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UNEMPLOYMENT, TRANS-BOUNDARY POLLUTION, AND ENVIRONMENTAL POLICY IN A DUALISTIC ECONOMY

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This study is intended to examine the effects of environmental policies on employment, the use of polluting goods, and the unemployment rate under a model introducing trans-boundary pollution affecting the productivity of the other productive sectors. That model was designed by Copeland and Taylor (1999), and transformed into a dualistic economy model constructed by Harris and Todaro (1970). Results of our analyses show that enforcement of environmental policy through control of emissions taxes does not necessarily worsen urban unemployment. Therefore, we show that it is not usually proper to maintain that some environmental pollution cannot be avoided to establish economic development. Moreover, we analyze the effect of some environmental policies on social welfare and discuss the effectiveness of those policies.

1. Introduction

Many countries' governments have conflicting perspectives about the environment and the policies to protect it. Most countries have not adopted effective policies for environmental preservation because environmental policies have impacts not only on the environmental level, but also on other sectors. Although "The Kyoto Protocol" was adopted at the third session of the Conference of the Parties (COP3) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Kyoto, Japan, in December 1997, it has taken numerous countries a long time to ratify it, along with its reduction obligations of greenhouse gas emissions. It at last came into effect in February, 2005. For example, Japan, a developed country, has committed to reducing its emissions by 6% from base-year emissions, but such a reduction obligation is not also imposed on developing countries. It is impossible to resolve environmental problems fundamentally by emission reduction efforts in only some developed countries when we take account of environmental problems on a global scale. However, it is difficult to impose emission reduction obligations with numerical targets on most developing countries because actual environment policies greatly influence each segment of industry, including the manufacturing sector. Economic development is required in developing countries. Therefore, it tends to be given priority over environment policies. On the other hand, most developing countries face serious difficulties with unemployment and must resolve those accompanying issues as their most urgent task. Therefore, increasing employment through the pursuit of economic policies is paramount in developing countries, which face serious unemployment problems; such goals vastly supersede those of environmental policies. Thus, an environmental policy plan that is compatible with economic development is a pressing need. Recently, it has become more important to consider an economic theoretical model upon which economic policy making is based.

In development economics, Harris and Todaro (1970) conceived a mechanism by which unemployment occurred endogenously in the framework of a dualistic economy. In Harris and Todaro (1970), the wage rate in the urban area is fixed, and higher than that in the rural area, for several reasons. Although laborers in the rural area have an incentive to migrate from the rural area to the urban area to gain a higher wage income, unemployment occurs in the urban area because the fixed wage rate does not act on the wage decision mechanism to achieve full employment. Therefore, labor migrates between the urban area and the rural area according to a comparison of the expected wage, while taking account of unemployment with wages in the rural area. Labor has no incentive to migrate to another area when the expected wage in the urban area is equal to that in the rural area. Moreover, they show that the "Todaro paradox" may occur, by which the unemployment rate in the urban area increases in spite of increased employment in the manufactured goods sector.

This Harris and Todaro model, which describes endogenous occurrence mechanisms in the dualistic economy, has been extended from various viewpoints. Though Harris and Todaro (1970) consider capital as the fixed specific capital in each sector, Corden and Findlay (1975) relax this assumption, and analyze a model with free mobility of capital between the urban area and the rural area. Moreover, Neary (1981) refers to the stability of equilibrium in the Corden and Findlay model. Calvo (1978) introduces the behavior of labor unions into Harris and Todaro's model and determines the higher fixed wage in urban areas endogenously. Numerous researchers have pointed out the justification of this setting in the Harris and Todaro model. Calvo shows that a subsidy policy for wages in either sector in urban or rural areas does not necessarily improve the urban unemployment rate. Brueckner and Zenou (1995) introduce a monocentric city model, which is traditional in spatial economics, into Harris and Todaro's model. They show that the Todaro paradox does not occur often. The effectiveness of various policies is examined in many studies, of which Naito (2004) is one. That study constructs a spatial model with industrial zoning policy that stimulates productivity in the manufactured goods sector in the framework of the Harris and Todaro model. Using that model, the author analyzes an optimal zoning policy.

Harris and Todaro (1970) has been extended from the various viewpoints above, and some extended models have included environmental problems that we address in our model. Dean and Gangopadhyay (1997) present an intermediate sector, which is the manufactured goods sector in the urban area. It decreases environmental quality. They further include an agricultural goods sector in a rural area. Their model analyzes social welfare effects of export bans on manufactured goods via tariffs. Results of their analyses emphasize that unemployment has a negligible impact on the case for an export ban if environmental problems are severe.

Chao, Kerkvliet and Yu (2000) consider the production function in the manufactured goods sector with labor and virgin materials as input. Environmental conditions worsen if virgin materials are used increasingly. They analyze the amount of virgin materials used in the manufactured goods sector as the optimal policy from a cost-benefit perspective under both an open and a closed economy. Beladi and Frasca (1999) consider a model with two manufactured goods sectors in an urban area and an agricultural goods sector in the rural area. One sector of the urban area is a polluting sector, which degrades the environment; the other has no effect on the environment. They derive the optimal cap of the amount of the used polluting goods. Daitoh (2003) discusses whether or not an environmental policy can create employment and decrease the urban unemployment rate. Moreover, he shows a necessary and sufficient condition for improvement of social welfare. Itoh and Tawada (2003) introduce a model, in which the amount of production in manufactured goods affects the productivity of the agricultural goods sector, into the Harris and Todaro model. They subsequently perform comparative statics analyses.

One of our motivations in this paper is to elucidate whether or not an environmental policy and economic development can coexist. Moreover, we attempt to analyze how the environmental differences among regions affect the behavior of households' migration. Particularly, we want to focus on the effect of three factors on the equilibrium in our model: a change in the difference in pollution damage among sectors; a higher emission tax in the manufactured goods sector; and an improvement in pollution reduction technology. We pay attention to these points for the following reasons.

First, the spatial aspect has been ignored in environmental economics, in models like that of Harris and Todaro. However, the difference in environmental quality is great between the urban area and the rural area. When households make a decision as to whether they will reside in urban area or rural area, environmental quality becomes an important deciding factor. Thus, we are attaching importance to the difference in environmental quality that exists between regions. Though Daitoh (2003) takes the environmental factor into account in the household's utility, he has not introduced the difference in pollution damage among regions. As the result, the environmental factor does not affect the decision regarding the household's area of residence at all. It is important, therefore, to so account for this difference. Thus, our model, which takes account of the difference in pollution damage among regions, can reflect the actual situation.

Second, we focus on the emission tax to the manufactured goods sector on the equilibrium in our model. Governments in developing countries often give priority to economic development rather than environmental problems. So some politicians in those countries often oppose the introduction of an emission tax, which can control the economic activity, on the manufactured goods sector. However, is an assertion like this true? As we explain in the model in Section 2, the environmental damage caused by the manufactured goods sector affects the household's utility and the productivity of the agricultural goods sector. One motivation of our paper is to examine whether or not environmental policy can coexist with economic development under Harris and Todaro's model, which describes the economy including urban unemployment.

Finally, we analyze the effect of improvement in pollution reduction technology. Most developing countries do not have the technology to reduce the pollution produced in their own regions. Though it is fact that they value economic development more than environmental protection, it is also true that they have no effective method to improve the environmental situation. Those developing countries often receive technical assistance from developed countries. For example, Japan's Official Development Assistance (ODA) supports the antipollution policy and the life environment improvement (air pollution, water pollution, and waste management, and so on) in the urban area, an emphasis aimed at Asian countries that are accomplishing rapid economic growth.

We introduce the manufactured goods sector using polluting goods as input into the Harris and Todaro model, and take account of trans-boundary pollution within that framework. The settings of the polluting goods and trans-boundary pollution are relative to Daitoh (2003) and Copeland and Taylor (1999). Regarding polluting goods, we assume that the government can impose the emission tax on the manufactured goods sector, which emits the pollution, to control the its use of polluting goods. Thus, the government can use this emission tax as one method of carrying out environmental policies. We explore the effects on employment of environmental policies, like the operation of an emission tax or improved reduction of pollution technology. We also examine urban unemployment. Although Daitoh (2003) addresses the effects of pollution on households' utility, he ignores effects of trans-boundary pollution on agricultural goods sector productivity. Although Itoh and Tawada (2003) take account of trans-boundary pollution and perform comparative statics analyses, they do not examine the damage to households by pollution or environmental policies put forth by governments or agencies. It is extremely important, therefore, to consider environmental policies. Because we construct a model that incorporates aspects of the models of many researchers, we can make a salient contribution to the study of this area using our model.

The paper proceeds as follows. The next section outlines the basic model. Section 3 shows the equilibrium condition. Section 4 presents comparative static analyses for each parameter and explores the effectiveness of environmental policies. Finally, section 5 contains our concluding remarks.

2. The model

We consider the dualistic economy model described by Harris and Todaro (1970) and having an urban area with a manufactured goods sector and a rural area with an agricultural goods sector. We assume that the urban wage is fixed above the market-clearing level, and that it has downward rigidity attributable to the minimum wage system and so on. Particularly, let $\overline{w}_x$ represent the minimum wage in the urban area, which is higher than the rural wage. That rural wage is determined in the labor market of the agricultural goods sector and is equal to the marginal product of the agricultural goods sector. Moreover, we assume that labor has free mobility between urban and rural areas, and we deal with the agricultural goods as numeraire in our model.

2.1 Production

Our model is a two-sector model, with a manufactured goods sector in an urban area and an agricultural goods sector in a rural sector. As we assume above, labor in an economy is free to migrate between urban and rural areas. Herein, X and Y, respectively, denote manufactured goods and agricultural goods.

2.1.1 Manufactured goods sector

Manufactured goods are produced in the urban area and require two factors, -labor and polluting goods- to produce the manufactured goods. Now the production function in the manufactured goods sector is given as

$$X = X(L_x, Z_x), \tag{1}$$

where L_x and Z_x, respectively, indicate the amount of labor input and the polluting goods input into the manufactured goods production. We regard a thing such as carbon dioxide as one example of pollution goods. It is well known that sulfuration gas and carbon dioxide cause acid rain. This acid rain, caused by the manufactured goods secto, affects soil and plant growth. Thus, the polluting goods, like carbon dioxide, affect the productivity of agricultural goods rather than the manufactured goods. Moreover, we assume that this production function is concave, continuous, and differentiable. It has the following properties:

$$\frac{\partial^2 X}{\partial L_x^2} < 0, \qquad \frac{\partial^2 X}{\partial L_x^2}\frac{\partial^2 X}{\partial Z_x^2} - \left(\frac{\partial^2 X}{\partial L_x \partial Z_x}\right)^2 > 0. \tag{2}$$

Supposing that one unit of labor and the polluting goods are required to pay $\overline{w}_x$ and τ for input, respectively, the first order conditions with respect to labor and the polluting goods are as follows.[1]

$$pX_L - \overline{w}_x = 0 \tag{3}$$

$$pX_Z - \tau = 0 \tag{4}$$

In those equations, X_i, $(i = L, Z)$ represents the partial derivative of a function with respect to variable i (e.g.$X_L = \partial X/\partial L$) and p denotes the (relative) price of manufactured goods to the price of the agricultural goods produced in the rural area.

2.1.2 Agricultural goods sector

While the manufactured goods are produced in the urban area, the agricultural goods are produced in the rural area. The production of manufactured goods in the urban area does not affect the productivity of agricultural goods in the rural area under the traditional Harris and Todaro model. The production of the manufactured goods sector in the urban area affects the productivity of agricultural goods negatively because it uses polluting goods as input factors for manufactured goods production under our model. For this setting, we follow Copeland and Taylor (1999).[2] Since we adopted the agricultural goods as numeraire in our model, we describe the production function of agricultural goods as

$$Y = D(t, Z_x)\overline{Y}(L_y), \tag{5}$$

where L_y denotes the labor input in the agricultural goods sector. Let $D(t, Z_x)$ represent the productivity function of agricultural goods depending on the polluting goods used in the manufactured goods sector and the parameter meaning the reduction technology of pollution caused by using the polluting goods. As for the parameter t, the larger this parameter t, the greater

[1] One is required to pay the emissions taxτ per unit of polluting goods.

[2] Although the agricultural sector productivity depends on the total amount of manufactured goods production in Copeland and Taylor (1999), the amount of polluting goods affects the agricultural productivity.

the reduction effect of pollution caused by using the polluting goods. On the other hand, little reduction effect on pollution is achieved if t is close to zero. In most developing countries, the reduction technology of pollution is supplied as technological support by the developed countries. Since this technological support level is determined not by the countries receiving it but the countries supplying it, their economies deals with this level of reduction technology of pollution as given. Thus, we consider the reduction technology of pollution t is not an endogenous variable but an exogenous parameter. We assume that the damage caused by polluting goods input affects not the productivity of the manufactured goods sector but that of the agricultural goods sector in our model. Most water used in an industrial division is for cooling or simple washing. It seems that water does not affect the productivity of manufactured goods. Actually, as for the water service, some classifications are made according to quality in Japan, and most water for industrial use is "routine duties water", which is the lowest quality tap water. It is, however, a well-known fact that low quality water has a bad influence on the human body and the growth of plants. This is clear from various scientific data. So improvement of the reduction technology of pollution raises productivity of the agriculture goods sector and the utility of households in the economy. Thus, we consider that reduction technology of pollution t does not affect the productivity of the manufactured goods sector and affects only the productivity of the agricultural goods sector and the households' utility in our model.[3]

Here, this productivity function of agricultural goods has the following properties.

$$\frac{\partial D}{\partial Z_x} < 0, \qquad \frac{\partial D}{\partial t} > 0 \tag{6}$$

In other words, this productivity function is a decreasing function with respect to the polluting goods input of the manufactured goods sector in the urban area, and is an increasing function with respect to the reduction technology parameter. However, we must pay attention to the property of this function. The agricultural goods sector deals with productivity, which is described by the above productivity function, as an externality; for that reason, the agricultural goods sector cannot determine the level of that productivity. Finally we assume the following properties for the function $\overline{Y}$.

$$\frac{\partial \overline{Y}}{\partial L_y} > 0, \qquad \frac{\partial^2 \overline{Y}}{\partial L_y^2} < 0 \tag{7}$$

Thus, the first order condition of the agricultural goods sector for profit maximization is given as

$$D(t, Z_x)\,\overline{Y}_L - w = 0, \tag{8}$$

[3] Supposing that polluting goods use affects the productivity of the manufactured goods sector, the labor demand in the manufactured goods sector decreases. Moreover, the damage of pollution on the rural area affects only the utility function itself and does not affect the wage rate. Thus, the incentive to reside in the rural area is increases under this assumption.

where $\overline{Y}_L$ refers to the partial derivative of a function with respect to variable L_y (e.g. $\overline{Y}_L = \partial \overline{Y}/\partial L_y$). The assumption about the shape of function $\overline{Y}$ obviously satisfies the second order condition.

2.2. Households

Households in the economy are of three types: labor employed in the manufactured goods sector; unemployed labor in the urban area; and labor in the agricultural sector in the rural area. Index x, u and y mean households employed in the manufactured goods sector, the unemployed in the urban area, and households employed in the agricultural goods sector, respectively. We set up the following utility function of households in the economy. Now let $U_i\,(C_x^i,\ C_y^i;\ Z_x)\ (i = x, u, y)$ represent each household's utility function. Though Daitoh (2003) assumes the additively-separable utility function, we adopt the multiplicative utility function, which depends on consumption of manufactured goods and agricultural goods and the level of environmental damage. The reasons we used this utility function are to describe the following. One reason is that households in the economy deal with the environmental level as externality. The other is that we can express a difference in the pollution damage between the urban area and the rural area by using this utility function form. This difference in the pollution damage affects migration between the urban area the and rural area.

$$U_i\left(C_x^i, C_y^i; Z_x\right) = \begin{cases} \beta E(t, Z_x)u\left(C_x^i, C_y^i\right) & (i = x, u) \\ E(t, Z_x)u\left(C_x^i, C_y^i\right) & (i = y) \end{cases} \tag{9}$$

where C_x^i, C_y^i $(i = x, u, y)$ and E, respectively, represent the manufactured goods consumption, the agricultural consumption, and the level of environmental damage for each household. Parameter β denotes a difference in pollution damage between the urban area and the rural area. Supposing that β is larger (smaller) than one, the pollution damage in the urban area is smaller (larger) than that in the rural area.[4] Moreover, we assume that the property of function $E(t, Z_x)$ is according to the following.

$$\frac{\partial E}{\partial Z_x} < 0, \qquad \frac{\partial E}{\partial t} > 0, \qquad \frac{\partial^2 E}{\partial Z_x^2} < 0, \qquad \frac{\partial^2 E}{\partial t^2} < 0, \tag{10}$$

Therein, t denotes the technology parameter of pollution reduction. The property of function $E(t, Z_x)$ means that the increase of Z_x worsens the disutility of pollution and that the improvement of reduction technology of pollution improves the disutility of pollution. Moreover, we assume that the marginal disutility of pollution with respect to Z_x is increasing. We assume that the sub-utility function $u(C_x^i, C_y^i)$ is homothetic. Let U_x, U_u and U_y, respectively, represent the utilities of labor employed in the manufactured goods sector, unemployed labor in the urban area, and labor in the agricultural sector in the rural area. We assume that the profits of the manufactured goods sector, the agricultural goods sector, and the emission tax revenue are allocated to all

[4] We assume that there is no difference in pollution damage between urban workers and urban unemployed people and that β is positive.

households at a per capita rate. The profit's allocation per capita is denoted as I, that is,

$$I \equiv \frac{1}{L}\left(pX(L_x, Z_x) - \overline{w}_x L_x - \tau Z_x + D(t, Z_x)\overline{Y}(L_y) - wL_y + \tau Z_x\right) \tag{11}$$

Because wages in the urban area and the rural area are denoted as $\overline{w}_x$ and w, the budget constraints of each type of labor are given as follows.

$$\overline{w}_x + I = pC_x^x + C_y^x \tag{12}$$

$$I = pC_x^u + C_y^u \tag{13}$$

$$w + I = pC_x^y + C_y^y, \tag{14}$$

where C_x^i and C_y^i denote the consumption of manufactured goods and the agricultural goods of each household $i(i = x, u, y)$, respectively. Each household deals with the environmental damage as given: they cannot control this level. Because they determine the consumption of manufactured goods and agricultural goods to maximize their utility, the first order condition for maximization is the following.

$$\frac{u_x}{u_y} = p, \quad for \quad \overline{w}_x, w_u, w \tag{15}$$

Assuming that $u(C_x^i, C_y^i)$ is homothetic, the indirect utility functions of respective households, V_x, V_u, V_y, are described as

$$V_x = \beta E(t, Z_x)\xi(p)(\overline{w}_x + I), \tag{16}$$

$$V_u = \beta E(t, Z_x)\xi(p)I, \tag{17}$$

$$V_y = E(t, Z_x)\xi(p)(w + I), \tag{18}$$

where $\xi(p)$ is the decreasing function of p.[5] Here, we define $\overline{C}_x$, $\overline{C}_y$ as total demand for manufactured goods and agricultural goods in the economy, respectively; that is,

$$\overline{C}_x = C_x^x L_x + C_x^u L_u + C_x^y L_y, \tag{19}$$

[5] For example, now we assume that the sub-utility function in this paper is the Cobb-Douglas utility function, which is a typical homothetic utility function. In this case, the indirect utility function v is $v = (\frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{p^\alpha})I$. If we define $\xi(p) = (\frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{p^\alpha})$, $\xi'(p)$ is negative.

$$\overline{C}_y = C_y^x L_x + C_y^u L_u + C_y^y L_y. \tag{20}$$

We assume that households are free to migrate between regions. They compare the expected utility level in the urban area with that of the rural area and determine their residential location. Following Harris and Todaro (1970), the equilibrium is established when the expected utility level in the urban area is equal to that of the rural area. Therefore, we define this equilibrium, where no household has an incentive to migrate to the other region, as the migration equilibrium. Moreover, we define the unemployment rate as

$$\lambda = \frac{L_u}{L_x + L_u}, \tag{21}$$

where L_u denotes the amount of unemployed labor. The amount of labor in the rural area is represented as L_y; the population constraint is given by

$$L_x + L_u + L_y = L, \tag{22}$$

where L means the total number of households in this economy. Combining (21) with (22), we can rewrite the (22) as follows.

$$L_x + (1 - \lambda)L_y = (1 - \lambda)L \tag{23}$$

Because the unemployment rate is defined as (21), the migration equilibrium condition between the urban area and the rural area is described as follows.

$$(1 - \lambda)V_x + \lambda V_u = V_y \Leftrightarrow (1 - \lambda)\beta\,\overline{w}_x + \beta I = w + I \tag{24}$$

2.3 Environment

Environmental damage in our model results from the production of manufactured goods using the polluting goods as input, which creates two kinds of damage of the environment. One is damage to productivity of the agricultural goods sector. This model is similar to those of Copeland and Taylor (1999) and Itoh and Tawada (2003): increased production of manufactured goods worsens the productivity of agricultural goods. The other is the direct effect on the level of households' utility in using polluting goods in the production of manufactured goods. We formulate this effect as similar to the representation in Daitoh (2003). However, the effect of environmental damage on households is asymmetric among households in between the urban area and the rural area, though Daitoh (2003) considered the symmetric environmental effect among households. Thus, this setting of asymmetrical environmental damage for households is one of the parts that we extended in our model. Moreover, the government can control the use of polluting goods in the manufactured goods sector via an emissions tax. Since we assume that this emission tax revenue is allocated to all households at a per capita rate, it returns a benefit to all households.[6]

3. Equilibrium

We have described the behaviors of respective production sectors, households, and the government. The relative price p is given exogenously if we set up the small country model assumption.

Thus, the following equation is satisfied.

$$pX + Y = p\overline{C}_x + \overline{C}_y \tag{25}$$

Now ten variables, which are L_x, Z_x, w, V_x, V_u, V_y, λ, L_y, L_u, and I are determined by the system comprising (3), (4), (8), (11), (16), (17), (18), (21), (22), (24). Arranging these conditions, the system in our model is described using the following four equations:

$$pX_L = \overline{w}_x \tag{26}$$

$$\beta(1-\lambda)\overline{w}_x - (1-\beta)I - D\overline{Y}_L = 0 \tag{27}$$

$$L_x + (1-\lambda)L_y = (1-\lambda)L \tag{28}$$

$$pX_Z = \tau. \tag{29}$$

Differentiating the equations from (26) to (29) totally and expressing them using the matrix, they are as follows.

$$\begin{pmatrix} pX_{LL} & 0 & pX_{LZ} & 0 \\ 0 & -D\overline{Y}_{LL} & -(1-\beta)I_z - D_z\overline{Y}_L & -\beta\overline{w}_x \\ 1 & 1-\lambda & 0 & L-L_y \\ pX_{ZL} & 0 & pX_{ZZ} & 0 \end{pmatrix} \begin{pmatrix} dL_x \\ dL_y \\ dZ_x \\ d\lambda \end{pmatrix} = \begin{pmatrix} -X_L dp \\ ((1-\beta)I_t + D_t\overline{Y}_L)dt - ((1-\lambda)\overline{w}_x + I)d\beta + I_L dL \\ (1-\lambda)dL \\ d\tau - X_Z dp \end{pmatrix} \tag{30}$$

[6] We deal with this emission tax τ as the exogenous parameter. If we consider this emission tax τ as the endogenous variable, we have to determine it by solving the maximization problem of green GDP. However, we do not take problems of optimization like this into account.

4. Comparative statics

We analyze the comparative statics for the system represented by (30) and the effects of some parameters on the system in our model. To begin with, we derive the determinant of the coefficient matrix as the left-hand side of (30) preparatory to comparative statics. Let Δ represent the determinant of the coefficient matrix as the left-hand side of (30), Δ is as follows.[7]

$$\Delta = p^2\left(X_{LL}X_{ZZ} - X_{LZ}^2\right)((L - L_y)D\,\overline{Y}_{LL} - \beta(1-\lambda)\,\overline{w}_x) < 0. \tag{31}$$

4.1 Effect of the difference in damage caused by pollution between regions

As we explained regarding the effect of β in the previous section, we consider the effect of β on the equilibrium. Results of comparative statics by taking account of (30), (31), and by Cramer's formula, show the effect of an emissions tax β on each variable as

$$\frac{dL_x}{d\beta} = 0 \tag{32}$$

$$\frac{dL_y}{d\beta} = \frac{1}{\Delta}p^2((1-\lambda)\,\overline{w}_x + I)(L - L_y)\left[X_{LL}X_{ZZ} - X_{LZ}^2\right] < 0 \tag{33}$$

$$\frac{dZ_x}{d\beta} = 0 \tag{34}$$

$$\frac{d\lambda}{d\beta} = -\frac{1}{\Delta}p(1-\lambda)((1-\lambda)\,\overline{w}_x + I)\left[X_{LL}X_{ZZ} - X_{LZ}^2\right] > 0. \tag{35}$$

We can know some properties of the asymmetry of environmental damage by the comparative statics from (32) to (35). Though the behavior of the manufactured goods sector is independent of the effect of the asymmetry of environmental damage on households, and it has an effect on both the labor input in agricultural goods sector and the urban unemployment rate. Thus, we can derive the following lemma.

Lemma 1. As the asymmetric parameter β increases, the labor input for the agricultural goods sector decreases and the unemployment rate increases. However, its parameter has no effect on the behavior of the manufactured goods sector in the urban area.

Since the increase of β improves the environment in the urban area, the households have an incentive to migrate from the rural area to the urban area. Thus, as we know from (33), the labor input of the agricultural goods sector decreases. On the other hand, the labor input

[7] We assume that $X_{LL}X_{ZZ} - X_{LZ}^2$ is positive, to satisfy the second order condition.

of the manufactured goods sector is not changed, due to the fixed wage rate in the urban area. Therefore, the urban unemployment rate gets worse and worse through increasing the value of β.

4.2 Effect of the emissions tax

We consider the effect on the system of an emissions tax that must be paid for the use of polluting goods in the production of manufactured goods. Because the manufactured goods sector manager must use the polluting goods as inputs, she must pay the government an emissions tax τ. In talking about the emission tax in previous sections, we assume that this tax revenue is reallocated to households in a lump-sum fashion. Results of comparative statics in taking account of (30), (31), and by Cramer's formula, show the effect of an emissions tax τ on each variable as

$$\frac{dL_x}{d\tau} = \frac{1}{\Delta} pX_{LZ}\{-D\overline{Y}_{LL}(L - L_y) + \beta\,\overline{w}_x(1 - \lambda)\} < 0 \tag{36}$$

$$\frac{dL_y}{d\tau} = \frac{1}{\Delta} p\{X_{LL}(-(1 - \beta)I_Z - D_Z\overline{Y}_L)(L - L_y) - X_{LZ}\beta\,\overline{w}_x\} \geq (<)0 \tag{37}$$

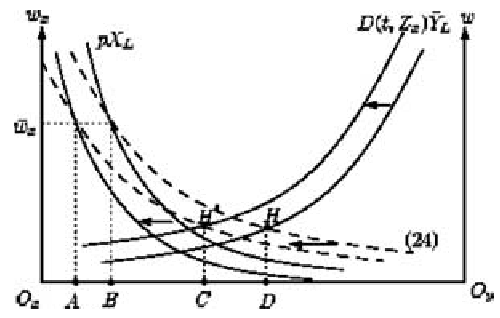
$$\frac{dZ_x}{d\tau} = \frac{1}{\Delta} pX_{LL}\{-\beta(1 - \lambda)\,\overline{w}_x + D\overline{Y}_{LL}(L - L_y)\} < 0 \tag{38}$$

$$\frac{d\lambda}{d\tau} = \frac{1}{\Delta} p\left\{X_{LL}(1 - \lambda)((1 - \beta)I_Z + D_Z\overline{Y}_L) + X_{LZ}D\overline{Y}_{LL}\right\} \geq (<)0. \tag{39}$$

We explain the results of the above comparative statics from (36) to (39) in terms of economic effects. First, we consider the effect of increasing the emissions tax τ on the input of polluting goods in the manufactured goods sector. We understand that the increased emissions tax τ engenders decreased input of polluting goods because of (38). The manufactured goods sector has an incentive to substitute low-price labor inputs for polluting goods, whose price t is high, by increasing the emissions tax. The marginal product of labor decreases concomitant with the input of polluting goods. Because we assume that the wages in the urban area are fixed, the manufactured goods sector decreases labor input.

Second, we consider the effect of increasing the emissions tax τ on the agricultural sector in the rural area. The effect of increasing the emissions tax on the labor input of the agricultural sector in the rural area L_y is shown by (37). As shown by the production function of the agricultural goods sector (5), the use of polluting goods by the manufactured goods sector in the urban area affects agricultural goods sector productivity in the rural area as trans-boundary pollution. Thus, the agricultural goods sector productivity of $D(t, Z_x)$ becomes high as the increased emissions tax τ engenders a decrease in polluting goods input in the urban area. Consequently, the agricultural goods sector increases the labor input of the sector L_y. In other

Figure 1. Effect of a rise in the emissions tax on the equilibrium.



words, an environmental policy with emissions taxes engenders increased labor input of the agricultural goods sector. However, supposing that I_Z is negative and β is large enough, the household has an incentive to move from the rural area to the urban area, and the rise of τ increases I and improve the environment in the urban area.

Finally, we consider the effect of increasing the emissions tax τ on the unemployment rate in the urban area. As we know from (39), the effect of increasing the emissions tax τ on the unemployment rate in the urban areas has no unique sign. Figure 1 shows the effects of the emissions tax on the equilibrium. The increase of an emissions tax shifts the marginal product of the manufactured goods sector to the left. It also shifts that of the agricultural goods sector to the left. Consequently, the equilibrium changes from H to H'. In this case, the labor input of the manufactured goods sector decreases from O_xB to O_xA and that of agricultural goods sector increases from O_yD to O_xC. On the other hand, the unemployed labor changes from BD to AC and its effect is determined uniquely. Assuming that a decrease of labor input for the manufactured goods sector attributable to a rise of τ is greater than the increase of labor input of the agricultural goods sector, the urban unemployment rate λ falls: $\lambda/d\tau$ is negative. On the other hand, supposing that the opposite case is satisfied, the rate in the urban area λ rises: $d\lambda/d\tau$ is positive. Therefore, the effect of τ on the unemployment rate depends on the relation between the elasticity of the labor input of manufactured goods sector with respect to the emissions tax and that of the agricultural goods sector with respect to the emissions tax.

We further examine this result. Recently some politicians have maintained that strict environmental policies should not be carried out because they threaten many industries with decline. Because we know that the enforcement of environmental policy (increased emissions tax τ) does not usually degrade the unemployment rate because of (39), such assertions are not necessarily justified. It is impossible to justify the position of many developing countries that policies promoting economic development must necessarily have priority over environmental policies. Therefore, we derive the following proposition through an analysis of comparative statics.

Proposition 1. *The enforcement of environmental policy (increased emissions tax τ) restricts the input of polluting goods into the manufactured goods sector. As a result, although such a policy engenders decreased labor input of the manufactured goods sector in the urban area, it is possible to engender increased labor input of the agricultural goods sector in rural areas. However, it is not necessary to degrade employment in the urban area because of the enforcement of environmental policy.*

4.3 Effects of pollution reduction technology

We consider effects of pollution reduction technology on this system. The enforcement of environmental policy reduces environmental damage by decreasing the input of polluting goods in the manufactured goods sector: effective pollution reduction technology improves environmental conditions by reducing pollution caused by the production of manufactured goods. For example, higher quality machinery can filter out impurities from unclean water damaged by using polluting goods in the manufactured goods sector. Higher quality processes and devices can mitigate the effects of pollution on both the productivity of the agricultural goods sector and the utility level of households. Because the government does not increase the emissions tax imposed on the manufactured goods sector when the government carries out reduction of environmental damage, this case does not distort the production activity of the manufactured goods sector. We have introduced the reduction technology parameter t into (9) or (5) to analyze the effects of pollution reduction technologies on the system. Although reduction technology requires some expenditure towards its improvement, we assume that its cost is partially compensated by outside donations such as ODA. Similarly, in the case of the emissions tax, taking account of (30), (31) and Cramer's formula, we can determine the effect of the improvement of reduction technology on each variable as follows.

$$\frac{dL_x}{dt} = 0 \tag{40}$$

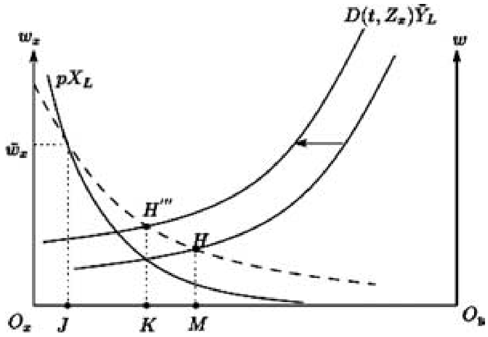
$$\frac{dL_y}{dt} = -\frac{1}{\Delta}\left(X_{LL}X_{ZZ} - X_{LZ}^2\right)p^2(L - L_y)((1-\beta)I_t + D_t\overline{Y}_L) \geq (<)0 \tag{41}$$

$$\frac{dZ_x}{dt} = 0 \tag{42}$$

$$\frac{d\lambda}{dt} = \frac{1}{\Delta}\left(X_{LL}X_{ZZ} - X_{LZ}^2\right)p^2(L - L_y)((1-\beta)I_t + D_t\overline{Y}_L) \geq (<)0. \tag{43}$$

We make an interpretation of the results of comparative statics from Equations (40)–(43) in economic terms. First, we consider the pollution reduction technology on labor input for the agricultural goods sector. Presuming that $\partial D/\partial t$ is positive, the improvement of pollution reduction function technology brings higher productivity to the agricultural goods sector. However, supposing that β is large enough, the household has an incentive to reside in the urban area. Thus, the rise of t does not always increase the labor demand in the agricultural sector L_y. On the other hand, supposing that β is smaller than one, the labor input to the agricultural goods sector increases because of the increased production of the agricultural goods sector. Thus, the improvement of pollution reduction technology promotes employment in the agricultural goods sector. Next, we evaluate the effect of pollution reduction technology on the labor input of the manufactured goods sector. As we know from the results of (40) and (42), there is no effect from the improvement of pollution reduction technology on the manufactured goods sector because

Figure 2. Effects of pollution reduction technology on equilibria.



its improvement has an effect only on both the productivity of the agricultural goods sector and the utility level of households. Finally, we refer to the effect of pollution reduction technology on the urban unemployment rate, which is represented as (43). As shown by the result of comparative statics from (43), we know that $d\lambda/dt$ does not have a unique sign. However, supposing that β is enough small ($\beta < 1$), it is satisfied that $d\lambda/dt$ is positive. Figure 2 depicts the effect of reduction technology improvement on the equilibrium. Since the reduction technology improvement induces the marginal product of the agricultural goods sector to shift to the left, the point, where the marginal product of both sectors is same, moves from H to H'''. Though the labor input of the manufactured goods sector, O_xJ, does not change, that of the agricultural goods sector changes from O_yM to O_yK. Thus, the number for unemployed labor decreases from JM to JK. Consequently, we derive the following proposition.

Proposition 2. *Though the environmental policy, which decreases the damage caused by pollution goods input, (the improvement of pollution reduction technology) may increase the labor input of the agricultural goods sector, it does not affect the labor and pollution goods input of the manufactured goods sector. As for the unemployment rate, it may be decreased by the improvement of pollution reduction technology.*

5. Social welfare

5.1 Effect of the emission tax on social welfare

We have analyzed the effect of some environmental policies on variables in the previous section. However, we have not yet analyzed the effectiveness of these environmental policies for the society. Since the argument regarding the effectiveness of these policies cannot be ignored in terms of environmental policy, we discuss the impact of these policies on social welfare. We define the social welfare function as follows.

$$W \equiv L_x V_x + L_u V_u + L_y V_y \tag{44}$$

V_x, V_u, and V_y are given by (16), (17), and (18), respectively. Substituting (22) and (24) into (44), the social welfare function can be rewritten as follows.[8]

$$W = E(t, Z_x)\xi(p)\,\overline{w}_x\,\beta\left(L_x + (1-\lambda)L_y + \frac{LI}{\overline{w}_x}\right) \tag{45}$$

Differentiating the social welfare function with respect to β,

$$\begin{aligned}\frac{dW}{d\beta} &= E(t, Z_x)\xi(p)\,\overline{w}_x\left(L_x + (1-\lambda)L_y + \frac{LI}{\overline{w}_x}\right)\\ &+E(t, Z_x)\xi(p)\,\overline{w}_x\,\beta\left(-\frac{d\lambda}{d\beta}L_y + (1-\lambda)\frac{dL_y}{d\beta}\right) \geq (<)0.\end{aligned} \tag{46}$$

Though the increase of β raises the indirect utility level of households who reside in the urban area, the increase of β decreases the labor input of the agricultural sector, worsens the urban unemployment rate due to Equation (33) and Equation (35), and decreases social welfare. Thus, the sign of comparative statics is not determined uniquely.

Next, we consider the effect of the emission tax τ on social welfare. Differentiating (45) with respect to τ, the following equation is derived.

$$\begin{aligned}\frac{dW}{d\tau} &= E(t, Z_x)\xi(p)\,\overline{w}_x\,\beta\left(\frac{dL_x}{d\tau} + (1-\lambda)\frac{dL_y}{d\tau} - L_y\frac{d\lambda}{d\tau}\right)\\ &+\frac{dE}{dZ_x}\frac{dZ_x}{d\tau}\xi(p)\,\overline{w}_x\,\beta\left(L_x + (1-\lambda)L_y + \frac{LI}{\overline{w}_x}\right) \geq (<)0\end{aligned} \tag{47}$$

Here, supposing that $\beta < 1$ and $I_Z < 0$ hold, the sign of (37) is positive. Since the increase of τ leads to increase the labor input in the agricultural goods sector and decreases the input of pollution goods in the manufactured goods sector due to (37) and (38), social welfare is improved. On the other hand, social welfare gets worse because the increase of τ decreases the labor demand in the manufactured goods sector and worsens social welfare due to (36). As we know from the result of (47), the sign of $dW/d\tau$ is not generally unique. Here, the sign of (39) is negative if the emission tax elasticity of labor demand for the manufactured goods sector is smaller than that of labor demand for the agricultural goods sector. Therefore, the sign of $-L_y\frac{d\lambda}{d\tau}$ and the second clause in (47) is positive at this time. We consider the sign of $\frac{dL_x}{d\tau} + (1-\lambda)\frac{dL_y}{d\tau}$ in (47). Substituting (36) and (37) into $\frac{dL_x}{d\tau} + (1-\lambda)\frac{dL_y}{d\tau}$ and transforming this, the following equation is derived.

$$\frac{dL_x}{d\tau} + (1-\lambda)\frac{dL_y}{d\tau} = -\frac{1}{\Delta}p(X_{LL}(1-\lambda)((1-\beta)I_Z + D_z\overline{Y}_L) + X_{LZ}D\overline{Y}_{LL}) \geq (<)0 \tag{48}$$

Here we can understand that the sign of (48) is positive if the sign of (39) is negative, comparing (39) with (48). In other words, the sign of (48) is positive if the emission tax elasticity of

[8] Note that L_x, L_y, λ, Z_x are the function with respect to τ and t. Thus, the social welfare W is also the function with respect to τ and t.

labor demand for the manufactured goods sector is smaller than that of labor demand for the agricultural goods sector. Therefore, the increased emission tax improves social welfare at that time. As a result of this analysis, we derive the following proposition.

Proposition 3. *Supposing that the emission tax elasticity of labor demand for the manufactured goods sector is smaller than that of labor demand for the agricultural goods sector, the increased emission tax τ may improve social welfare.*

5.2 Effect of pollution reduction technology improvement on social welfare

Here, we consider the effect of pollution reduction technology improvement on social welfare. Similar to the previous analysis of the emission tax, we differentiate the social welfare function with respect to the parameter t, which shows the degree of pollution reduction technology, to analyze the effect of reduction technology on social welfare; that is,

$$\begin{aligned} \frac{dW}{dt} &= E(t, Z_x)\xi(p)\overline{w}_x\,\beta\left(-\frac{d\lambda}{dt}L_y + (1-\lambda)\frac{dL_y}{dt} + \frac{LI_t}{\overline{w}_x}\right) \\ &+\frac{\partial E}{\partial t}\xi(p)\overline{w}_x\,\beta\left(L_x + (1-\lambda)L_y + \frac{LI}{\overline{w}_x}\right) \geq (<) 0. \end{aligned} \tag{49}$$

Here, supposing that $\beta < 1$ holds, the sign of (41) is positive and that of (43) is negative. Taking account of (41), (43), and $\partial E/\partial t > 0$, we know that $\frac{dW}{dt}$ becomes positive; that is, the improvement of pollution reduction technology increases social welfare. Though the reduction technology improvement does not distort manufactured goods production, it improves the welfare of the agricultural goods sector and the households' utility level. Thus, social welfare as a whole is improved. So we derive the following proposition.

Proposition 4. *The improvement of pollution reduction technology may increase social welfare.*

6. Concluding remarks

We constructed a model that combines the Harris and Todaro model, which determines unemployment endogenously, with the Copeland Taylor model, in which pollution affects productivity of other goods sectors. Using that hybrid model, we analyzed the effects of some environmental policies – the emissions tax and the pollution reduction technology – on each endogenous variable. Our analyses show that the unemployment rate is not necessarily raised because of an increased emissions tax, but that increased unemployment can raise inputs of polluting goods. This result shows that an environmental policy does not necessarily restrain economic development; it is not justified to maintain that environmental damage is inherent in the economic development of a developing country. Moreover, we consider the effects of improved pollution reduction technology as an environmental policy on each endogenous variable. Although the emissions tax is an environmental policy that directly restrains the input of polluting goods by the manufactured goods sector, improvement of pollution reduction technologies is an environmental policy reducing pollution caused by the input of polluting goods without restraining production of the manufactured goods sector. We know that there is no effect of this policy on variables as to the manufactured goods sector. However, this policy increases the labor input of the agricultural goods sector. Thus, the unemployment rate in the urban area is improved by this policy. Although the results of our analyses are shown as a lemma to focus attention on the environmental policy in our model, we analyze the effects of the relative price and labor endowment on endogenous variables. When considering environmental policies, it is necessary for us to take account not only of the effects of environmental policies on restraining a specified sector but also the effects of that policy on other economic factors, such as labor mobility. For simplification of analysis, we set some assumptions. First, we assume that the wage rate in the urban area is fixed and that it is higher than that of the rural area, though this is mainly a comment on Harris and Todaro (1970). Regarding this point, we must extend our model to determine it endogenously, as Calvo (1978) does in a model assuming a labor union. Second, we consider an emission rights market, in which the government can grasp the use of polluting goods by the manufactured goods sector exactly and restrain the activity of the manufactured goods sector via an emissions tax. Consequently, we do not consider the case in which the government can carry out ex post restraint of the manufactured goods sector. However, the government must take account of a situation without an emissions tax if it considers introduction of an emissions tax. The manufactured goods sector managers have an incentive to increase the input of polluting goods in a situation without an emissions tax because the manufactured goods sector can thereby increase its production in our model. For that reason, we must construct an environmental policy to control those emissions. Because Beladi and Frasca (1999) consider a model that sets an emissions cap for the input of polluting goods as an environmental policy, it is interesting to introduce such a cap into our model and analyze its effects. Finally, it is necessary to analyze a closed economy model, but we analyze the effects of some environmental policies on the system under a small open economy model. Relative price p is determined endogenously if we consider our analysis under a closed economy model. These remaining points are left as subjects for future studies because they can potentially complicate these analyses.

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