Chapter 2

Relevant Theory and Literature Review

2.1 Relevant Theory

2.1.1 Environmental Kuznets Curve (EKC) Hypothesis

Environmental Kuznets Curve (EKC) is named for Simon Smith Kuznets (1955), a Russian American economist who won the 1971 Nobel Memorial Prize in Economic Sciences for his empirical founded interpretation of economic growth, who hypothesized income equality first rises and then falls as economic development proceeds, this relationship explains graphically as inverted-U curve. EKC, was first proposed by Grossman and Krueger in 1991-1992 and restated in 1995, is a hypothesized relationship between environmental improvement or degradation and economic development. The graphically explanation is that pollution levels are increased as an economic develops in early stages, up to a certain point when it has reached high income level, the relationship will be reversed as the economic growth leads to environmental improvement as the below figure.

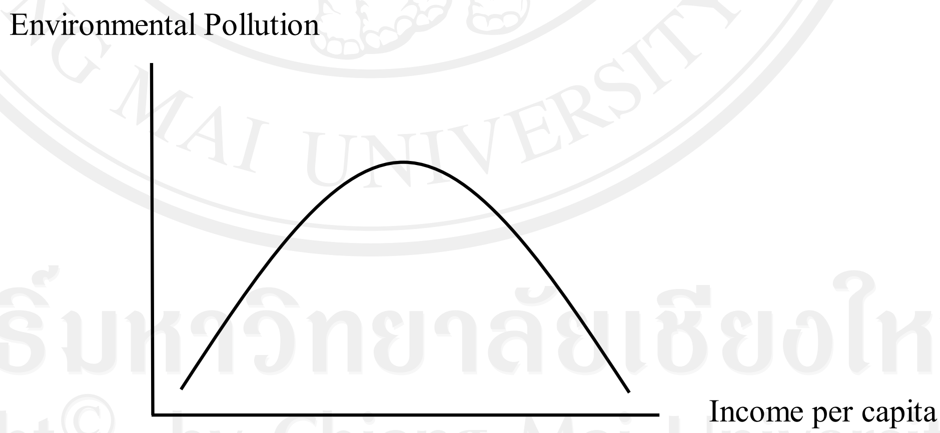

Figure 2.1: Environmental Kuznets Curve Hypothesis

Grossman and Krueger (1991 Quoted in Stern, 2004: 1422) created the standard EKC regression model as follows:

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2\left(\ln\left(\frac{GDP}{P}\right)\right)_{it}^{2} + \varepsilon_{it} \qquad (2.1)$$

Where "E" is emissions, "P" is population, and "ln" indicates natural logarithms. The first two terms on the right hand side are intercept parameters which vary across countries or regions "i" and years "t". The assumption is that, though the level of emissions per capita may differ over countries at any particular income level, the income elasticity is the same in all countries at a given income level. The time specific intercepts account for time-varying omitted variables and stochastic shocks that are common to all countries. The "turning point" income, where emissions or concentrations are at a maximum, is given by: $\tau = \exp\left(\frac{-\beta_1}{2\beta_2}\right)_{it}$

Usually the model is estimated with panel data, both the fixed effects model (treats the $\boldsymbol{\alpha_i}$ and $\boldsymbol{\gamma_t}$ as regression parameters) and random effects models (treats the $\boldsymbol{\alpha_i}$ and $\boldsymbol{\gamma_t}$ as components of the random disturbance) will be estimated by the study.

Dinda (2004) summarized the model of relationship from the empirical evidence for the existence of an EKC has been found in various studies and shared some common characteristics with respect to the data and methods employed. Most of the data used in the studies are cross-sectional panel data. The following reduced form model is used to test the various possible relationships between pollution level/environmental pressure and income:

$$Y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^{2} + \beta_3 x_{it}^{3} + \beta_4 z_{it} + \varepsilon_{i,t} \qquad (2.2)$$

Where y is environmental indicators, x is income and z relates to other variables of influence on environmental degradation. Here, the subscript i is a country, t is time, α is constant, $\boldsymbol{\beta}_k$ is the coefficient of the k explanatory variables. Equation (2.2) provides us to test several forms of environment and economic growth relationships:

(i) $\beta_1 = \beta_2 = \beta_3 = 0$

A flat pattern or no relationship between x and y.

(ii) $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$

A monotonic increasing relationship or a linear relationship between x and y.

(iii) $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$

A monotonic decreasing relationship between x and y.

(iv) $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$

An inverted-U-shaped relationship, i.e., EKC.

(v) $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$

A U-shaped relationship.

(vi) $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$

A cubic polynomial or N-shaped figure.

(vii) $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 < 0$

Opposite to the N-shaped curve.

The study observes that the EKC is only one of the possible outcomes of Equation (2.2). From (iv), the turning point of EKC is obtained at: $x^* = -(\beta_1/2\beta_2)$

A large number of econometric studies have used the Equation (2.2) to test for the emergence of an EKC in a wide variety of income based environmental pressure or pollution levels.

Bruyn et al. (1998) collected the various relationships between environmental pressure (E) and per capita income (Y) following basic reduced form model; this form are transformed from panel data analysis to time series data analysis:

$$E_{i,t} = \alpha_{i,t} + \beta_1 Y_{i,t} + \beta_2 Y_{i,t}^{\ 2} + \beta_3 Y_{i,t}^{\ 3} + \beta_4 t + \beta_5 V_{i,t} + e_{i,t} \qquad (2.3)$$

where

E = Air pollutants concentration of "i" type at "t" period.

Y = Income per head at "t" period.

V = Other variables that that influence the relationship between *E* and *Y,* such as population density, number of factories.

α = Constant term of air pollutant of "i" type at "t" period.

β = Parameter

e = Error term

i = Type of air pollutants

t = Period of time

Equation (2.3) allows for testing the various forms of environmental and economic growth relationships.

(1) $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$ reveals a monotonically increasing linear relationship (Figure 2.2 a), indicating that rising incomes are associated with rising levels of emissions;

(2) $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$ reveals a monotonically decreasing linear relationship (Figure 2.2 b);

(3) $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$ reveals a quadratic relationship, representing the EKC. The turning point of this representation of the inverted-U curve is obtained by setting the derivative of (1) equal to zero, which yields: $Y_t = -(\beta_1/2\beta_2)$ (Figure 2.2 c).

(4) $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$ reveals a cubic polynomial, representing the N-shaped figure (Figure 2.2 d).

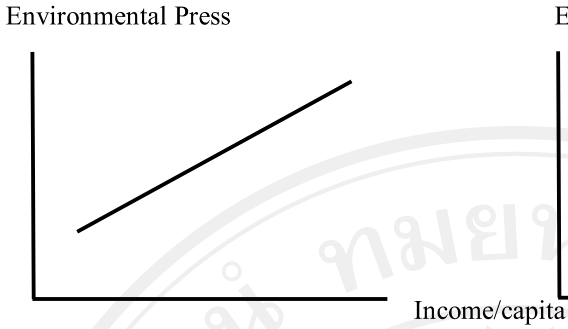

Figure 2.2 (a):
A monotonically increasing linear relationship

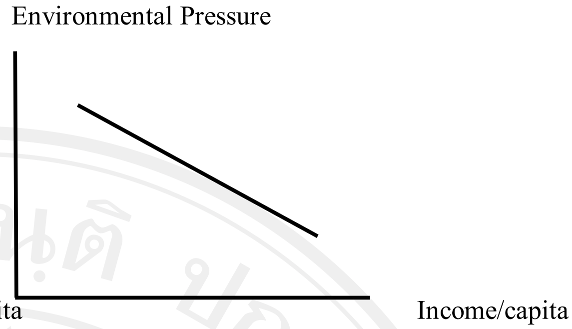

Figure 2.2 (b):
A monotonically decreasing linear relationship

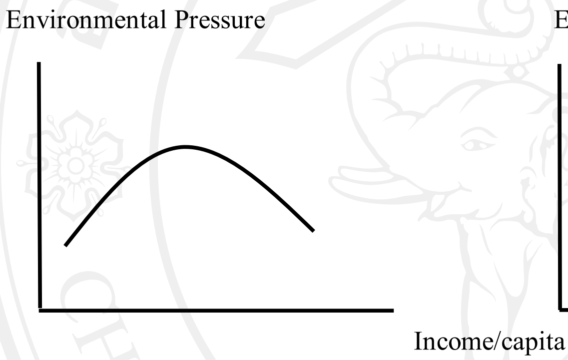

Figure 2.2 (c): Inverted-U curve

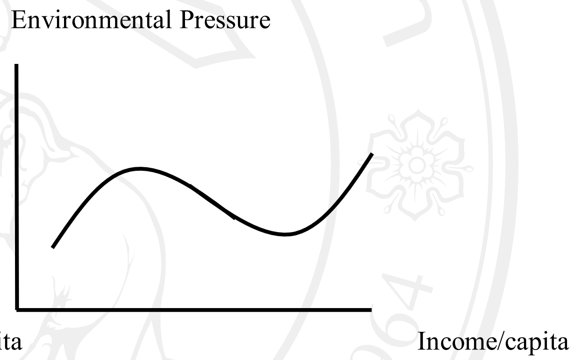

Figure 2.2 (d): N-Shaped

Figure 2.2: Various Shapes of Environmental Kuznets Curve

Other valuable related ideas and concepts according to Environmental Kuznets Curve Hypothesis from various literatures are summarized in the integrated graph of Environmental Kuznets Curve Hypothesis in the figure below.

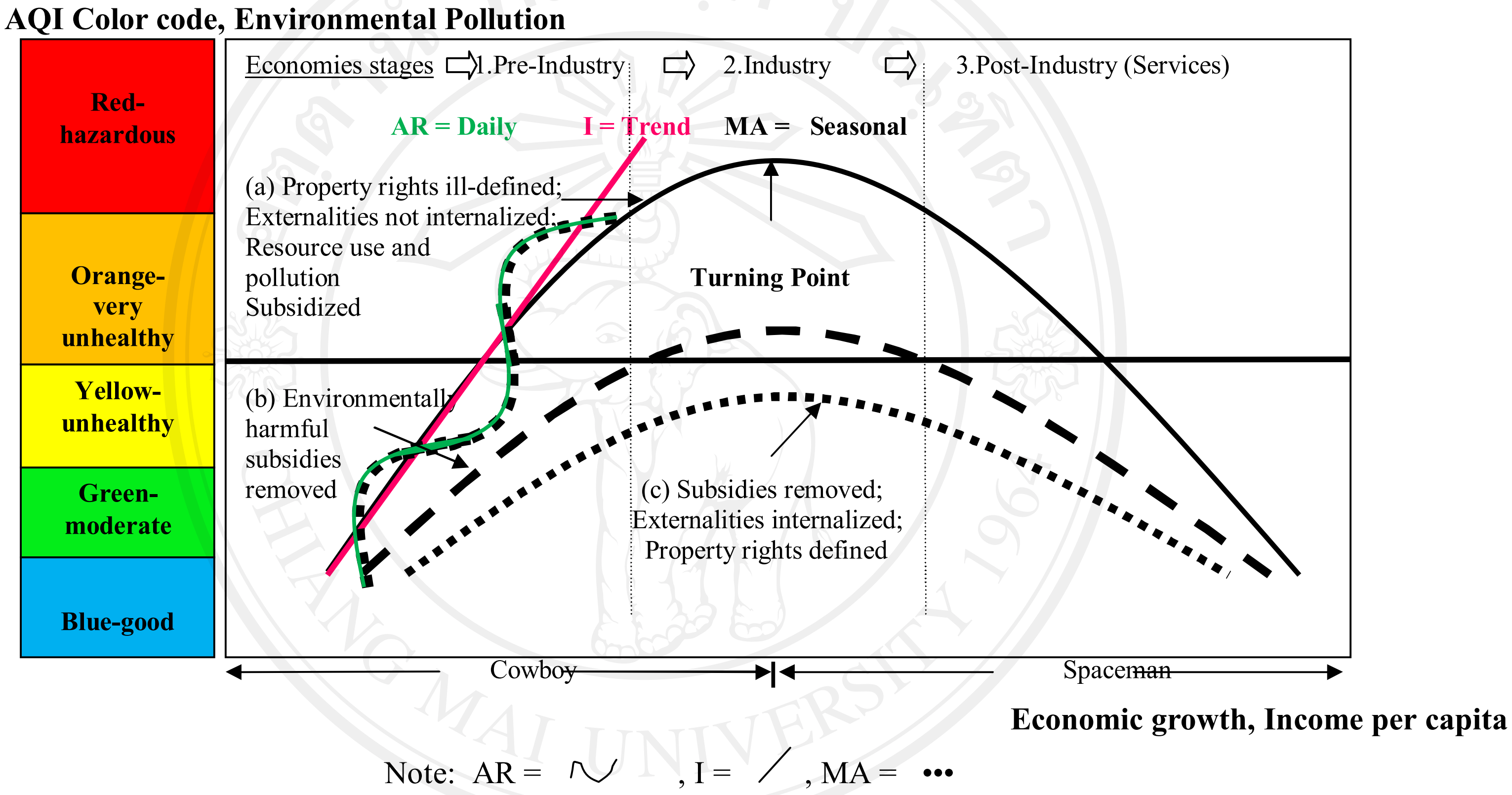

Figure 2.3: Integrated Graph of Environmental Kuznets Curve Hypothesis

The integrated graphically explanation could refer to Panayotou (2003) who found the studies have hypothesized that the relationship between economic growth and environmental quality, whether positive or negative, is not fixed along a country's development path; indeed it may change sign from positive to negative as a country reaches a level of income at which people demand and afford more efficient infrastructure and a cleaner environment. The implied inverted-U relationship between environmental degradation and economic growth came to be known as the "Environmental Kuznets Curve" by analogy with the income inequality relationship postulated by Kuznets. At low levels of development, both the quantity and the intensity of environmental degradation are limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As agriculture and resource extractions intensify and industrialization takes off, both resource depletion and waste generation accelerate. At higher levels of development, structural change towards information-based industries and services, more efficient technologies, and increased demand for environmental quality result in leveling-off and a steady decline of environmental degradation. Thus, stages of economic development are divided into three time paths from EKC curve; pre-industrial economies, industrial economies, and post-industrial economies (or services).

Panayotou (1997) incorporated explicit policy consideration into the income-environmental relationship and explored its potential as a policy tool, the role of economic growth rate, and population density. The main finding from ambient SO_2 level case is that the policies and institutions can significantly reduce environmental degradation at low income levels and speed up improvements at higher income levels, thereby flattening the EKC and reducing the environmental price of economic growth. Three groups of figures were revealed in three inverted-U curves in the figure. The income-environment relationship under different policy and institutional scenarios; the EKC is flattened out by removing environmentally harmful subsidies, internalizing externalities and ensuring a clear definition of and enforcement of property rights over natural resources.

The sustainability principle quote from classic essay by Kenneth E Boulding (1996) who described "cowboy economy" as industrialized countries which maximize production and consumption as desirable goals, and success is attained by continually increasing the throughput of materials and energies. On the contrary, “spaceman economy” tries to minimize throughput (Beder, 2006).

Time series analysis may be explained by the original EKC curve (top line of inverted-U shape) with Autoregressive daily data (AR), trend data (I), and Moving Average (MA) of the seasonal dots in the graph.

2.1.2 Time Series Analysis (Source: www.statsoft.com)

There are two main goals of time series analysis: (a) identifying the nature of the phenomenon represented by the sequence of observations, and (b) forecasting the future values of the time series variable. Both of these goals require that the pattern of observed time series data is identified and more or less formally described. Once the pattern is established, we can interpret and integrate it with other data. Regardless of the depth of our understanding and the validity of interpretation or theory of the phenomenon, we can extrapolate the identified pattern to predict future events.

As in most other analyses, in time series analysis it is assumed that the data consists of a systematic pattern (usually a set of identifiable components) and random noise (error) which usually makes the pattern difficult to identify. Most time series analysis techniques involve some form of filtering out noise in order to make the pattern more salient.

Most time series patterns can be described in terms of two basic classes of components: trend and seasonality. Those two general classes may coexist in real-life data. For example, sales of a company can rapidly grow over years but they still follow consistent seasonal patterns (e.g., as much as 25percent of yearly sales each year are made in December, whereas only 4percent in August).

Trend Analysis: There are no proven automatic techniques to identify trend components in the time series data; however, as long as the trend is monotonous (consistently increasing or decreasing) that part of data analysis is typically not very difficult. If the time series data contain considerable error, then the first step in the process of trend identification is smoothing.

Smoothing always involves some form of local averaging of data such that the nonsystematic components of individual observations cancel each other out. The most common technique is ***moving average*** smoothing which replaces each element of the series by either the simple or weighted average of *n* surrounding elements, where *n* is the width of the smoothing window. Medians can be used instead of means. The main advantage of median as compared to moving average smoothing is that its results are less biased by outliers (within the smoothing window). Thus, if there are outliers in the data (e.g., due to measurement errors), median smoothing typically produces smoother or at least more reliable curves than moving average based on the same window width. The main disadvantage of median smoothing is that in the absence of clear outliers it may produce more jagged curves than moving average and it does not allow for weighting. In the relatively less common cases (in time series data), when the measurement error is very large, the distance weighted least squares smoothing or negative exponentially weighted smoothing techniques can be used. All those methods will filter out the noise and convert the data into a smooth curve that is relatively unbiased by outliers. Series with relatively few and systematically distributed points can be smoothed with bicubic splines.

Fitting a function. Many monotonous time series data can be adequately approximated by a linear function; if there is a clear monotonous nonlinear component, the data first need to be transformed to remove the nonlinearity. Usually a logarithmic, exponential, or (less often) polynomial function can be used.

Seasonal Analysis: Seasonal dependency is another general component of the time series pattern that can be examined via correlograms. The correlogram (autocorrelogram) displays graphically and numerically the autocorrelation function (*ACF*), that is, serial correlation coefficients (and their standard errors) for consecutive lags in a specified range of lags. Ranges of two standard errors for each lag are usually marked in correlograms but typically the size of auto correlation is of more interest than its reliability because we are usually interested only in very strong (and thus highly significant) autocorrelations. Seasonal dependencies must be removed to make the series stationary which is necessary for ARIMA technique.

2.1.3 Autoregressive Moving Average (ARIMA)

ARIMA econometric modeling takes into account historical data and decomposes it into an Autoregressive (AR) process, where there is a memory of past events; an Integrated (I) process, which accounts for stabilizing or making the data stationary and ergodic, making it easier to forecast; and a Moving Average (MA) of the forecast error, such that the longer the historical data, the more accurate the forests will be, as it learns over time.

There are many reasons why an ARIMA model is superior to common time series analysis and multivariate regression. The common finding is the error residuals are correlated with their own lagged values. The serial correlation violates the standard assumption of regression theory that disturbances are not correlated with other disturbances. The primary problems associated with serial correlation are:

(i) Regression analysis and basic time series analysis are no longer efficient among the different liner estimators. However, as the error residuals can help to predict current error residuals, we can take advantage of this information to form a better prediction of the dependent variable using ARIMA.

(ii) Standard errors computed using the regression and time series formula are not correct and are generally understated. If there are lagged dependent variables set as the regressors, regression estimates are biased and inconsistent but can be fixed using ARIMA.

ARIMA(p,d,q) models are the extension of the AR model that uses three components for modeling the serial correlation in the time series data. The first component is the autoregressive (AR) term. The AR(p) model uses the p lags of the time series in the equation.

AR(p) model has the form: $Y_t = a_1 Y_{t-1} + \ldots + a_p Y_{t-p} + e_t$

The second component is the integration (d) order term. Each integration order corresponds to differencing the time series. I(1) means differencing the data once. I(d) means differencing the data d times.

The third component is the moving average (MA) term. The MA(q) model uses the q lags of the forecast errors to improve the forecast.

MA(q) model has the form: $\boldsymbol{Y_t = e_t + b_1 e_{t-1} + \ldots + b_q e_{t-q}}$

Finally, ARMA(p,q) model has the combined form:

$$Y_t = a_1 Y_{t-1} + \ldots + a_p Y_{t-p} + e_t + b_1 e_{t-1} + \ldots + b_q e_{t-q} \quad (2.4)$$

In interpreting the results of ARIMA model, most of the specifications are identical to the multivariate regression analysis. However, there are several addition sets of results specific to the ARIMA analysis. The first is the addition of Akaike Information Criterion (AIC) and Schwarz Criterion (SC), which are often used in ARIMA model selection and identification. That is, AIC and SC are used to determine if a particular model with a specific set of p,d, and q parameters is a good statistical fit. SC imposes a greater penalty for additional coefficients than the AIC but generally, the model with the lowest AIC and SC values should be chosen. Finally, an additional set of results called the autocorrelation (AC) and partial autocorrelation (PAC) statistics are provided in the ARIMA report.

For instance, if autocorrelation AC(1) is nonzero, it means that the serials is first order serially correlated. If AC dies off more or less geometrically with increasing lags, it implies that the series follows a low-order autoregressive process. If AC drops to zero after a small number of lags, it implies that the series follows a low-order moving-average process. In contrast, PAC measures the correlation of values that are k period apart after removing the correlation from the intervening lags. If the pattern of autocorrelation can be captured by an autoregression of order less than k, then the partial autocorrelation at lag k will be close to zero. The Ljung-Box Q-statistics and their p-values at lag k are also provided, where the null hypothesis being tested is such that there is no autocorrelation up to order k. The dotted lines in the plots of the autocorrelations are the approximate two standard error bounds. If the autocorrelation is within these bounds, it is not significantly different from zero at approximately the 5 percent significance level. These AC, PAC, SC, and AIC are highly useful diagnostic tools to help identify the correct model specification. The ARIMA parameter results are obtained using sophisticated optimization and iterative algorithms, which means that although the functional forms look like those of a multivariate regression, they are not the same. ARIMA is a much more computationally intensive and advanced econometric approach.

ARIMA Methodology

Autoregressive moving average model. The general model introduced by Box and Jenkins (1976) includes autoregressive as well as moving average parameters, and explicitly includes differencing in the formulation of the model. Specifically, the three types of parameters in the model are: the autoregressive parameters (*p*), the number of differencing passes (*d*), and moving average parameters (*q*). In the notation introduced by Box and Jenkins, models are summarized as ARIMA (*p, d, q*); so, for example, a model described as (0, 1, 2) means that it contains 0 (zero) autoregressive (*p*) parameters and 2 moving average (*q*) parameters which were computed for the series after it was differenced once.

Identification. The input series for ARIMA needs to be stationary, that is, it should have a constant mean, variance, and autocorrelation through time. Therefore, usually the series first needs to be differenced until it is stationary (this also often requires log transforming the data to stabilize the variance). The number of times the series needs to be differenced to achieve stationarity is reflected in the *d* parameter (see the previous paragraph). In order to determine the necessary level of differencing, you should examine the plot of the data and autocorrelogram. Significant changes in level (strong upward or downward changes) usually require first order non seasonal (lag=1) differencing; strong changes of slope usually require second order non seasonal differencing. Seasonal patterns require respective seasonal differencing (see below). If the estimated autocorrelation coefficients decline slowly at longer lags, first order differencing is usually needed. However, you should keep in mind that some time series may require little or no differencing, and that over differenced series produce less stable coefficient estimates.

At this identification phase, we also need to decide how many autoregressive (*p*) and moving average (*q*) parameters are necessary to yield an effective but still parsimonious model of the process (parsimonious means that it has the fewest parameters and greatest number of degrees of freedom among all models that fit the data). In practice, the numbers of the *p* or *q* parameters very rarely need to be greater than 2.

Estimation and Forecasting. The parameters are estimated, so that the sum of squared residuals is minimized. The estimates of the parameters are used in the last stage; which is Forecasting, to calculate new values of the series (beyond those included in the input data set) and confidence intervals for those predicted values. The estimation process is performed on transformed (differenced) data; before the forecasts are generated, the series needs to be integrated (integration is the inverse of differencing) so that the forecasts are expressed in values compatible with the input data. This automatic integration feature is represented by the letter "I" in the name of the methodology (ARIMA = Auto-Regressive Integrated Moving Average).

The constant in ARIMA models. In addition to the standard autoregressive and moving average parameters, ARIMA models may also include a constant, as described above. The interpretation of a (statistically significant) constant depends on the model that is fit. Specifically, (1) if there are no autoregressive parameters in the model, then the expected value of the constant is μ, the mean of the series; (2) if there are autoregressive parameters in the series, then the constant represents the intercept. If the series is differenced, then the constant represents the mean or intercept of the differenced series; For example, if the series is differenced once, and there are no autoregressive parameters in the model, then the constant represents the mean of the differenced series, and therefore the linear trend slope of the un-differenced series.

Identification Phase

Number of parameters to be estimated. Before the estimation can begin, we need to decide on (identify) the specific number and type of ARIMA parameters to be estimated. The major tools used in the identification phase are plots of the series, correlograms of auto correlation (ACF), and partial autocorrelation (PACF). The decision is not straightforward and in less typical cases requires not only experience but also a good deal of experimentation with alternative models (as well as the technical parameters of ARIMA). However, a majority of empirical time series patterns can be sufficiently approximated using one of the 5 basic models that can be identified based on the shape of the autocorrelogram (ACF) and partial auto correlogram (PACF). Since the number of parameters (to be estimated) of each kind is almost never greater than 2, it is often practical to try alternative models on the same data.

1. One autoregressive (p) parameter: ACF - exponential decay; PACF - spike at lag 1, no correlation for other lags.

2. Two autoregressive (p) parameters: ACF - a sine-wave shape pattern or a set of exponential decays; PACF - spikes at lags 1 and 2, no correlation for other lags.

3. One moving average (q) parameter: ACF - spike at lag 1, no correlation for other lags; PACF - damps out exponentially.

4. Two moving average (q) parameters: ACF - spikes at lags 1 and 2, no correlation for other lags; PACF - a sine-wave shape pattern or a set of exponential decays.

5. One autoregressive (p) and one moving average (q) parameter: ACF - exponential decay starting at lag 1; PACF - exponential decay starting at lag 1.

Seasonal models. Multiplicative seasonal ARIMA is a generalization and extension of the method introduced in the previous paragraphs to series in which a pattern repeats seasonally over time. In addition to the non-seasonal parameters, seasonal parameters for a specified lag (established in the identification phase) need to be estimated. Analogous to the simple ARIMA parameters, these are: seasonal autoregressive (*ps*), seasonal differencing (*ds*), and seasonal moving average parameters (*qs*). For example, the model (*0,1,2*)(*0,1,1*) describes a model that includes no autoregressive parameters, 2 regular moving average parameters and 1 seasonal moving average parameter, and these parameters were computed for the series after it was differenced once with lag 1, and once seasonally differenced. The seasonal lag used for the seasonal parameters is usually determined during the identification phase and must be explicitly specified.

Cointegration (Source: Wikipedia)

Cointegration is a statistical property of time series variables. If two or more series are individually integrated (in the time series sense) but some linear combination of them has a lower order of integration, then the series are said to be cointegrated. A common example is where the individual series are first-order integrated (I(1)) but some (cointegrating) vector of coefficients exists to form a stationary linear combination of them. For instance, a stock market index and the price of its associated futures contract move through time, each roughly following a random walk. Testing the hypothesis that there is a statistically significant connection between the futures price and the spot price could now be done by testing for the existence of a cointegrated combination of the two series.

Spuriousness can only be avoided if a stationary cointegrating relationship is established between the variables. The particular relevance of the error correction form is the modelling of cointegrated series. According to Engle and Granger (1987), when variables are cointegrated there exist a valid error correction model describing their relationship, with the implication that cointegration between variables involved is a precondition for the error correction model. In testing for cointegration, we apply the ADF test to the residuals of the co-integrating regression rather than the levels of the series. If the residuals of the bivariate or multivariate co-integrating regressions are found to be stationary, implying co-integration, we will then specify an error correction model, which is the second step of the Engle-Granger two-step method. Following Engle and Granger (1987), the cointegration regression between Y_t and Z_t can be specified.

$$Y_t = \alpha_0 + \alpha_1 Z_t + \varepsilon_t \tag{2.5}$$

The residuals $\varepsilon_t = (Y_t - \alpha_0 - \alpha_1 Z_t)$ is simply a liner difference of the non-stationary series (e.g. $Y_t - Z_t$).

The ADF test equation based on the residuals is given as:

$$\Delta\hat{\varepsilon}_t = \emptyset + \beta\hat{\varepsilon}_{t-1} + \sum_{t-1}^{i} \lambda\Delta\beta\hat{\varepsilon}_{t-j} + V_t \tag{2.6}$$

The test statistic is a t-ratio for $\beta = 0$. If this null hypothesis cannot be rejected against the alternative that $\beta < 0$, then the variables are not cointegrated, on the other hand if the null hypothesis is rejected then the conclusion would be that the estimated ε_t is stationary (that is, does not have a unit root). In our estimations, bivariate and multivariate co-integrating regressions were carried out between the export supply of cocoa and the price variables and income to establish the existence of long-run cointegrating relationship.

Finally, in stage two, the residuals of the valid multivariate co-integrating regressions were included in the model as explanatory variable, before it was estimated with the use of ordinary least squares regression. From the example in equation (1), the error correction mechanism (ECM) can be specified as:

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta Z - \alpha_2 (Y_t - \bar{Z}_t)_{t-1} + \varepsilon_t \qquad (2.7)$$

where,

$\overline{Z}$ = the vector of explanatory variables

Y_t and Z_t = the co-integrating variables

α_2 = the error correction mechanism (ECM)

α_1 = the vector of parameters.

Cointegration

Engle and Granger proposed a two-step estimation technique to do cointegration. In the first step, a regression of the variables in the set of I(1) is run:

$$y_t = \alpha_1 x_{t,1} + \alpha_2 x_{t,2} + \cdots + \alpha_K x_{t,K} + z_t \qquad (2.8)$$

for t = 1,… , T, where z_t assigns the error term. The estimated (K+1) cointegrating vector is given by $\hat{\alpha} = (1, -\hat{\alpha})'$. Hence, the cointegrating vector is normalized to the regression. Whether such a model can be fitted or not can be tested by Dickey-Fuller (DF) test or the Augmented Dickey-Fuller (ADF) test. Once the null hypothesis of a unit root in the series $\widehat{Z}_t$ has been rejected, the second step of the two-step procedure is to specify a vector error correction model (VECM).

A Vector Error Correction Model (VECM) can lead to a better understanding of the nature of any non stationarity among the different component series and can also improve longer term forecasting over an unconstrained model. The VECM(p) form is written as:

$$\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Phi_j^* \Delta y_{t-i} + e_t \quad (2.9)$$

where Δ is the differencing operator, such that $\Delta y_t = y_t - y_{t-1}$. To specify a VECM, the lag order, the cointegration rank and possibly further restrictions have to be determined.

Optimal Level of Pollution

One of the clearest examples of market failure resulting from externalities is pollution. A valid question is, how much pollution do you want? The realistic answer is not "none" but instead, "less". How much less? Economist approaches this question as follows.

The costs associated with pollution are many and varied. There are costs associated with cleaning everything from cars to windows, there are health costs associated with the increased incidence of illness, and there are aesthetic costs associated with sunsets missed or outdoor works of sculpture ruined. As with any costs the marginal social costs of pollution increase as the amount of pollution increases. This is illustrated in figure below where marginal social costs per unit of pollution are measured on the vertical axis, and the amount of pollution is measured on the horizontal axis, ranking from zero pollution at the origin to 100 percent at the end of the horizontal axis.

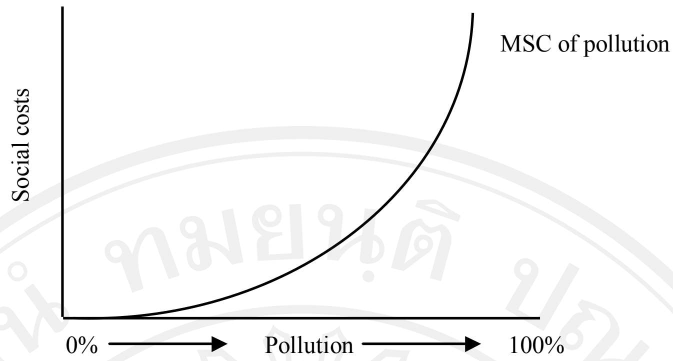

Figure 2.4: Social costs of pollution

Following the usual canons of economics, as the amount of pollution is increased, *ceteris paribus*, the marginal social costs of each additional unit of pollution increases. The social costs of the last marginal unit of additional pollution will be very high. Obviously the marginal social costs of the last and next to last units of pollution are so great that this pollution must be avoided. Likewise, the costs of the first and second units of pollution (close to the origin) are so low that they are probably acceptable. The trick is to find the middle ground.

In order to reduce pollution, society must spend money on **pollution abatement** or control. AS with other economic goods, the marginal social cost of pollution abatement increases as the amount of abatement increases. This is illustrated in the figure below, which is similar to figure above except that units of pollution abatement are measured on the horizontal axis. The first two or three units of abatement (that is, pollution control) come at a very low marginal social cost, while the last few units of abatement have such high social cost as to be of little practical relevance. Once again, no abatement is not enough and total abatement is too much.

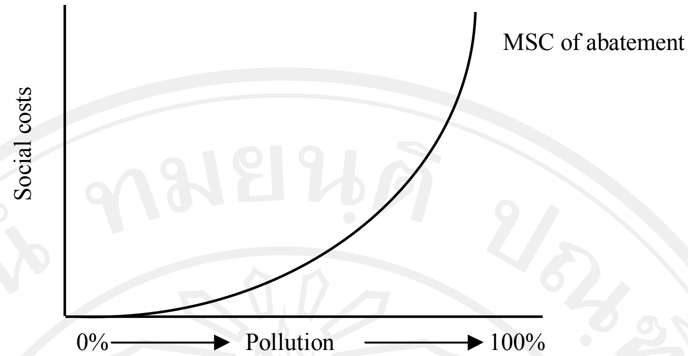

Figure 2.5: Social costs of abatement

To find the “right” amount of pollution (and abatement) we need to combine the information from the previous two figures. The result is shown in the following third figure where the second figure has been flipped over and superimposed on the first figure. This is possible since one more unit of abatement is equal to one less unit of pollution. Therefore, we can use a common horizontal axis on which pollution increases as abatement decreases (or reading from right to left, as abatement increases pollution decreases). Since the two curves in the third figure measure the marginal social costs of pollution and abatement, the socially optimal amount of pollution and abatement will occur the point where marginal social costs of adding and additional unit of abatement are just equal to the marginal social costs of an additional unit of pollution. Abatement beyond the social optimum would have higher marginal social costs than the marginal social benefits gained from reduced pollution.

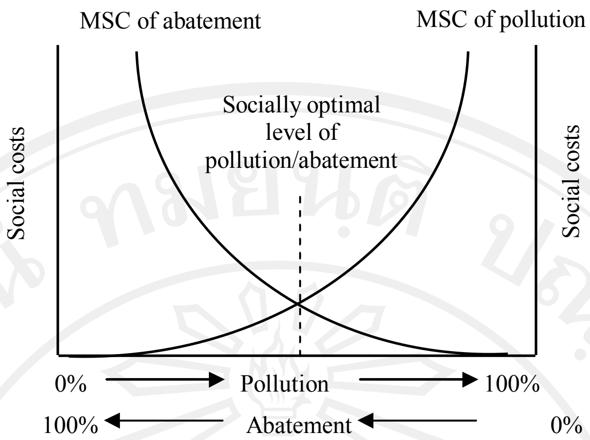

Figure 2.6: Social costs of pollution and abatement

To abate either more or less than that, the amount shown as socially optimal in the third figure above would imply higher total social costs. This can be seen in the fourth figure below.

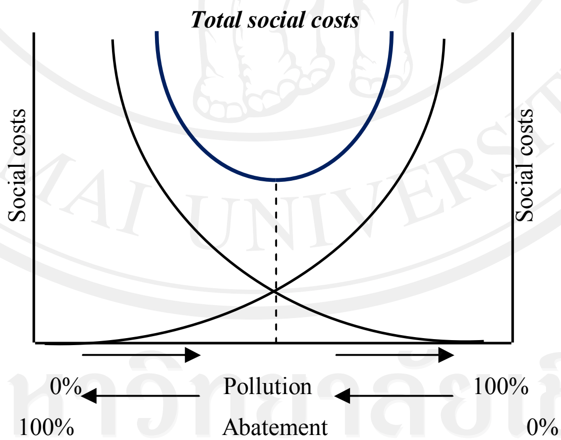

Figure 2.7: Total social costs of pollution/abatement

Here the total social costs of pollution plus abatement are shown. At zero abatement, the total social costs are very high because there is a lot of pollution. The first few units of abatement have low social costs but eliminate pollution with very high social costs. As a result, the total cost falls rapidly as the first few units of abatement are added. The socially optimal amount of pollution (shown by a dotted line in the forth figure) is that amount for which the total of pollution costs plus abatement costs is minimized. To add abatement beyond this level would cause the cost of abatement to increase more than the reduced cost of pollution and the total social cost would increase.

Returning to the question at the beginning of this section – How much pollution do you want? – we find that the answer depends on the marginal social costs of pollution and the marginal social costs of pollution abatement. The cynic might look at the fourth figure above and say, "Nice diagram, but how do you measure that in the real world?" The solution could be the "Benefit-Cost Analysis"

Benefit-Cost Analyses

When market fail to provide socially optimal solution because of the existence of externalities, the economist can attempt to estimate the socially optimal price/quantity using the technique of benefit-cost analyses or B/C analysis which is basically a form of investment analysis in which all the private and social costs and benefits are measured in a consistent fashion. As with investment analysis, all future costs and benefits must be reduced to the present value using an appropriate discount rate.

The trick to B/C analysis is to place a value on the externalities associated with the proposed economic activity. In many cases assigning these values is very difficult because there are no well-defined markets in which these values are established. This is where economics and art become very close, for it is certainly a subjective art to determine the best way of valuing an externality.

For example, suppose a proposed pollution abatement project is estimated to save 100 lives per year from reduced cancer. What is the value of 100 lives? The answer, of course, depends greatly on who the 100 folks are. If my mother is one of the 100, then the value of the lives is quite great. But if they are all computers, then the value may not be so great. Obviously, this is something that is very subjective. The creative economist would look for a market in which people are putting a value on their own life. It could be done with interviews or a contact panel, but a better way is to let markets operate. Each of us answers the question "What am I worth?" when we buy life insurance. To find the value of 100 lives saved, simply determine the average insurance coverage for people in that population and multiply that by 100.

Once the economist has identified all externalities, has placed a value on all costs and benefits, and has converted all costs and benefits to present value, then simply divide the total benefit by the total cost to determine the benefit/cost ratio. If the ratio is greater than one, then the social benefits are greater than the social costs and the investment is feasible. If it is less than one, the activity is not viable, from a societal point of view. A private B/C ratio can also be computed and compared with the social B/C ratio to highlight the divergence between private and social interests caused by externalities.

A marginal approach to solving the optimal pollution problem is possible using multiple benefit-cost analyses for alternative levels of abatement. If benefit-cost analyses were completed for abatement levels of 10 percent through 90 percent in increments of 10 percent what we would find is that the B/C ratio for the first 10 percent of abatement would be quite high and the B/C ratio for the last 10 percent would be quite low. Somewhere in between 10 percent abatement and 90 percent abatement, the B/C ratio would cross over from being greater than 1.0 to being less than 1.0. This would be the point of socially optimal abatement/pollution.

Some innovative ways beyond simple taxes and subsidies that have been used to correct market failures caused by externalities called "Policy Alternatives".

Policy Alternatives

If the welfare of society is best served by applying less pesticide than what the farmer wants to apply, then how is that application rate to be enforced? We have already seen that farmers left to their own self-interests in a freely competitive market will apply more pesticide than is socially optimal. Therefore, we have a case where a freely competitive market will not generate a socially optimal level of pesticide use. Society, through its democratic processes, can resolve this dilemma in either of five manners:

i) Allow the free market to operate, with those sectors affected by the externalities paying the costs of those externalities.

ii) Allow the free market to operate, with the government using moral suasion in an effort to effect markets.

iii) Allow the free market to operate, with those sectors affected by the externalities being reimbursed by society for the additional costs.

iv) Allow the free market to operate, with those sectors creating the externalities being forced to pay for the additional social costs created by their private decisions.

v) Have the government intervene in the market to force private decisions to conform to the broader interests of society.

A fourth alternative is to make the polluter to pay the full social cost rather than just the private cost for any economic activity. The simple way is to place a tax on the activity that creates the externalities. There are several alternative policy approaches that have been used in the field of pollution control to place the financial burden of the pollution on the producer of that pollution. Three approaches are presented here below.

Emission Charges: The traditional approach is to tax the polluter the amount of externality. The biggest problem with emission charges is in knowing at what level to set the tax and in taxing differently situated producers at the same rate. Should a plant that spews acid rain over the Grand Canyon be taxed at the same rate as the producer that creates acid rain over the Gulf of Maxico?

Transferable Pollution Right: One of the problems with pollution is that property rights to pollute are poorly defined. An alternative policy approach that is currently being used in the electric power industry is for the Environmental Protection Agency to create transferable pollution rights in the form of discharge permits. Each permit entitles the holder to discharge a given amount of a given pollutant per unit of time. The permits create clear property rights to pollute. Initially the permits were auctioned off to buyers. Once all the permits were sold, a private market for permits emerged with any holder perfectly free to sell excess discharge capacity to another firm at a mutually agreeable price. Suppose a firm is constrained by permits held for carbon monoxide. The firm can either:

- Keep its current technology and buy more permits or
- Install new abatement equipment that will allow it to expand production within the limits of currently held permits.

Since permits and new pollution control equipment are almost perfect substitutes, it stands to reason that in time the price of permits will approach that of the equipment. Since the number of permits does not change, the total amount of pollution never increases. The beauty of this plan is that poverty rights are clear and the freedom of the market is used to guide producer towards a socially optimal solution.

The advent of transferable rights has resulted in some interesting economic behavior. Recently a large utility in New York exchanged rights for one pollutant with a utility in Arizona for another pollutant. Since the current value of the permits was far greater than the original cost of the permits, both firms earned "profits" in an accounting sense without any change in the amount of pollution rights held. Both firms agreed to donate these profits to charity. A second interesting use of the permits has been a move by some environmental organizations to enter the market for permits and then hold them unused. In essence, if an environmental group wants to reduce pollution, it can buy the real thing on the open market.

Bubble Policies: A "bubble" policy is essentially a local pollution control policy. A small geographic area can decide to put a bubble over the region and not allow any more pollution to be generated under the bubble. Suppose Gary, Indiana, put a bubble over itself and declared that no more pollution could be generated under the bubble. If Fran wanted to open a dry cleaning shop in a new shopping center, she could not open her new store until such time as she reduced the pollution elsewhere in an amount equal to what she would add to the bubble. Fran has two choices:

- She could buy an existing dry cleaning establishment in an older, run-down part of town and close it down, thus reducing pollution and allowing her to open her new store.
- Fran could find the owner of old store with old, high-pollution equipment and offer to help pay the cost of putting in new equipment that would reduce the pollution from the old shop so she could open her new store.

If Fran is not able to reduce pollution elsewhere under the bubble, then she cannot open her fancy new store. A disadvantage of the bubble approach is that the biggest "winners" are the oldest, worst polluters before the bubble was put in place. So while the bubble policy works, it tends to reward the past "bad" guys at the expense of good ol' Fran.

Government Intervention

The final policy alternative is for the government to intervene directly in the private market in an effort to make the market achieve social aims. This can be done by altering either of the two dimensions of a market - price or quantity. If governmental intervention changes one, then the other will certainly follow. Intervention on the price side usually takes the form of a tax or subsidy to offset the externality, but in some cases direct price fixing by government regulators completely replaces the allocative role of the market. The other avenue for governmental intervention into a market is through the quantity side of the market. Examples include restrictions on the amount of pollution a car may produce and the quantity of mature trees that can be harvested in the Pacific Northwest. These are cases where the government forsakes the velvet glove of market persuasion and uses the ugly club of bureaucratic mandates.

The choice of approach is strictly a political decision. The role of the economist in this political framework is twofold. First, the economist can estimate the magnitude and distribution of the costs and benefits of alternative courses of action; and second, the economist can evaluate the impact of each approach and identify appropriate means to achieve it.

The serious questions of environmental concern raised in the past two decades have been addressed with a combination of each of the five policy alternatives previously indicated. Examples of each of the five will demonstrate how economic externalities have been handled in a world of political reality. In all but the first case, governmental intervention into the private, competitive market s necessary to resolve the differences between private and social benefits and costs.

2.1.4 Environmental Principles

Beder (2006) summarized the environmental principles into two major parts:

Part I: Environmental Protection Principles

(I.1) The Sustainability Principle: The quote from classic essay by Kenneth E Boulding (1996) who described "cowboy economy" as an industrialized countries which maximize production and consumption as desirable goals, and success is attained by continually increasing the throughput of materials and energies. On the contrary, "spaceman economy" tries to minimize throughput in a closed economy according to the sustainability principle as following aims.

(i) limit extraction and pollution;
(ii) decrease consumption;
(iii) continuously reproduce the material form;
(iv) increase stock maintenance – goods would be built to last as long as possible.

Economic success in a spaceman economy would be measured by the "nature, extent, quality, and complexity of the total capital stock, including in this the state of human bodies and minds".

(I.2) The Polluter Pays Principle (PPP): This principle seeks to remedy the negative externalities by forcing the polluters to pay for the appropriate pollution control measures as following government's actions.

(i) Regulating what polluters are able to discharge into the environment, so that they have to install their own pollution control equipment;
(ii) Charging polluters taxes and levies to cover government costs of protecting the environment, including the cost of sewage treatment facilities;
(iii) Making polluters liable for the damage they cause.

(I.3) The Precautionary Principle: This principle aims to prevent known risks rather than anticipate and prevent uncertain potential harm. Actions, result of the participatory process, are interventions that are undertaken before harm occurs.

Part II: Social Principles and Environmental Protection

(II.1) The Equity Principle: Three aspects are involved.

(i) People have certain rights that must be respected.

(ii) People get what they deserve – fairness.

(iii) People's needs should be met and their contribution to meeting such needs is based on their ability to do so.

(II.2) Human Rights Principles: Human rights are entitlements based on morality, justice and fairness which, collectively, the nations of the world have agreed all people ought to have. They include the rights to life, liberty, health and well being. The rights apply to every human being throughout their life, no matter where they live or what their religion, occupation, race, color, age or gender, and are regarded as essential to human dignity and are inalienable, which means they cannot be taken away, sold, or given away. Moreover, Environmental Human Rights are agreed to at a UN Conference, it stated that:

Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations.

(II.3) The Participation Principle: A number of declarations, treaties and conventions have reinforced and elaborated these rights. The importance and wisdom of providing the public with full information and encouraging public participation is recognized in the Rio Declaration of 1992:

Environmental issues are best handled with participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate to access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes, States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

Similarly, Agenda 21, which was agreed to by over 100 nations at the Rio Conference in 1992, emphasizes the need for public participation:

One of the fundamental prerequisites for the achievement of sustainable development is broad participation in decision-making. Furthermore, in the more specific context of environment and development, the need for new forms of participation has emerged. This includes the need for individuals, groups, and organizations to participate in environmental impact assessment procedures and to know about and participate in decisions, particularly those which potentially affect the communities in which they live and work.

Austin (1999) summarized an overview of economic instruments for pollution control and prevention which aim to control pollution by harnessing the power of market incentives, offer a more cost-effective, flexible and dynamic form of regulation than conventional measures. Two approaches are analyzed among the expansion of using the economic instruments nationally.

2.1.5 Economic Instrument

A Traditional Approach: Command and Control Instrument (CAC)

Command and control regulations can be set from two types as follow.

(i) **Technology-based** specify the methods and equipment that firms must use to meet the target.

(ii) **Performance-based** set an overall target for each firm and give firms some discretion in how to meet the standard. This standard still hold firms to a uniform level across the industry, ignoring the possibility that some companies may be able to make reductions more readily than others.

Market-based Incentives Approach

Economists have long advocated the use of economic instruments as an alternative, or supplement, to direct regulation. Most importantly, economists argue that economics instruments can create a system for pollution reduction that achieves the same level of environmental protection for a lower overall cost (or achieve more for the same cost). Economic instruments also allow for a more hands-off regulation and decentralized decision-making, giving greater freedom to firms and plants about how to comply.

Economic instruments for environmental protection include these following tools.

1) Charges, Fees or Taxes

These are prices paid for discharges of pollutants to the environment, based on the quantity and/or quality of the pollutants. To be most effective the charge is livied directly on the quantity of pollution (emission tax or charge), though if this is difficult to measure or monitor, it may be necessary to levy a charge on a proxy for the emission, typically on the resource that causes the pollution (product tax or charge). Product charges occur at different usage points. They have been levied on products either as they are manufactured, consumed or disposed of.

2) Tradable Permits

These are similar to charges and taxes except that they operate by fixing an aggregate quantity of emissions rather than charging a price for each unit of emissions. Polluters need to hold a permit; which is tradable to other polluters, to emit or discharge under the aggregate pollution quantity controlling by government.

3) Charge-Permit Hybrids

It is possible to blend the quantity-based permit approach with a price-based charge or tax approach to try to harness their different strengths while avoiding their weaknesses. A good example is RFF's proposal to use a hybrid mechanism to control CO_2 emissions in the U.S. This would consist primarily of a permit program that would require domestic energy producers (and importers) to obtain permits equivalent to the volume of carbon dioxide eventually released by the fuels they sell. However, by setting the overall permit quantity, one has no idea what price permits will sell for –this will only be revealed as businesses and consumers begin to reduce their CO_2 emissions.

4) Deposit-refund schemes

A surcharge is levied on a product at the point of payment. When pollution is avoided by returning the product, or its polluting components, to a specified collection stream the surcharge is refunded. These economic instruments have been used most often for drinks containers, batteries and packaging.

5) Subsidies

Where taxes or charges can be used as a penalty on discharges, subsidies can be used to reward the reduction of discharges in a similar manner. The financial incentive is effectively the same, though the flow of funds is in a different direction. A subsidy program will involve a transfer of funds from the government to the industry, while a charge program would be a revenue source for the government. Subsidies may be relatively explicit in the form of grants and soft loans, or be somewhat indirect, such as in adjusted depreciation schedules.

Panayotou (1994) analyzed the role and scope of economic instruments in four aspects in correcting institutional, market, and policy failures.

1) Full-Cost Pricing

Economic instruments aim to bridge the gap between private and social costs by internalizing all external costs (both depletion and pollution costs) to their sources: the producers and consumers of the resource depleting and polluting commodities. Economic instruments aim to institute full cost pricing by costing and charging full scarcity cost for resource depletion and full damage cost for environmental degradation. See figure below for the full cost pricing which is giving by the formula:

P = MPC + MUC + MEC

Where;

P = Price

MPC = Marginal (or Incremental) Production Cost

MUC = Marginal User (or Depletion) Cost

MEC = Marginal Environmental (or Damage) Cost

Policy failures such as subsidies, reduce marginal production costs (the cost of capital, labor, energy, and materials) below the social opportunity costs, (that is, the true cost of these factors of production to society), encouraging inefficient and excessive use of subsidized inputs.

Institutional failures such as open access and insecure tenure, reduce the user's benefits from the conservation of depletable resources and remove the marginal user (or depletion) cost from the decision-maker's calculus. The cost of depletion to the user is effectively set equal to zero even though the cost of depletion to society is high and rising. As a result the resource is undervalued, and used excessively and inefficiently. Resource-based goods and services are thereby underpriced and over-consumed.

Market failures such as environmental externalities (and public goods), leave important social costs (and benefits) outside the producers' and consumers' decision calculus. The lack of market prices for environmental services effectively sets the marginal environmental cost (that is, the cost to society from the diminution of these services) equal to zero from the individual producer's or consumer's perspective. This becomes one more source of underpricing of environmentally damaging commodities and overpricing of environmentally friendly commodities.

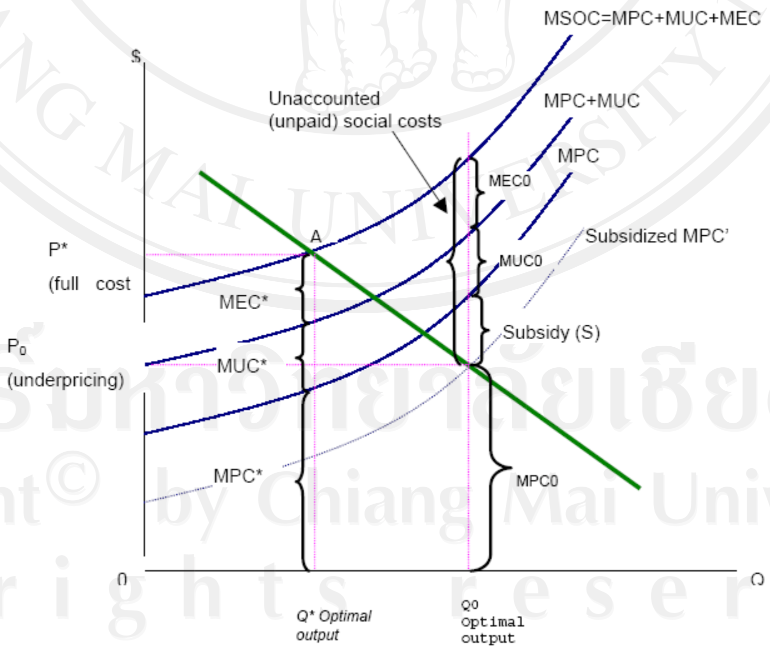

Figure 2.8: The role of economic instruments in internalizing external costs with full- cost pricing.

At A: P* = MSOC≡MPC + MUC + MEC

where P* = optimal price,

MSOC = marginal social opportunity cost,

MPC = marginal production cost;

MUC = marginal user (or depletion) cost;

MEC = marginal environmental (damage) cost.

Q* = optimal output; resources freed by the reduction of the polluting output from Q0 down to Q* move to other products with lower social costs (e.g., resource saving and environment-friendly).

MPC* internalized by removal of distortionary subsidies.

MUC* internalized through secure property rights (assuming no discrepency between private and social discount rates; if such discrepancy exists output taxes or tradeable production quotas can be used for further correction).

MEC* internalized through taxes, charges, tradeable permits or other economic instruments (optimal tax = optimal price of permit = MEC*).

2) Internalizing External Costs through Economic Instruments

Economic instruments for environmental management aim to correct the failure (institutional, market, and policy failure), reinstate full-cost pricing, and bring about a alignment of resource allocation with society's objectives and interests which is a necessary condition for sustainable development. Economic Instruments are ideally situated for reconciling environmental concerns with development needs and integrating environmental and economic policy by virtue of their a) market correction quality, b) efficiency or cost-minimization objective, c) flexibility in accommodating heterogeneity, and d) adjustability to changing circumstances.

3) Efficiency, Cost Effectiveness and Equity

To minimize costs or to be cost effective, pollution control and resource conservation should be carried out by those who are able to do it at the lowest cost. To be efficient, no more pollution control should take place than is justified by the ensuing benefits; the pollution control should be carried out to the point where the incremental pollution control costs equal the incremental benefits i.e., additional damages avoided. To be equitable, the cost of pollution control should be paid by those whom society has determined it is fair to do so. Polluters are liable not only for the cost of pollution control to socially optimal levels, but they are also liable for payment for the use of the assimilative capacity of the environment, a scarce, renewable, but depletable resource. This is known as the “polluter pays principle” and is widely accepted by most countries internationally as a fair distribution of pollution control costs but this principle does not suggest who and how to control pollution

4) Economic Instruments as a Source of Revenue

Economic instruments raise large amounts of revenue that can be spent either on public goods that improve environmental quality or can be used to reduce distortionary taxes such as income taxes, which reduce the incentive for work, or sale taxes which distort consumption decisions.

2.2 Literature review

Literature review in this study is divided into three categories for air pollution which are EKC hypothesis, Time Series Analysis, and previous empirical studies and survey of Air pollution in Chiang Mai province.

2.2. Review of the EKC

There are sizable empirical studies on EKC hypothesis for foreign cases while there is only one case is found from thesis by Krirkchai Suntipongpiboon (2003). The results appear in various relationships. However, both rationally supportive and non-supportive explanations were described for EKC hypothesis, the review is summarized in table below.

Table 2.1: Literature review of EKC Hypothesis

Literatures	Data Selection	Conclusions
Krirkchai Suntipongpiboon (2003) (Topic: An analysis of economic growth and environment relationship in Thailand using environmental kuznets curve)	Annual data 1987-2000 (1) SO2, NOx and CO for brown agenda. (2) forest area for green agenda (3) mangrove forest area for blue agenda	(1) Result: (i) Brown agenda – EKC exists for SO_2 (Turning point of income 90,427 baht/head during 2003-2004) and CO (Turning point of income 65,117 baht/head during 1994-1995), but not for NO. (ii) Green agenda - EKC exists with turning point of income 71,729 baht/head during 1995-1996. (iii) Blue agenda – EKC does not occur. (2) The inverted U-shaped relationship indicates the success of environmental policies and measures of environmental protection together with public participation in using environmentally friendly technologies. (3) The positive slope (no turning point) suggests the needs for effective policies, measures and raising awareness and enhancing public participation through economic incentives and regulations.
Lan Xu (2003) (Topic: Environmental Kuznets Curve Hypothesis Revisited: With Approach of Growth Theory and Statistical Analysis)	131 countries 1986-1998	(1) Result: (i) Turning point for CO2, CO, and NOx are much higher and are relatively less detrimental, more globally oriented, and thus less concerned by the public opinion. (ii) SO2, PM, and VOC are more locally oriented result the lower turning point. (2) Peak of turning point may occur differently with various income level, depending on the scale of economy; the faster accumulating rate of the capital stock, the higher income level of turning point. (3) Stock pollutants level will be lower than flow level over the entire range of the income level due to the additional decaying factor in the pollution stock, no matter what the economy of scale is. (4) EKC relationship is more reasonable to describe the environmental path within an economy (horizontally) rather than cross-country environmental path (vertically). (5) EKC existence does not mean environmental improvement will come automatically, but on the contrary, policies actively seeking both environmental and economic gains.
Stern and Common (2000) (Topic: Is there an Environmental Kuznets Curve for Sulfur?)	73 countries (OECD and non-OECD subsamples) 1990-1959	(1) Integrated trends of fixed effects for OECD countries yields a lower estimated turning point than the world's dataset. (2) Global's estimated EKC turning point is farther than all countries's income levels. (3) The global emission-income relation is essentially monotonic. (4) Reduction in emission are time-related rather than income-related. (5) Sulfur case for a single global EKC model is a misspecification as well as an individual country EKC model.

Table 2.1: Literature review of EKC Hypothesis (Continued)

Literatures	**Data Selection**	**Conclusions**
Stern (2003) (Purpose: Following the development of EKC concept, reviewing articles, and discussing an alternative approach)		(1) Emission-income relationship is likely monotonic but the curve shift down over time. Particular innovation is likely to be adopted in high-income countries first with a short lag before it is adopted in the majority of poorer countries. (2) Structural factor on both the input and output sides play a role in modifying the gross scale effect through they are less influential on the whole than time related effects. (3) The income elasticity of emission is likely to be less than one - but not negative in wealthy countries. (4) In slower growing economies, emission-reducing technological change can overcome the scale effect of rising income per capita on income emission, while the effects of rising income overwhelmed the contribution of technological change in reducing emission in faster growing middle income economies.
Stern (2004) (Topic: Global sulfur emission from 1850 to 2000)	Sulfur emission by country for the period 1850-2000	Falling emissions in East Asia, particularly in China, partly as a result of explicit environmental policies.
Dinda, et al. (2000)	Re-examined the hypothesis of EKC using cross-country time series data on two air pollutants, i.e. SPM and SO_2.	Only the result from SO_2 supports EKC hypothesis with the turning point of $12,500 per capita GDP while SPM relation shows a U shaped. An upward turn represents a high level of material consumption where technology progress is available and able to ensure sustainability of such a high consumption level at steady deterioration of the environmental quality. This study explains on the existing EKC hypothesis in three economic variables which result the negative partial effect rather than per capita GDP were brought into the analysis. Firstly, the economy-level capital intensity which provides environmental-friendly technology and vice versa. Secondly, the sectoral composition of GDP, the more industrialized an economy is, the lower and flatter would be its pollution-per capita GDP curve. Finally, the growth rate of GDP, beyond a threshold level of income implies the capable economy to give more concern on pollutions.

Table 2.1: Literature review of EKC Hypothesis (Continued)

Dinda (2005)	Theoretical explanation for the Environmental Kuznets Curve in the framework of endogenous growth model.	The EKC exists dynamically in the off-steady state. Generally, less developed economies use their whole stock of capital for commodity production that generates pollution, which damages their existing environmental stocks. This model suggests that each economy should allocate one part of their capital for abatement activity. Environmental degradation continues at early stage because of insufficient investment for abatement activity, but in later stage, sufficient investment (viz., optimal allocation of capital) prevents further degradation of environmental quality. Thus, to restore environmental quality, a sufficient investment is needed that is possible only when economy accumulates enough capital stocks. The shift from insufficient to sufficient investment for upgrading environment is the basis for curve down the pollution level, and thus, correspondingly forms the inverted U-shaped relationship between pollution and economic growth. Optimal allocation of capital for abatement activity is the sufficient investment demand to curve down the pollution level.
Nahman and Antrobus (2005)	Surveyed literatures on EKC hypothesis	Some groups agree with the existence of EKC and believe that today's developing countries will be able to "tunnel through" the EKC and follow a much less environmentally damaging development path than today's developed countries. The literature review suggests that even if the EKC does exist, it does not imply that economic growth will bring an improvement in environmental quality per se, at best it implies that the levels of certain pollutants decline, most probably at the expense of other environmental problems. Although those pollutants that do decline are often counted from a public health perspective, pollutants that are counted from a global perspective, such as CO_2, continue to rise with per capita income. It is revealed that the very existence of EKC is questionable; the EKC may very well arise as a "methodology artifact". Alternatively, the EKC may be a "historical artifact" arising from the relocation of pollution-intensive industries from developed to developing countries. In this case, the EKC may describe a development path that is no longer available to today's developing countries.

Table 2.1: Literature review of EKC Hypothesis (Continued)

Takeda (2005) (Topic: Investigated the relationship between economic growth and carbon dioxide emissions)	- Six Annex I regions and eight goods including five different energy goods - 27 sectors and nine goods produce carbon emissions covering 100 years (1995-2095) for Japan Double Dividend Hypothesis	(1) Although economic growth raises per capita income, and therefore, emission regulations are strengthened in all regions, but emissions also increase significantly in all regions because of the responsiveness of regulations to income changes, which is inferred from the Kyoto Protocal-type regulations, is too weak to restrain emissions. (2) Carbon emissions are likely to increase throughout the world with further increase in economic growth implies EKC relationship is unlikely to apply to carbon emission. (3) Double Dividend Hypothesis: This hypothesis advises that emission regulations improve not only the environment (the first dividend) but also the efficiency of the tax system (the second dividend) for public benefits. Thus, the double dividend refers to the situation in which emission regulations yield the second dividend as well as the first dividend. The results show the possibility of the double dividend is fair low, even though the previous empirical studies in Europe and U.S. showed that the double dividend is not likely to occur in most situations. Researcher suggested to evaluate gross benefit from the abatement additionally as well as its gross cost.

Table 2.1: Literature review of EKC Hypothesis (Continued)

Panayotou (1997)	Explicit policy consideration into the income-environmental relationship and explored its potential as a policy tool, the role of economic growth rate, and population density	(1) The role of policies and institution: Policies (such as removal of distortionary subsidies and introduction of more secure property rights over resources and pollutions taxes or other efficient instruments to internalize externalities) and institutions can significantly reduce environmental degradation at low income levels and speed up improvements at higher income levels, thereby flattening the EKC and reducing the environmental price of economic growth. (2) The role of growth, policies, and population density: Firstly, significantly higher growth results in marginal higher EKC. Secondly, Better policies result in dramatically lower EKC. Lastly, significantly higher population density results in moderately higher EKC. (3) Decomposing the EKC: (3.1) SO_2 versus GDP, higher growth rates result in slower improvement in environmental quality as income rises, everything else being held constant. U shaped appears that may be from rapid economic growth causes less environmental expenditures and environmental regulations trail farther behind the faster economic growth. However, the effect is quite small, especially at low income levels. (3.2) SO_2 versus scale of economy, in contrast from (a), the effect of better policies/institutions on the income-induce environmental improvement is very large, this effect from the bigger scale of economy shows positive slope. (3.3) SO_2 versus GDP composition (industrial share) controlling for scale of economy, per capita GDP, and population density. Manufacturing tends to be more pollution-intensive than either agriculture or services, a positive relationship is expected to appear in J-curve. (3.4) SO_2 versus population density, controlling for scale of economy, industrial share GDP per capita. The Engle's law-type relationship between income and demand for environmental quality translates into an inverted-J curve.

2.2.2 Review of Time Series Analysis of Air Pollution

Most of time series studies of air pollution are the international studies, the literature review is summarized in the table below. The first three studies use the ARIMA modeling as a tool while the fourth one use the Receptor modeling which is from chemical engineering field.

Table 2.2: Literature review of Time Series Analysis of Air Pollution

Literatures	**Pollutants**	**Conclusion**
1 G. Saffarini and S Odat (2008) (Topic: Time Series Analysis of Air Pollution in Al-Hashimeya Town Zarqa, Jordan)	PM_{10}, TSP, CO, NO_x, SO_2, H_2S and Pb. in Jordan	Yearly air pollution data for the period 1992–2004 showed an overall decreasing trend in ambient air pollutants NO_2, CO, H_2S, NO and TSP. This is likely due to regulatory measures implemented by the government in the preceding 13 years. There was an increasing trend in PM_{10}, NO_x and Pb, whereas SO_2 did not change much.
2. Ujjwal Kumar • V. K. Jain (2009) (Topic: ARIMA forecasting of ambient air pollutants (O3, NO, NO2 and CO)	O3, NO, NO2 and CO (Daily mean ambient air pollutants from urban traffic site (ITO) of Delhi, India)	Forecasting performance of the selected ARMA(p,q)/ARIMA(p,d,q) models has been evaluated on the basis of MAPE (mean absolute percentage error), MAE (mean absolute error) and RMSE (root mean square error) indicators. Result is satisfactory and the suggested forecasting procedure can be effectively utilized for short term air quality forewarning purposes.
3. Anurag Kandya and Manju Mohan (2009) (Topic: Forecasting the urban air quality using various statistical techniques; 1.SES, 2.ARRSES, 3.HLM, 4.ARX, 5.ARIMA)	NO2, SO2, SPM and RSPM (Seven year daily data, 1998-2004, at ITO-Income Tax Office, Urban air quality over Delhi, India)	- No single modeling approach, which generates optimum results in terms of full range of performance indices considered. - ARIMA technique scores well over the other techniques. - Given the uncertainty and unavailability of most of the inputs of deterministic and advance statistical techniques, the methods adopted here have great potential for air pollution forecasting.

Table 2.2: Literature review of Time Series Analysis of Air Pollution (Continued)

4. Nguyen Thi Kim Oanh, Prapat Pongkiatkul, Nabin Upadhyay and Phillip P. Hopke (2009) (Topic: Designing ambient particulate matter monitoring program for source apportionment study by receptor modeling) – Chemical Engineering	PM 2.5 (fine) and PM10 (coarse) in Bangkok, Thailand	- The relationship between EC and BC (black carbon) varies with site and season suggesting the variation in the nature and processing of the emitted PM; the sampling time/flowrate would vary from site to site and from season to season. - The developed PM monitoring framework was implemented for the PM data collection in BMR of Thailand. The QA/QC chemical composition data set can be used in the receptor modeling to enhance our understanding of the contributing sources for better PM pollution abatement strategies.

2.2.3 Previous empirical studies and survey of air pollution in Chiang Mai province

Thaveesak (2007) reported the smoke situation in upper northern areas of Thailand where usually experience with the severe smoke problem, especially in March 2007 when the emission of PM_{10} was higher than the previous year crucially and higher than the ambient standard (not exceed than 120 $\mu g/m^3$) consequently. This pollution level is very unhealthy for sensitive people and environment. The highest levels of PM_{10} from 2004 – 2004 are summarized in the table below.

Table 2.3: PM_{10} levels

Province	Monitoring Stations	2004	2005	2006	2007
Chiang Mai	City Hall	Mar 27th. = 205	Mar 29th. = 157	Mar 20th. = 249	Mar 14th. = 304
	Yupparaj Wittayalai School	Mar 27th. = 275	Mar 29th. = 149	Mar 19th. = 237	Mar 14th. = 383
Lampang	Thammasat University	Mar 10th. = 176	Mar 10th. = 345	Mar 29th. = 247	Mar 5th. = 259
	Water Office-Mae Moh	n.a.	n.a.	n.a.	Mar 5th. = 219
Chiang Rai	Samakkhi Wittayakhom School	n.a.	n.a.	n.a.	Mar 15th. = 212
Mea Hong Son	Amphur Muang	n.a.	n.a.	n.a.	Mar 20th. = 340

Source: Pollution Control Department, Thailand

The researcher has observed the real situations and secondary data, interviewed the concerned local people from agriculture and entrepreneurs, and concluded the main causes of smoke problem during that period is from the topography in most of the northern areas of Thailand which are the valleys while there are the communities who live in watersheds among the surrounding valleys. This is the main obstacle for smoke to spread out. In addition, there are other three supporting reasons of smoke problem.

1) Forest fires: Most critical sites are from man-made.
2) Agricultural burnings: These are the traditional behaviors, such as burning for being a buffer zone, burning before cultivating (e.g. corn crops), brush burning, fumigation in handicraft industries, burning to get forest products which can be sold at high market price due to it's seasonal availability (e.g. Hed-Thob; a kind of mushroom that will grow under the burned bole of trees and the second burning for easily harvest – market price is about 100-300 baht per liter, Pak-Waan; a kind of vegetable that will available only northern area once a year during late of dry season and beginning of rainy season– market price is about 200-300 baht per kilogram).
3) Others: Such as vehicles. During the high season for tourist industry in November 2006–January 2007, there were more vehicles from transportation, pollutions from factories and construction, and particulate matters from roadsides.

However, the great smoke in upper northern areas of Thailand in March 2007 occurred terribly and more severe than the previous year due to these two major problems:

(i) Severe and more forest fires than previous year: Forest fires protection and control department reported the number of forest fires from October 2006 – April 2007 (7 months), there are 4,771 events with 54,580 rai of damaged areas in the north. These expanded 52.50 percent of events and 1.3 times of damaged areas from the previous fiscal year (October 2005–September 2006; 12 months). Furthermore, forest fires from neighbouring countries also effect to particles-trans-boundary to northern part of Thailand. The evidence shows 1,282 hotspots in Burma in March 8, 2007. (Data source: a cabinet council meeting on March 13, 2007)

(ii) Global warming: This results a higher global average temperature and a distortion of natural system causes the environment change, meteorological condition change. This effect to the drier condition at the beginning of year 2007, brushes from dried leaves and plants are good fuels cumulated for forest fires to be happened easily. Besides, the ending of winter season in 2007 is delayed causes the air pressure intercepts the particles and smoke to spread out.

Putnam (2009) studied the cause and effect of deliberate fire burning within the sub-district of On Nuea in Chiang Mai province during February-March 2009. 58 fires were recorded, the majority of which occurred within forests and a long roadsides and the open areas adjacent to them. Forest fires were mainly due to the collection of forest products; Hed Thob. Roadsides and open areas are also set alight for two main reasons a) to clear old vegetation since fire is cheap and fast, b) encourage the re-growth of certain grasses for cattle to graze on. The report sheds light on the livelihoods of those who still rely on fire as a mechanism for survival. A trek into a National Forest Reserve with a local farmer provides insight into what he burns and why, despite being an illegal act, he continues to do it. The study raises the role of the local authorities and the policies in order to get the best result by communities to focus and develop the local people to manage and prevent fire within their immediate vicinities.

In February 2009, a seminar was held at Chiang Mai University to discuss the ongoing problem of smog in the city. In attendance was Professor Phongthep Wiwatthanadej from Community Health–Faculty of Medicine, who stated that, due to constant exposure to seasonal smog, Chiang Mai residents face double the risk of lung cancer than people from other regions in Thailand.

Along with the peak of PM_{10} level comes a peak in hospital admissions. Putnam obtained the data from the Chiang Mai Public Health Department during February–April 2007 while the PM_{10} level stayed above the safe level for a total of 34 days. Public hospital admissions within the entire province for this period totaled 287,885. Where as during the same period in 2008, when PM_{10} level only breached the safe level for 6 days, admissions were almost 25 percent lower than 2007.