A SUSTAINABLE REGIONAL ECONOMIC GROWTH AND TRANSPORTATION MODEL

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abstract: Since the environment is widely affected, considerably by industrial production and partly by private consumption, it implies that the configuration of environmental problems depends largely on economic structure and economic growth rate. This conjecture may justify to use the economic growth theory as the starting point to deal with the sustainable development in a significant way. In this paper, we first show the formal mathematical structure of the regional economic growth model and, then refer to interrelation between the economic growth model and the conventional urban transportation planning models.

1. INTRODUCTION

Since the publication of the report by the World Commission on Environment Development in 1987, sustainability became a common sense as a political dimension for the global development, and has been considered almost the same important measure for economic growth as the gross national product (GNP). However, while the notion of " sustainability is widely accepted, its precise content has remained elusive (Goldin, I and Winters, A., 1995). Sustainable development is often defined as " path of progresses which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs." (Khalid, 1989). This and similar definitions of sustainable development which have been widely used are too complex to make tractable practical economic analyses at the present stage. Therefore, we adopt the more narrow definition here, following Golden and Winters (1995), in which sustainable development is referred to an economy in which future growth is not compromised by that of the present.

The characteristics and level of economic development strongly influence on the quality of environment. Since the environment is widely affected, considerably by industrial production and partly by private consumption, it implies that the configuration of environmental problems depends largely on economic structure and economic growth rate. For example, Grossman (1995) has provided interesting evidence on the correlation between *per capita* GDP and pollution. The main finding is that pollution follows an inverted U-shaped relationship with output; environmental quality deteriorates in the early stages in economic growth until a turning point is reached beyond which higher levels of *per capita* output are associated with improved measures of pollution. This might arise at least three main reasons: the structural transformation of economic activities from pollution intensive production to high-tech production with less intensive use of raw materials and natural resources; increasing demand for a cleaner and healthier environment as per capita incomes rise; the replacement of old capital equipment by new , and the replacement of older technologies by newer ones. These conjectures may justify to use the economic growth theory as the starting point to deal with the sustainable development in a significant way.

The regional multi-sector model described in the paper is a natural extension of the static input-output Leontief model to a dynamic case. As in the static case, the interaction among various industries in an economy is explicitly taken into account. A specific economic growth may be interpreted by the sum of demand as a current input , investment demand and final demand for certain goods, however, which is effected by pollution restrictions and the scarcity of imported raw materials. In that case, the dynamic input-output model along with the assumption of full employment of capital is not consistent with the basic claim for non-negative industrial output and capital stock vector. In order to avoid this inconsistency, we adopt Solow's linear dynamic optimization model (1959), and remove the assumptions of equilibrium and of full employment of output and capital. This implies that the demand condition is not determined in a decentralized way as the sum of each individual's desires but is rather determined by the central planning authority in such a fashion as to optimize a certain target. As for the objective function which should be optmized, there are several candidates such as utility , net social welfare and net national product so on , however, we adopt in this paper a simple function of total product to avoid nonliearity of the system.

A restrictive economic growth rate at each time period obtained from the sustainable economic growth model exactly influences on travel demands of regions because travel demands of regions are determined as a function of economic activities. In addition, the environmental conditions resulting from car traffic is dependent on to a large extent geographical configuration of economic activities and transportation infrastructure so that the emission of pollutants are strongly affected by land-use patterns, transportation network systems, traffic conditions of the time of day so on (Hayashi et. al., 1994; Miyamoto and Asard, 1995; Black, 1994). In order to gasp the local environmental condition and plan or evaluate effective transportation schemes, we need transportation models coordinated with the economic growth model (Oka and Miyagi, 1995).

In this paper, we first show the formal mathematical structure of the regional economic growth model and, then refer to interrelation between the economic growth model and the conventional urban transportation planning models.

2. ECONOMIC GROWTH AND ENVIRONMENTAL PROBLEMS

Environmental factors concerning with sustainability may be enormous and complex from its inherent nature, however, this paper essentially pays attention to more restricted factors. Those are pollutant emission and raw materials; the pollution exerted by the emission of poisonous and waste materials and energy release has the increasing effects on the ecological systems including mankind; secondly, the ever-increasing exploitation of industrial raw materials ,which advances in a worldwide scale with a global industrialization, brings about the scarcity of such resources.

The characteristics and level of economic development strongly influence on the quality of environment. Since the environment is widely affected, considerably by industrial production and partly by private consumption, it implies that the configuration of environmental problems depends largely on economic structure and economic growth rate. The remarkable regional differences in the emission of substances affecting the environment correspond to the high local differences in the concentration of industrial and consumptive activities. The regional capacity of pollutant absorption may also be different according to geographical and meteorological conditions.

Despite of the local differences in the emission of substances and the hardly clarified interdependence between the cause and the result of pollutants, we assume that maximum permissible pollution rates are established in each region and that the casual interdependence has been clarified in definitive pollutants and for energy releases.

If such region-specific maximum rates of emission are available and have a legal bearing, then there will be two important consequences to the production structure, which in turn affect the regional economic development: firstly, increased costs are required to avoid the emission of pollutants, in particular by installing the appropriate protective facilities such as filtration or purification plants, and secondly, restrictions have to be levied on those production processes where the emission of pollutants exceeds the standards despite the existence of protective facilities.

In order to gasp the effects of restrictions of pollutant emission and water- and energy releases on the regional economic development, we need the aid of a regional multi-sector model. Furthermore, technologically advanced economies may be largely dependent on the availability or supplies of limited raw material resources. Thus, the model should take into account the consequences resulting from the scarcity of certain raw materials which may bring about drastic price increases.

3. PRODUCTION MODEL

Let x(t) is an $m \times n$-vector whose element is $x^s_j(t)$, the output of sector j in region s in period t in which m and n represent the number of region and sector in question, respectively. We let T be the final period considered. Let $A(t)=[a_{ij}(t)]$ be an $n \times n$ matrix of input-output in period t, where $a_{ij}(t)$ denotes the amount of the i-th good necessary to produce one unit of the j-th good in period t. Let $B(t)=[b_{ij}(t)]$ be an $n \times n$ matrix, where $b_{ij}(t)$ denotes the quantity of the i-th good invested by the j-th sector in order to increase the output of that sector by one unit. The realized techical progress for primary inputs are reflected in the techical progress parameters λ with a suffix denoting a related primary input. Then the total production system in our model is described as follows:

$$x^s_{ij}(t) = a^s_{ij}(t)\, x^s_j(t) = a^s_{ij}(0)\, {}_a\lambda^s_{ij}(t)\, x^s_j(t) \quad (1)$$

$$K^s_{ij}(t) \geq b^s_{ij}(t)\, x^s_j(t) = b^s_{ij}(0)\, {}_k\lambda^s_{ij}(t)\, x^s_j(t) \quad (2)$$

$$W^s_j(t) \geq w^s_j(t)\, x^s_j(t) = w^s_j(0)\, {}_w\lambda^s_{ij}(t)\, x^s_j(t) \quad (3)$$

$$If^s_j(t) \geq \delta^s_j x^s_j(t) \quad (4)$$

$$R^s_{gj}(t) \geq r^s_{gj}(t)\, x^s_j(t) = r^s_{gj}(0)\, {}_r\lambda^s_{gj}(t)\, x^s_j(t) \quad (5)$$

$x^s_{ij}(t)$: current inputs in sector j of region s delivered by sector i in period t,
$W^s_j(t)$: labor input of sector j in region s in period t,
$K^s_{ij}(t)$: capital stock of type i investment goods, in sector j in region s in period t,
$x^s_j(t)$: output of sector j in region s in period t,
$a^s_{ij}(0)$: current input coefficient,
$b^s_{ij}(0)$: current capital coefficient,
$w^s_j(0)$: current labor coefficient,

$r^s_g(0)$: coefficient of raw material inputs,

$If^s_j(t)$: input of productively effective regional infrastructure in sector j of region s in period t,

δ^s_j : sector-specific coefficient of infrastructural inputs,

${}_a\lambda^s_{ij}(t)$: rate of technological change in input in period t,

${}_w\lambda^s_{ij}(t)$: rate of technological chages in labor in period t,

${}_b\lambda^s_{ij}(t)$: rate of technological change in capital in period t.

The dimension of each suffix attached to each variable is as follows:

$$s = 1, \cdots, m \quad ; \quad i, j = 1, \cdots, n$$
$$t = 1, \cdots, T \quad ; \quad g = 1, \cdots, h$$

In eqs. (2) to (5), quantities appeared in the l.h.s. represent supplies and at least meet the demands given by equations in the r.h.s.

The constancy of the technological progress parameters $\lambda^s_{ij}(t)$ implies that there is no technological progress. When we rewrite it as a function of capital stocks, $\lambda^s_{ij}(K_{ij}(t))$, these parameters can represent the scale economy and the agglomaration economy as well by selecting appropriate functional forms. However, including these economies makes the model nonlinear and computaion algorithm complex. Therefore we adopt more convienient form of functions so that $\lambda^s_{ij}(t)=[1+\lambda^s_{ij}]^t$ or $[1-\lambda^s_{ij}]^t$ are used for rates of technological changes of primary inputs of which signs and parameter values are approximated by using past data.

It is in order to describe the conditions on $\{K^s_{ij}\}$, $\{W^s_j\}$, $\{If^s_j\}$, $\{R^s_{gj}\}$. Hereafter, we describe exogenous variables given from outside of the system by letters with upper bar.

Capital stock supplied is determined depending on the net invesment for each period, ($I^s_{ij}(t)$):

$$K^s_{ij}(t) = \sum_{t=1}^{T} I^s_{ij}(t) + K^s_{ij}(0) \tag{6}$$

As in the usual Harrod-Domar model, $I_{ij}(t)$ is derived from the acceleration equation in the sense that

$$I_{ij}(t) = \beta_{ij}\left[x_j(t) - x_j(t-1)\right] + \bar{I}_{ij} \tag{7}$$

where β_{ij} stands for the accelerator coefficient and $\bar{I}_{ij}$ basic investment demand or replacement of worn-out capital goods (depreciation).

It is assumed that the sector-specific labor supply in each region cahnges depending on intra-regional and/or intra-sectral changing rate, $\mu^s_j(t)$, and inter-regional and inter-sectoral migration, $W^{rs}_{ij}(t)$, as well.

$$W_j^s(t) = w_j^s(0)\,\mu_j^s(t) + \sum_{\varepsilon=1}^{t}\sum_{r=1}^{m}\sum_{i=1}^{n} W_{ij}^{rs}(\varepsilon) - \sum_{\substack{\varepsilon=1}}^{t}\sum_{\substack{r=1\\ r\neq s}}^{m}\sum_{\substack{i=1\\ i\neq j}}^{n} W_{ji}^{sr}(\varepsilon)$$

$$= \overline{w}_j^s(t) + \sum_{\varepsilon=1}^{t} \overline{W}_j^s(t) \qquad (8)$$

where we assume that net values of inter-regional and inter-sectorial migration, $W_{ij}^{rs}(t)$, are exdogeneouslly given as outputs of an appropriate migration model which is not reffered to in this paper. The region-specific infrastructure expands from one period to another, depending upon the public investment in regions, $G_j^s(t)$.

$$If_j^s(t) = If_j^s(0) + \sum_{\varepsilon=1}^{t} \eta^s(\varepsilon) \sum_{j=1}^{n} \kappa_j^s(t)\, G_j^s(0)$$

$$= \overline{If}_j^s(t) \qquad (9)$$

The consumption of raw materials of type g on the nation level is confronted with a limited raw-material potential and will diminish or increase from one economic period to another at a rate of $\xi_g(t)$.

$$R_g(t) = \overline{R}_g(0)\,\xi_g(t)$$

$$= \overline{R}_g(t) \qquad (10)$$

Combined with the input functions (1) to (5), equations (6) to (9) result in the following inequality systems which determine the sectoral production capacities per period and per region:

i) Capital constraints:

$$\left(b_{ij}^s(t) - \beta_{ij}^s\right) x_j^s(t)$$

$$\leq K_{ij}^s(0) - \beta_{ij}^s x_j(0) + t\, \overline{I}_{ij}^s = \overline{K}_{ij}^s(t) \qquad (11)$$

for all i , j , s , t

ii) Labor constraints:

$$W_j^s(t)\, x_j^s(t) \leq \overline{w}_j^s(t) + \overline{W}_j^s(t) = \overline{W}_j^s(t) \qquad (12)$$

for all j , s , t

iii) Raw-material constraints:

$$\sum_{j=1}^{n}\sum_{s=1}^{m} r_{gj}(t)\, x_j^s(t) \le \overline{R}_g(t) \tag{13}$$

for all s , j , t

iv) Infrastructure constraints:

$$\sum_{j=1}^{n} \delta_j^s\, x_j^s(t) \le \overline{If}^{\,s}(t) \tag{14}$$

for all s , t

v) Causual indeterminancy constraints:

$$x_j^s(t) - x_j^s(t-1) \ge 0$$
$$x_j^s(t) \ge 0 \tag{15}$$

for all s , j , t

where all terms which are multiplied by $x_j^s(t)$ in the l.h.s. are constant.

4. DEMAND AND TRADE MODELS

Demands for goods and services consists of input demands for intermediate goods of sector j to sector i, $x_{ij}^s(t)$, household demand for consumption goods, $c_i^s(t)$, demands for investments , $I_{ij}^s(t)$, government expenditure, $G_i^s(t)$ and demands generated from the balance of export and import, $H_i^s(t)$. Then the total demand for the i-th good (or sector) in period t is

$$d_i^s(t) = \sum_{j=1}^{n} x_{ij}^s(t) + \sum_{j=1}^{n} I_{ij}^s(t) + c_i^s(t) + G_i^s(t) + H_i^s(t) \tag{16}$$

where $\Delta K^s_{ij}(t) = K^s_{ij}(t) - K^s_{ij}(t-1)$. The household demand for consumption goods of type i depends upon disposable incomes, Y^s, taking account of the autonomous component of consumption (or a basic consumption) $z^s{}_i$, independent of income and can be described by the consumption function as is usually used in macro economic models:

$$c_i^s(t) = c_i\, Y^s(t) + \varphi^s(t)\, z_i^s(0) \tag{17}$$

where c_i^s is the marginal propensity to consume and $\varphi^s(t)$ the rate of change which takes into consideration the population development retraceable to natural changes and migration.

The disposable income $Y^s(t)$ results from the regional gross value of production , subtracting the portion of real costs for current inputs, the costs of raw materials, the costs for emission prevention, and taking account of the average rates of direct and indirect taxes:

$$Y^s(t) = D^s + I^s + \sum_{j=1}^{n} \left[1 - \sum_{i=1}^{n} a_{ij}(t) - \sum_{i=1}^{n} r^s_{gj}(t) - es^s_j \right] x^s_j(t) \tag{18}$$

D^s denotes the equal lump sum transfer if it is positive and the equal lum sum tax if it is negative. I^s represents the unequal lump sum transfer if it is positive and the unequal lump sum tax if it is negative. es^s_j is anti-emission facility costs of sector j in region s, which will be reffered in the next section. Government expenditure increases with production-specific, autonomously given rate:

$$G^s_i(t) = (1 + u^s_i)^t \; G^s_i(0) \tag{19}$$

Foreign trade reflects the net values of regional sector-specific export and import demands. The net figure of the trade-balance of sector i in region s is trend-extrapolated on the basis of past rates:

$$\begin{aligned} H^s_i(t) &= Ex^s_i(t) - IM^s_i(t) \\ &= (1 \pm v^s_i)^t \; H^s_i(0) \end{aligned} \tag{20}$$

We adopt the Chenery- Moses type of trade model . Let t^{rs}_i be trade coefficient. Then the total supply of sector i in region s from all other regions is given as:

$$x^s_i = \sum_{r=1}^{m} t^{rs}_i x^r_i(t) \tag{21}$$

The total supply must exceed the total demand:

$$x^s_i \geq d^s_i(t) \tag{22}$$

5. ENVIRONMENTAL MODEL

During the production process, a variety of undesirable environmental pollutants is generated aside from the desired output $X_n(t)$, and / or energy in the form of waste heat or noise is emitted. These emissions $E^r_{fi}(t)$ are assumed to be generated in proportion with the factual production volume. Thus we have the following emission functions:

$$E^r_{fi}(t) = e^r_{fi} x^r_i(t) \tag{23}$$

where e^r_{fi} denots the emission pollutant generated per unit output in sector i , being reffered to emission coefficient. Some examples of emission coefficients are given in Clarke and Winters (1995). Eq. (23) has three main implications in it when we quote from Grossman (1995). First, *all else equal*, an increase in output means an equiproportionate increase in pollution. But this effect may be offset by two others. Emissions may fall if the shares in total output of relatively cleaner economic activities rise over time. Finally, if technological progress, market-induced substitution, or government regulation cause less-polluting technologies to replace dirtier ones, then the rate of emissions may fall over time. The first statement is straightforward from eq. (23), however, to make the second and third points clear we need to explain about additional constraints: environment capacity constraints. Before proceeding it, we first address emissions of environmental pollutants which may occur in private and public consumption , in particular in the transport sector . Demand for fuel and gasoline may represent the main cause of this type of pollution so that it appears reasonable to assume that pollutant emissions of the consumption sector change in proportion to a total mileage of automobile, $E^r_c(t)$, which is exogeneouly given for each period.

We assume that the environmental standards $\hat{E}^r_{f*}$ are given which represent the legal bound for the maximum permissible emission rates for each region. The environmental standards may result in the necessity of cut down on pollutant-generating production in certain regions, or to limit the growth of such production. However, if the protecting facilities in such production plants would not provide an adequate reduction of emissions with resonable costs, the environmental constraints must be applicable to the non-reducible types of emission, $f = f^*$:

$$\hat{E}^r_{f*} \geq \sum_{i=1}^{n} e^r_{f*i} x^r_i(t) + E^r_c(t) \qquad (24)$$

As for other types of emissions, $f \neq f^*$, it is assumed that those are adequately contralable with affordable costs. Anti-emission facilities within production sectors involved, which will be installed to avoid pollution rates exceeding the region-specific maximum permissible values, result in increasing resource requirements necessary to construct such facilities. Let $IE^s_{fj}(t)$ be the demand of sector j in region s for such facilities from sector i and assume that such demand is approximately proportional to the output of sector j in region s:

$$IE^s_{fj}(t) = Q^s_{ij} x^s_j(t) \qquad (25)$$

where Q^s_{ij} represents the environmental incident coefficient denoting net investment demand of anti-emission facilities from sector i for pollutant emission generated per unit production of sector j. This invesment demand forms capital stock for each period together with other invesment demand represented by eq. (7). The basic idea for such a environmental related investment demand was proposed by Rembold (1975). He also takes account of the costs for anti-emission facilities in his economic growth model: The real production costs in sector j in region s, $EC^s_j(t)$, will increase by the costs extended for anti-emission facilitie and occupies a certain rate of output. This assumption can be described as:

$$\frac{EC^s_j(t)}{x^s_j(t)} = es^s_j \qquad (26)$$

In order to reduce these additional production costs and to avoid the reduction of GDP, the share in GDP of relative cleaner economic activities must rise and technological innovation must be progressive over time.

6. SUSTAINABLE ECONOMIC GROWTH MODEL

If the relative configuration of the initial outputs (or the initial stock of goods) does not coincide with that of any possible balanced growth path of the economy, then the growth path may ultimately reach a situation at which the output (and the stock) of at least one good becomes negative. If this happens, then we say that we have causal indeterminacy

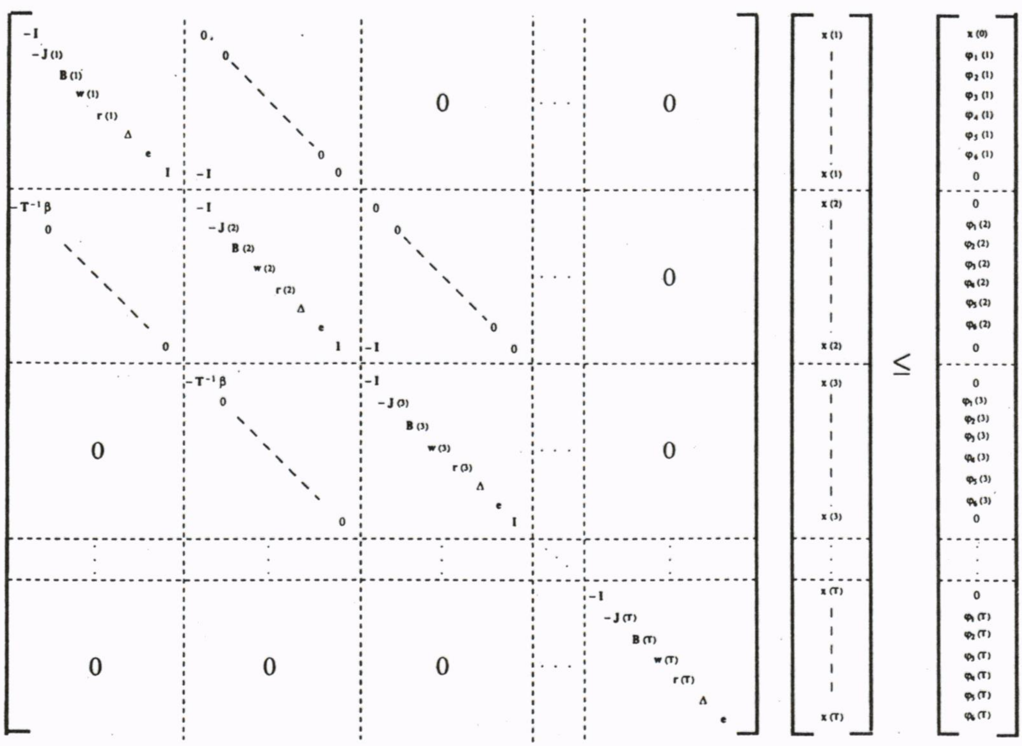
(Takayama, 1985). In other words, such a economy is not sustainable. In order to make the economy sustainable or to guarantee the existence of nonnegative output and stock vector for all time periods, we need to introduce inequalities in the system as is already demonstrated in the previous sections. Let us pay attention to eqs. (1) and (2) for a while. Inequalities on capital stocks (2) imply that we allow the possibility that there exists excess capacity and that we can no longer define a unique output path x(t). The relations (1) and (2) define only a feasible path of an output vector and a stock vector, x(t) and K(t). How to choose the output path and the stock path in the economy actually depends on the demand conditions. Solow (1959) proposed to consider this demand condition as a solution of an optimization model.

As a target, we choose a weighted sum of the terminal outputs:

$$\max\ Z = \sum_{j=1}^{n}\sum_{s=1}^{m} \alpha_j^s\, x_j^s\,(T) \qquad (28)$$

where αsj is equal to 1 for t=T and 0 for otherwise.

Since the values of α are given, our problem is a simple linear programming problem subject to eqs. (11) to (15) and eqs. (18) and (27). The constraints are written out as follows:



Since the constraints can be simply written as $\overline{A}X \leq \overline{b}$ where $\overline{A}$ is block-triangular matrix, computational procedures for extensive structures like modified Simplex methods are applicable. The linear programming problem is composed of $(n \times m \times T)$ unknown variables, $\{x_j^s(t)\}$, and $(2 \times n \times m \times T - n \times m)$ constraints for **I**, $(n \times m \times T)$ constrains for **J**, $(n^2 \times m \times T)$ constraints for **B**, $(h \times T)$ constraints for **r**, $(n \times m)$ constraints for **Δ**, $(k \times m \times T)$ constraints for **e**. The total number of constraints is thus $\left[m\{T(n^2+4n+k)-n\}+hT\right]$. In order to obtain the price system corresponding to the above problem, we have to solve the dual of this linear programming problem. Thus we can investigate on how the price system can be influenced by tightning or relaxing legal bounds for the maximum permissible emission rates for each region.

7. ENVIRONMENTAL ANALYSIS OF TRANSPORTATION SYSTEM

Environmental analysis of transportation system is not a new topic and has been part of the project development process in transportation since the 1960's, when legislation such as the 1962 Federal Aid Highway Act in U.S. became common. So we do not intend to refer this problem deeply here, but only discuss the analytical part of it in conjecture with the economic growth model developed in the previous sections. Environmental analysis in transportation system can be categorized into two types: a microscale analysis and a mesoscale analysis.

Mesoscale analysis usually is a very general planning procedure, and it provides the local planning authority with data the total amount of emissions being emitted so that planners can obtain useful information on the emission levels in the area comparable with alternatives and the effectiveness of transportation policies. In mesoscale analysis, the total pollutant on a regional basis is estimated using emission factors which are based on rates of activities. When emission factors corresponding the industry classification standards are available, the economic growth model can directly provide the estimated pollutant of each area and the aerial concentration at each period useful for planning purposes.

The remarkable characteristic of the emission of substances can be seen in the high local differences in pollutant-concentration rate with geographical and meteorological conditions. In addition, an important aspect of environmental impacts is their typically dynamic nature. Although a mesoscale analysis is useful for planners, emission inventories obtained from the direct outputs of the economic growth model are not directly comparable to the environmental standards because the data are in the form of total amount of each regulated pollutant. Therefore, we need more sophisticated procedures to examine the local environmental conditions, especially those caused by transportation system. Even if the output levels of the economy is contained to keep the maximum allowable limits of pollutant on a regional base, it can happen to violate the environmental standards at a local level. In order to proceed to a microscale analysis, the economic growth model should be linked with the conventional travel demand models and environmental impact models such as a dispersion model. During microscale analysis worst case scenarios are often used for analysis because if the environmental standards are not violated in this case, then there is no worry of the standards being violated in the typical or real-world case.

Our scheme of a microscale of analysis may be executed as follows: the computational outputs at each period from the economic growth model are used as the input data for prediction of trip generation and trip attraction of each traffic zone where appropriate break-down procedures should be used to convert regional data to more smaller size of zonal data, which is followed by the usual sequential travel demand forecasting procedure. The local environmental conditions can be examined through the final step of the sequential method, in which dynamic assignment procedure, in associated with some environmental impact models, should be applied to evaluate local environmental conditions in areas along transportation network facilities. The dynamic assignment procedure applicable to real size of transportation networks was developed by Miyagi and Makimura (1990) and applied to Gifu city to assess the effects of flexible working-hour policy on the reduction of road traffic congestion , emission pollutant and energy consumption (Miyagi, Asai and Oka, 1995).

8. CONCLUDING REMARKS

The proposed model in this paper is largely dependent on the traditional dynamic linear growth model and is not novel in this respect. It must be inevitable to take into account of scale economies to figure out the acutual economic dynamics whether we try to construct an economic growth model or an environmental model because perhaps the most fundamental reason for the existence of cities stems from economies of scale in production and consumption. However, to bring scale economies into economic growth models make the models nonlinear and complex. In particular it seems almost impossible at the present stage to solve a large scale of nonlinear dynamic model with inequality constraints .

Many regression models with economic activities as explanation variables for estimating emission pollutants have been developed so far, however , it should be noted that a statistical-empirical oriented model is certainly convenient to gasp a total amount of emission pollutants of a region at macro level, but, those are incapable to reflect changes in economical systems and to evaluate various economic or environmental policies. While economic growth models have some drawbacks as mentioned above, it can be a rational approach for examining the interaction of economic policies, growth and the environment: in particular for the question: is growth sustainable ?

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