as the anxiety about food safety affects equally to the reduction of insecticide, fungicide and herbicide, respectively. Under such a presumption, there must be a difference between insecticide and the other two categories in positive influential factors. In other words, it is suggested that the effect of cosmetic use and the effect of food demand shift would differently reveal in the case of insecticide. In particular, cosmetic use should be noticed as a unique characteristic for insecticide. It is predicted that the requirements of food quality, including appearance, will be retained from now on. As a result, cosmetic use would not be diminished. Consequently, it is concerning that among pesticide categories, insecticide would remain as the most difficult category to reduce.

Another point is that the mechanism of how the downward movement of the environmental pollution indicator is brought about as a complex system of various factors' influences should be considered carefully in order to understand the policy

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15 From the agronomic point of view, the argument might be expected that the reason is that insect damage is a threshold type. Surely, in the case of threshold type, pesticide is apt to be overused with excessive anxiety to damage and this causes difficulty to reduce. However, this characteristic also holds on fungi damage. This cannot adequately explain the reason for a higher turning point in the case of insecticide.

implication. With regard to industrial pollution, there are arguments which factor the recent environmental improvement is attributed to most decisively; i.e. industrial structural shift, demand side change, technological progress, or government regulation. Ekins (1997) points out that it seems to be a result of exogenous government policy rather than endogenous economic structure change or technological progress.

With regard to pesticide, Ekins' concern seems to be valid to a considerable extent. It was clarified in previous sections that endogenously, there are rather strong positive influential factors such as food demand shift and cosmetic use. Surely, the anxiety about food safety and the concern for farmers' health and environment exist as an endogenous factor. Nevertheless, the latter can only be realized in practice by government regulations. It should actually be classified as an exogenous one. The former is certainly an endogenous one, however, the effect to the control of the emission to the environment is restricted. That anxiety is only effective to the restriction of the pesticide residue in food. Suppose that there were newly devised varieties of pesticide which would be surely improved in the light of little pesticide residue in food, but not improved for the amount of active ingredients. In this case, the reduction of pesticide residue would be achieved to a significant extent and the endogenous mechanism would be employed. However, another problem of how to reduce the emission of pesticide to ecosystems would not be resolved at all.

From a pessimistic viewpoint, it is suspected that the observed fact of the negative relationship between the income growth and the intensity of pesticide consumption in developed countries would be merely the consequence of temporary policy by which the production has artificially been restricted towards more extensive farming for the purpose of escaping from overproduction. If we interpreted the present situation like this, it would be more realistic to consider that observed pesticide reduction is only temporary, not firmly and endogenously fixed in the structure of pesticide consumption.

In this context, within the various scenarios set in the previous section, the one with an upper limit setting seems to be most realistic. It is not just an assumed scenario but the one on the ground of the argument revolving around an "N-shaped" EKC. In the previous studies related to the EKC hypothesis, a quadratic and cubic style formula has been observed. Within the cubic style formulae, those which have a bottom turning point after attaining an upper turning point, which is called an N-shaped pattern, should be noticed for policy implication. In some studies, the N-shaped curve is more strongly supported than the inverse U-shaped curve[16]. The implication of the N-shaped pattern is that passing over the upper turning point cannot necessarily mean to release from the close relation between economic growth and environmental degradation. In other words, the phenomenon like N-shaped curve may probably occur when the downward movement would derive from not an intrinsic and endogenous mechanism, but a superficial and exogenous mechanism.

According to the argument so far, in the case of pesticide, it must be said that the internal mechanism of reduction in developed countries is possible to be the latter one. It is reasonable to suppose that the N-shaped curve rather than the inverse U-shaped

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16 Bruyn and Opschoor (1997) illustrate that there is a commonly observed N-shaped curve in many environmental indicators. Ekins (1997) lists twelve cases of an N-shaped curve, compared with nineteen cases of an inverse U-shaped curve and concludes that the N-shaped curve, rather than the inverse U shaped curve, is a key clue to deeply analyze the relationship between the economic growth and the environmental degradation.

curve hold true. In this context, the upper limit scenario seems to be most realistic.

Concluding remarks

In conclusion, the following points should be noted. It was found that the pesticide consumption per land was significantly explained by the EKC hypothesis for all of the three pesticide categories. Although there would be several positive influential factors expected even at a higher income level, it was empirically demonstrated that the influence of negative factors, such as the anxiety about food safety and the concern for farmers' health and the environment outweighs the influence of those positive factors.

In spite of these results, it was also demonstrated that the great increase of pesticide consumption in developing countries would be predicted. Furthermore, the increase of insecticide consumption would be predicted even in developed countries.

It is unlikely that an endogenous reduction mechanism would be employed to achieve the aim of minimizing pesticide. Government efforts to set the appropriate regulations, to invest R&D in technological progress such as Integrated Pesticide Management (IPM) should be indispensable to resolve the problem.

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Table 1 Estimation and empirical test of the models

Explanatory variable	Insecticide	Fungicide	Herbicide
Intercept	-40.5703	109.9505	101.8351
(β 0)	(-5.1775)***	(1.3791)*	(1.4532)
Log(GDP per capita)	5.2515	-50.6374	-47.1207
(β 1)	(2.7950)***	(-1.7680)*	(-1.8555)*
(Log(GDP per capita))^2	-0.2592	6.6539	6.2480
(β 2)	(-2.2987)**	(1.9608)*	(2.0577)**
(Log(GDP per capita))^3		-0.2785	-0.2627
(β 3)		(-2.0988)**	(-2.1955)**
Log(Sustained Population per land)	1.2320	1.1276	0.9128
(β 4)	(6.8997)***	(5.9997)***	(5.8422)***
Log(Trade Index)	2.3480	1.9113	1.8064
(β 5)	(5.6461)***	(3.3508)***	(3.8030)***
Log(Temperature)	1.0590		
(β 6)	(3.0772)***		
Log(Rainfall)			
(β 6)			
R^2 (Adjusted)	0.5399	0.5848	0.6138
LR test (β 2= β 3=0)	Prob=0.0015	Prob=0.0047	Prob=0.0029
Adopted function form	Quadratic form with temperature	Cubic form without climate conditions	Cubic form without climate conditions

Source: FAOSTAT (FAO), World Development Indicator (World Bank),

Rikanenpyou (Meteorological data handbook in Japan),

Noyakuyoran (Annual report of pesticide inJapan),

Web site of http://www/worldclimate.com..

Sample size: Insecticide; 108, Fungicide; 97, Herbicide; 99.

Estimation method: Insecticide; OLS,

Fungicide and Herbicide; OLS (White heteroskedasticity consistent standard error)

Note: 1) The figures in the brackets are t-value.

2) * means P<0.10, ** means P<0.05, and *** means P<0.01 respectively.

3) Here are shown only the finally adopted function forms

Table 2 Prediction of the consumption in 20 years later

Present and scenarios	World consumption	Consumption in developing countries	Consumption in developed countries
<Pesticide total>			
Standard scenario	1.12	2.17	0.62
High growth scenario	1.14	2.42	0.51
Low growth scenario	1.12	1.92	0.73
More population scenario	1.25	2.41	0.69
Less population scenario	1.01	1.95	0.55
Upper limit scenario	1.24	2.17	0.79
<Insecticide>			
Standard scenario	1.53	2.05	1.10
High growth scenario	1.59	2.22	1.07
Low growth scenario	1.47	1.88	1.13
More population scenario	1.73	2.31	1.25
Less population scenario	1.36	1.81	0.98
Upper limit scenario	1.53	2.05	1.10
<Fungicide>			
Standard scenario	1.00	2.32	0.51
High growth scenario	1.00	2.66	0.38
Low growth scenario	1.02	2.02	0.65
More population scenario	1.11	2.59	0.57
Less population scenario	0.89	2.08	0.45
Upper limit scenario	1.13	2.32	0.68
<Herbicide>			
Standard scenario	0.94	2.18	0.43
High growth scenario	0.94	2.47	0.32
Low growth scenario	0.96	1.90	0.58
More population scenario	1.03	2.38	0.48
Less population scenario	0.86	1.99	0.40
Upper limit scenario	1.12	2.18	0.70

Note:1) Figures are the ratio to the present consumption level.

2) The condition of upper limit scenario is the same as that of standard scenario other than the limit set at 30% to the reduction of per land pesticide consumption.

Figure 1 Influential Factors to Pesticide Consumption