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Environment and Regional Growth*

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Public goods have long been recognized as an instrument of regional planning and as a means to promote regional development. An array of literature has dwelled on the effects mainly of business oriented infrastructure outlays on regional output and interregional factor mobility[1]. Public bads, however, have not yet been considered in the context of regional growth theory.

In the following a simple two-region growth model is discussed including one such public bad, namely pollutants.

1. The Model

Assume a linear-homogenous production function with capital (K) and labor (L).

$$X = f(K, L) \text{ with } f_K', f_L' > 0 \text{ and } f_K'', f_L'' < 0 \tag{1}$$

For the change in output we have

$$dX - f_K' \, dK - f_L' \, dL = 0 \tag{1'}$$

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[1] On public goods and economic growth compare. E. Drandrakis and E. Mighas: Public Investment in Infrastructure and Optimal Economic Growth, Zeitschrift für Nationalökonomie *31* (1971; Suppl. 1), pp. 167—184. On public goods in regional growth theory: N. Sakashita: Regional Allocation of Public Investment, in: Papers and Proceedings of the Regional Science Association *19* (1967), pp. 161—182; H. Siebert: Infrastruktur und regionales Wachstum, Jahrbücher für Nationalökonomie und Statistik Bd. 186 (1971), pp. 185—202. On public bads in general growth theory: R. C. d'Arge and K. C. Kogiku: Economic Growth and the Environment, Review of Economic Studies, Vol. XL (1973), pp. 61—77.

with f_K' and f_L' denoting the partial derivatives with respect to capital and labor.

Assume output generates a single pollutant[2] S

$$S = h\,(X) \text{ with } h' > 0 \text{ and } h'' > 0 \tag{2}$$

and

$$dS = h'\,dX \tag{2'}$$

h' indicating the marginal tendency to pollute of the production activity.

The pollutant is a by-product of production. Assuming that the level of pollution increases progressively may not be realistic for the pollution generation function of a single firm. However, if the h-function is interpreted on a macroeconomic scale for a whole region, a progressively increasing level of pollution as a consequence of economic activity may be rather realistic, especially since the assimilative capacity of the regional environment is limited.

The regional labor supply is sensitive to the relative wage rate $w = W/\overline{W}$ with $\overline{W}$ denoting the variable in the second region. The regional labor supply is also sensitive to the relative level of pollution in the region, being measured by the relation of the level of pollution in both regions $s = S/\overline{S}$. From

$$L = g\,(w, s) \text{ with } g_w' = \frac{\delta g}{\delta w} = \frac{\delta g}{\delta\,(W/\overline{W})} > 0$$
$$\text{and } g_s' = \frac{\delta g}{\delta s} = \frac{\delta g}{\delta\,(S/\overline{S})} < 0 \tag{3}$$

and setting the initial wage rates and initial pollution levels equal to 1, we have

$$dL - g_w'\,dW + g_w'\,d\overline{W} - g_s'\,dS + g_s'\,d\overline{S} = 0 \tag{3'}$$

Assuming profit maximization and assuming that a pollution control board levies a charge z per unit of pollutant, maximum profit[3] is

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[2] Compare B. A. Forster: A Note on Economic Growth and Environmental Quality. Swedish Journal of Economics 74 (1972), pp. 281—285.

[3] This follows from the definition of profits as

$$G = pX\,(K, L) - rK - wL - zS\,[X\,(K, L)].$$

The price of the commodity is treated as a constant for the firm. Also the effluent charge is a parameter.

reached when

$$W = f_L' \, (1 - zh') \tag{4}$$

with the initial price being set to 1. The change in the wage rate is given by

$$dW - [f_L'' \, (1 - zh') - zf_L'^2 \, h''] \, dL = 0 \tag{4'}$$

or for simplicity

$$dW + udL = 0 \tag{4''}$$

The regional supply of capital is not influenced by the level of pollution. It only depends upon the relative profit rate $r = R/\bar{R}$,

$$K = k\,(r) \text{ with } k' = \frac{\delta K}{\delta r} = \frac{\delta K}{\delta\,(R/\bar{R})} > 0 \tag{5}$$

and

$$dK - k' \, dR + k' \, d\bar{R} = 0 \tag{5'}$$

assuming that R, $\bar{R}$ are set equal to 1 initially.

The profit rate is given by

$$R = f_K' \, (1 - zh') \tag{6}$$

and its change by

$$dR - [f_K'' \, (1 - zh') - zf_K'^2 h''] \, dK = 0 \tag{6'}$$

or for simplicity

$$dR + qdK = 0 \tag{6''}$$

Assume that for a given period the supply of capital and labor in the two-region system is fixed, so that

$$d\bar{K} = -dK \tag{7}$$

and

$$d\bar{L} = -dL \tag{8}$$

but that some autonomous increase in capital ΔK and/or labor ΔL may occur in region I to start a development process there.

Relations (1')—(6') describe the system of region I. A similar system of equations can be developed for the second region with the variables of the second region being characterized by a bar. Becuase of (7) and (8) (5') and (6') also relate to region II. Therefore only four new equations have to be introduced to close the system.

The system is shown in matrix form in Eq. (9). Derivatives are regarded as constants for the equilibrium solution.

$$\begin{bmatrix} 1 & 0 & -h' & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -\bar{h}' & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & -f_L' & -f_K' & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & \bar{f}_L' & \bar{f}_K' & 0 & 0 & 0 & 0 \\ -g_s' & g_s' & 0 & 0 & 1 & 0 & -g_w' & g_w' & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -k' & k' \\ 0 & 0 & 0 & 0 & u & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & v & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & q & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & t & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} dS \\ d\bar{S} \\ dX \\ d\bar{X} \\ dL \\ dK \\ dW \\ d\bar{W} \\ dR \\ d\bar{R} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \Delta L \\ \Delta K \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad (9)$$

2. Solutions

The model answers the question how the different variables of the two-region-system are affected if development takes place in region I being initiated by an increase of capital and/or labor. Labelling the matrix of coefficients A, the variables x and the absolute elements a, we have from

$$Ax = a \text{ or as a solution } x = A^{-1}a \qquad (9')$$

Solving for specific variables we obtain for the change of output in region I as a consequence of an autonomous change in capital

$$dX/dK = D_1/D \qquad (10)$$

with

$$D = [g_w' (v-u) - 1]\, [k' (t-q) - 1] - g_s' [k' (q-t) + 1]\, [\bar{f}_L' \bar{h}' + f_L' h'] \qquad (10')$$

and

$$D_1 = f_K' - f_L' k' (q-t) - g_s' \bar{h}' [f_K' g_w' (u-v) + \bar{f}_L' f_K' - f_L' \bar{f}_K'] \qquad (10'')$$

For a given increase in the capital supply, growth in region I will depend on the marginal productivities of capital and labour, on the marginal tendencies to pollute, on the second derivatives of both the production and pollution functions, all parameters relating to both regions. Finally the increase in regional output will be affected by the mobility of capital and labor, for the latter both with respect to relative regional factor rewards and relative regional differences in the level of pollution.

The discussion whether D, $D_1 \lessgtr 0$ yields the following: $v = \bar{f}_L''\ (1-z\bar{h}') - z\bar{f}_L'^2\ \bar{h}'' < 0$ since $f_L'' < 0$, $\bar{h}'$, $\bar{f}'$, $\bar{h}'' > 0$ and $(1-z\bar{h}') > 0$ from (4), unless the wage $W = 0$. $-u < 0$ for the same reasons. Also $q > 0$, and $t = \bar{f}_K''\ (1-z\bar{h}') - z\,\bar{f}_K'^2\ \bar{h}'' < 0$. g_w', $k' > 0$ and $g'_s < 0$. Since both brackets of the first term of D are negative, the first term is positive. The second term of D is also positive; consequently $D > 0$.

Assume the capital mobility is zero, so $k' = 0$. Then D_1 is positive if as a sufficient condition for identical marginal productivities of labor $f_K' > \bar{f}_K'$, i. e. if region I has a greater marginal productivity of capital. Then $dX > 0$, that is output in region I will rise.

Assume, however, $k' > 0$. Then the necessary and sufficient condition for an increase of output in region I is given by

$$\frac{f_K'}{f_L'} \{1 - g_s'\bar{h}'\,[g_w'\,(u-v) + \bar{f}_L']\} > k'\,(q-t) - g_s'\,\bar{h}'\,\bar{f}_K' \qquad (10''')$$

This condition shows that the potential increase in output may be negatively affected by the two terms on the right side of Eq. (10'''). The first term indicates the effect of capital mobility. The second term which is positive since $q' < 0$, denotes labor mobility with respect to pollution levels. Thus the potential increase in the output of region I is partially reduced by capital mobility and environmental quality as a determinant of labor mobility.

Solving for dL it can be easily seen that an autonomous change in capital may lead to an outflow of labor from region I, after adoptions have taken place in the model. We obtain

$$dL/\Delta K = D_3/D \qquad (11)$$

with

$$D_3 = g_s'\,(h'f_K' + \bar{h}'\bar{f}_K') \qquad (11')$$

Since $g_s' < 0$, there is an outflow of labor from region I if there is an autonomous increase in labor, provided that $|g_s'| > 0$, i. e. that labor is sensitive to pollution.

For the change in pollutants in region I as a consequence of an autonomous increase in labor and capital we obtain

$$dS = \frac{D_2 \Delta L + D_3 \Delta K}{D}$$

with

$$D_2 = h'f_L'\,[1 + k'\,(r-t)]$$

and

$$D_3 = h'\,\{f_K'\,[1 + g_w'\,(u-v)] - g_s'\bar{h}'\,(\bar{f}_L'f_K' - f_L'\bar{f}_K')\}$$

Pollutants increase in region I with an autonomous change in the labor force and also with an autonomous positive change in capital, if as a sufficient condition $f_K' > \bar{f}_K'$ given identical marginal productivities of labor. Thus an increase in the level of pollutants has the same sufficient condition as an increase of output.

Please observe that in this simple model the autonomous increase of both factors takes place in region I and the model analyzes only those effects that occur after this increase has taken place and has affected the other variables like output and pollution.

The model shows the well-known conflict between economic growth and environmental quality, indicating that with an increase in output environmental quality declines. In a regional setting where the interregional migration of labour depends on the relative level of pollution the system has some built in mechanism of adjustment. This mechanism makes for a smaller increase or even a decrease in regional output if the region has a high level of pollution. By reducing the potential increase in output via labor mobility, also a potential increase in environmental disruption will be partly prevented.

3. Possible Extensions

Several extensions of the model are conceivable. Thus a similar decelerating effect on regional growth could be obtained by extending the model and introducing as an additional variable the marginal damage caused by one unit of pollutant. Assume a damage function $D = d(S)$ with $d' > 0$ and $d'' > 0$ indicating a progressive increase in damages with an increase in pollutants[4]. Since the reason for such a function would be the limited assimilative capacity of the environment and since we used the same rationale for the form of the pollution generation function, the h-function may now be changed into a linear concept. Assume an effluent charge z is levied according to the marginal damage, so that $z = d'$[5]. Now a very powerful slowing down mechanism for regional development is introduced. Not only will g_s' reduce increases in regional output if the volume of pollutants rises. With an increasing level of pollution, z will rise and consequently both regional wage and profit rates will decline. This will make for an

[4] On damage functions compare C. S. Russell and W. O. Spofford, Jr.: A Quantitative Framework for Residuals Management Decisions, in: A. V. Kneese and B. T. Bower (eds): Environmental Quality Analysis. Theory and Method in Social Sciences, Baltimore 1972, 115—178.

[5] On effluent charges: A. V. Kneese and B. T. Bower: Managing Water Quality: Economics, Technology and Institutions, Baltimore 1968.

outflow (or a smaller inflow) of both factors of production, conceivably bringing regional development to an end and switching it over to less developed areas.

Another possible extension is the consideration of interregional external diseconomies. Assume the highly developed region I exports pollutants to the less developed area via such environmental media as water ways and the atmosphere. This effect could formally be expressed with a diffusion function[6]. If an environmental agency can levy an effluent charge for these spillovers, another braking effect on regional growth will occur.

Possible other extensions of the model are to allow for more than one pollutant which implies to introduce more than one pollution generation function for each region. Also the assimilative capacity of the regional environment could be introduced as a limitation for regional development. Finally, capital mobility including entrepreneurial location decisions also may be related to environmental quality.

The conclusion is that the environment is an important factor of regional development that has not yet been taken into consideration by regional growth theory. Consequently, regional growth theory especially the theory of regional growth poles[7] and national development via regional big pushs will have to completely rewritten to account for this determinant of regional growth. Among other things, the three discussed decelerating effects via sensitivity of labor to environmental quality, via an effluent charge linked to marginal damage and its influence on regional factor rewards and regional output and via charges for interregional technological spillovers through media of the environment will have to be included in revised regional growth models.

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[6] On diffusion functions W. O. Spofford, R. S. Russell, and R. A. Kelly: Operational Problems in Large Scale Residuals Management Models, Conference of Resources for the Future and the National Bureau of Economic Research, Chicago, November 10, 1972, forthcoming.

[7] F. Perroux: Note sur la notion de Pole de Croissance, Economie Appliquée, 1955; N. M. Hansen (ed.), Growth Centers in regional development, New York 1972.