Pollution Control and Welfare in General Equilibrium: Is there a Tradeoff between Tax and Standard?

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ABSTRACT

The paper attempts to throw theoretically some light on the debate related to tax versus standard in the context of environmental pollution control in a developing economy. The motivation behind this study originates from the fact that this issue is particularly important from the point of view of policy making in the context of a developing economy and almost all the theoretical works on this subject focus on partial equilibrium framework .In fact there is absence of any work, at the theoretical level, that considers the debate between pollution tax and standard using a general equilibrium framework. Such a framework not only helps us to understand the inter-sectoral linkages that we find in a developing economy but also helps us to examine whether there actually exists any tradeoff between pollution tax and standard in a developing economy. Though our model has been constructed at a general level such a framework can easily be used for a developing economy like India. It is based on a three-sector general equilibrium framework for a small open economy where the issue of green capital has been brought explicitly. The assumption of small open economy implies that the product prices are internationally given, as the economy is a price taker. The three sectors of the economy are the agricultural sector, the polluting manufacturing sector and the non-polluting manufacturing sector. We assume that environmental pollution occurs through the production of goods of the polluting manufacturing sector using traditional capital. This sector is required to pay pollution emission tax. There is also a certain maximum allowable level of pollution decided by the pollution regulatory authority. Pollution emission tax is a proportion of the difference between the pollution emission by the polluting sector and the maximum allowable pollution. We have shown that even if there is an improvement in environmental standard captured through reduction in the maximum allowable level of pollution it produce under some reasonable conditions adverse effects on the actual environmental pollution level of the economy. However, we find that pollution control in the form of increase in the rate of emission tax on the polluting sector is successful in reducing pollution generated from the sector. The paper thus shows that definitely there exists a trade off between tax and standard in the context of general equilibrium. First we have the paradoxical result that improvement in environmental standard in the form of reduction in maximum allowable pollution increases pollution in the economy under some reasonable conditions. It also increases urban unemployment though it reduces welfare. On the other hand, pollution control in the form of increase in emission tax reduces pollution generated from the polluting sector. It also reduces urban unemployment. However, paradoxically, under some reasonable conditions, such an increase in the tax rate reduces welfare.

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1. Introduction

Today there is no controversy on the view that environmental pollution all over the world has reached an alarming level and immediate steps should be taken by all nations to save the global economy from its harmful effects. Economic activity affects environment in diverse ways. Land and water are adversely affected when materials and energy are drawn from them for performing economic activities like production and consumption. Discharge of wastes from industry and domestic living pollutes economy badly. The issue of pollution control has gained importance due to increasing concern among the environmentalists, academicians and policy makers regarding the state of natural environment and conservation of natural resources in developing countries.

The "Environmental Kuznets Curve" gives the most likely relation between the environment and economic development. It states that there exists an inverted U-shaped relationship between per capita income and environmental degradation. In case of developing countries it has been found that the peak of this curve is reached at a relatively high level of per capita income. There can be various reasons for this, and one of these can be the existence of a large informal sector causing huge environmental pollution.[1] In the developing countries informal sector constitutes a large part of manufacturing and service sector. This sector provides a major part of employment in most developing countries. Empirical evidence suggests that most of the informal sector units produce intermediate inputs for the formal manufacturing sector on a subcontracting basis, and this sector is a major source of environmental pollution.

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[1] See for example the works of Gupta (2002a, 2002b), Chaudhuri and Gupta (2004), Chaudhuri (2005), Basu (2006) etc.

Another important issue that needs to be mentioned in connection with pollution control is transfer of environmentally sound technology (EST hereafter) from developed to developing countries. EST is also referred to as *'green technology'* or *'green capital'* in the environmental economics literature. One of the most important aspects of liberalization is the inflow of foreign capital to developing countries in the form of foreign direct investment (FDI). As a result of FDI, residents of the host country come into contact with foreign entrepreneurs who possess superior technical skills and know how. These new ideas lead to transfer of technology from the foreigners to the residents of the host country and it takes place through observation discussion and training. This transmission can be considered as a spillover or external effect on the host country[2]. So technology transfer in developing countries takes place mainly through FDI. Empirical investigations in this area by Mansfield (1961, 1968) also support the validity of this hypothesis.

In the trade-environment literature it has been argued, following the 'industrial flight' and 'pollution haven' hypotheses that trade liberalization leads to FDI in pollution-intensive industries in the developing countries. However, empirical studies by Duerksen and Leonard (1980), Pearson (1987) and Leonard (1988) show that there is no evidence of widespread relocation of industries to pollution haven.

The question that arises here is that why the issue of pollution control is so important in the context of the globalization for most of the developing economies. Perrings, Bhargava and Gupta (1995) have tried to answer this question with special reference to a developing country like India. They have shown that much industrial growth in developing countries is due to employment, investment and value added by informal sector [or more broadly the small scale enterprises (SMEs)] in environmentally damaging activities like chemicals, textiles, leather and fur products, food processing, non-ferrous metal work, charcoal and fuel wood supply. It is difficult to get data on how far the informal sector is responsible for this pollution as against the

[2] See Koizumi and Kopecky (1977) for details. Findlay (1978) has also used this "contagion hypothesis" in his theoretical analysis of technology transfer and relative backwardness.

large firms. However, it can be argued that as the informal sector firms have limited access to EST and as they use backward technology these firm are responsible for a major share of pollutants. The formal sector firms in developing countries actually subcontract the informal sector firms to undertake a number of tasks and processes that are "dirty" from the environment point of view.

Hence we can argue that it is mainly due to the existence of informal sector firms in developing countries domestic pollution control measures fail to restrict pollution in developing countries. It also explains the fact as to why pollution level is so high in developing countries despite an insignificant share of FDI in polluting activities of these countries. In fact, following Findlay's (1978) 'contagion hypothesis' we find that FDI leads to technology transfer and it includes transfer of EST.

The present paper attempts to throw theoretically some light on the debate related to tax versus standard in the context of environmental pollution control in a developing economy. It is based on a three-sector general equilibrium framework for a small open economy where the issue of green capital has been brought explicitly. The motivation behind this study originates from the fact that this issue is particularly important from the point of view of policy making in the context of a developing economy and almost all the theoretical works on this subject focus on partial equilibrium framework .In fact there is absence of any work, at the theoretical level, that considers the debate between pollution tax and standard using a general equilibrium framework. Such a framework not only helps us to understand the inter-sectoral linkages that we find in a developing economy but also helps us to examine whether there actually exists any tradeoff between pollution tax and standard in a developing economy. Though our model has been constructed at a general level such a framework can easily be used for a developing economy like India.

The framework is based on a small open economy type general equilibrium structure that has been used by various authors to analyze trade and environmental issues [For example Chichilnisky (1994), Copeland and Taylor (1994,1995) etc.] Various authors to link informal sector with environmental pollution have also used this framework. [See for example the works by Gupta (2002a,2002b), Chaudhuri and Gupta (2004), Chaudhuri (2005), Basu (2006) etc.]. The present model considers a structure where the issue of pollution control tax as well as environmental standard has been considered without compartmentalizing the economy into formal and informal sectors. Moreover, the study brings the concept of green capital explicitly at the static level.

Some of the recent research studies on water pollution abatement in India have found that the pollution tax on industrial water use should be several times higher than the current rate of water cess to realize the prescribed water quality standard. Gupta, Murty and Pandey (1989) have estimated the cost of water treatment for the paper and pulp industry, oil refineries, chemicals and sugar. Mehta, Mundle and Sankar (1993) have also carried out one study for estimating the marginal cost of abatement. Again Murty, James and Mishra (1999) have conducted a study that estimated a kind of pollution tax for the manufacturing industry for realizing a specified standard. But all these empirical studies are based on partial equilibrium analysis, theoretically whose validity depends on various restrictive conditions. The present paper thus can be considered as an important contribution in the context of the theoretical literature on pollution control. Not only it takes into account of various inter-sectoral linkages in the context of pollution control by using a general equilibrium framework, but it also helps us to draw the welfare implications of pollution control for a developing economy.

The basic idea behind the paper can be explained as follows. We consider a three-sector general equilibrium model. We assume that environmental pollution occurs through the production of goods of the polluting manufacturing sector using traditional capital. This sector is required to pay pollution emission tax. There is also a certain maximum allowable level of pollution decided by the pollution regulatory authority. Pollution coefficient is assumed to be an increasing function of maximum allowable pollution the maximum allowable pollution. We have tried to show that even if the maximum allowable level of pollution is reduced the polluting sector may produce adverse effects on the actual environmental pollution level of the economy. However we find that pollution control in the form of increase in the rate of emission tax on the polluting sector is unambiguously successful in reducing pollution generated from the sector. Apart from this, it is also shown that pollution control in the form of reduction in maximum allowable pollution improves welfare under some sufficient condition although it leads to an increase in urban unemployment. However, pollution control in the form of increase in emission tax reduces both urban unemployment and welfare of the economy under some sufficient conditions. Thus our study shows in the context of a general equilibrium structure an increase in environmental tax is preferred compared to an improvement in environmental standard under reasonable conditions.

The plan of the paper is as follows. Section 2 specifies the basic model. Section 3 examines the impact of pollution control, and makes a comparison between the effectiveness of tax and standard. Section 4 is an extension of the model with unemployment. The concluding remarks are made in section 5.

2. The Model

We consider a small open economy with three sectors: the agricultural sector (x), the polluting manufacturing sector (y) and the non-polluting manufacturing sector (z). Thus both sectors x and z are assumed to be non-polluting sectors within the economy. The small open economy assumption implies that the economy is a price taker in the international market so that the product prices are fixed. Production function in each sector exhibits constant returns to scale, variable coefficient technology and diminishing marginal productivity to the variable factors. Sectors 'x' and 'y' use traditional capital, K_t, which is perfectly mobile between these two sectors. Sector 'z' uses sophisticated, sector-specific green capital K_g, which implies use of EST. Labour is mobile among the three sectors. Sectors 'y' and 'z' employ labour at the contractual (fixed) wage rate $\bar{w}$. The other sector (that is sector 'x') is the residual sector. It employs the remaining workers at the competitive (flexible) wage w. Thus there is full employment of labour. The product of the agricultural sector is considered as a numeraire and its price has been set equal to unity. Sector x produces exportable product, whereas sectors y and z are the import-competing sectors. These types of assumptions are widely used in the literature on general equilibrium theory of international trade as we find in various extensions of Jones' (1965,1971) type structure. The present model is also an extension of Jones' (1965,1971) type structure.

The following symbols will be used in the formal presentation of the model.

a_{Li} = Labour-output ratio in the i-th sector, i = x, y, z

a_{Ki} = Capital-output ratio in the i-th sector, i = x, y, z

P_i = Price of the product of the i-th sector, i = x, y, z

w = Competitive equilibrium wage of sector 'x'

$\bar{w}$ = Contractual fixed wage rate of sectors 'y' and 'z'

X = Level of output of sector 'x'

Y = Level of output of sector 'y'

Z = Level of output of sector 'z'

r = Rate of return on traditional capital

R = Rate of return on green capital

L = Labour endowment

K_t = Traditional capital stock

K_g= Stock of green capital

α = Emission coefficient of sector ‘y’

β = Emission tax rate

Ω = Maximum allowable pollution(in terms of per unit of output of sector ‘y’)

Competitive equilibrium conditions are given as follows:

$$w a_{Lx}(w/r) + r a_{Kx}(w/r) = 1 \quad (1)$$

$$\bar{w}\, a_{Ly}(\bar{w}/r) + r a_{Ky}(\bar{w}/r) + \beta\alpha(\Omega) = P_y \quad (2)$$

$$\bar{w}\, a_{Lz}(\overline{w/}\ R) + R a_{Kz}((\overline{w/}\ R) = P_z \quad (3)$$

In equation (2) $\alpha^{/} > 0$ implying that a reduction in maximum allowable pollution leads to less per unit emission from the polluting sector .

Mobility of traditional capital between sectors ‘x’ and ‘y’ is given by

$$a_{Ky}(\bar{w}/r)Y + a_{Kx}(w/r)X = K_T \quad (4)$$

Sector specificity of green capital is given by

$$a_{Kz}(\bar{w}/R)Z = K_G(\Omega) \quad (5)$$

where $K_G' < 0$

The reason behind the sign of K_G' is that when there is an improvement in environmental standard in the form of reduction in maximum allowable pollution we find that the suppliers of green capital are more motivated to supply environmentally sound sophisticated capital. This is because as a result of a reduction in Ω it is expected that there will be an increase in the use of green capital.

Mobility of labour among the three sectors is given by,

$$a_{Ly}(\bar{w}/r)Y + a_{Lz}(\bar{w}/R)Z + a_{Lx}(w/r)X = L \quad (6)$$

From equation (3) we can determine R as $\bar{w}$ and P_z are given. From equation (2), given P_y and Ω, we can determine r. Putting the value of r in equation (1) we can determine the value of w. Hence the input-output ratios are known. Equation (5) can be used to determine Z. Finally from equations (4) and (6) , we can determine Y and X. In this model R is determined independently of Ω. Thus a_{KZ} (and also a_{LZ}) remains unchanged due to any change in Ω.

3. The Comparative Static Exercises

We would like to examine the impact of a reduction in maximum allowable pollution on the economy's level of environmental pollution and welfare. We consider that in an attempt to improve environmental standard, government adopts strict environmental regulation policy by reducing maximum allowable pollution expressed in terms of reduction in Ω.

A reduction in Ω leads to adoption of EST and this leads to an increase in the supply of green capital K_G. From equation (5), we see that this change implies an increase in Z as a_{KZ} remains unchanged. Again there is no change in a_{LZ} due to reduction in Ω, implying an increase in a_{LZ} Z due to reduction in Ω. Thus (L-$a_{LZ}Z$) falls. This leads to a fall in the effective supply of labour for sectors 'x' and 'y'. This, we call effect 1 of a reduction in Ω. We can refer to it as the *'Primary Rybczynski type effect'*.

Again we see that a reduction in Ω leads to an reduction in α(Ω). As a consequence of this, effective price of sector 'y', i.e., [P_y-β α(Ω)]=P_y* increases. From equation (2), it can be said that this increase in P_y* with given $\bar{w}$, leads to an increase in r. From equation (1), we again find that this increase in r reduces w, given that the price of the product of sector 'x' is unity. Thus we find that there are reduction in the levels of a_{KY} and a_{KX} implying reduction in demand for traditional capital at initial levels of Y and X and increase in the levels of a_{LY} and a_{LX} implying increase in demand for labour at initial levels of Y and X. It actually implies there is an increase in effective supply of traditional capital and a reduction in effective supply of labour. This is our effect 2. We can refer to it as *'Secondary Rybczynski type effect'*. The ultimate effect is the combination of *'Primary Rybczynski type effect'* and *'Secondary Rybczynski type effect'*. We refer to this as the *'Rybczynski type effect'*. Given the assumption that sector 'y' is more capital-intensive than sector 'x', we find that an increase in effective supply of capital and reduction in effective supply of labour causes the capital-intensive sector to expand (i.e., Y increases) and the labour-intensive sector to contract (i.e., X falls).

Total emission of pollutants in the economy is the emission from the polluting sector, i.e., $E=\alpha Y$.

$$
\begin{aligned}
dE/d\Omega &= \alpha' Y + \alpha(dY/d\Omega) \\
&= \alpha Y\,[(\alpha'/\alpha) + (1/Y)(dY/d\Omega)] \\
&= (\alpha Y/\Omega)\,[(\alpha'\Omega/\alpha) + (\Omega/Y)(dY/d\Omega)] \\
&= (\alpha Y/\Omega)[e_{\alpha,\Omega} + e_{Y,\Omega}] \qquad (7)
\end{aligned}
$$

where $e_{\alpha,\Omega} > 0$ is the elasticity of the emission coefficient with respect to Ω and $e_{Y,\Omega} < 0$ is the elasticity of output of the polluting sector with respect to Ω

So we find that $dE/d\Omega < 0$ if and only if .$|e_{Y,\Omega}| > |e_{\alpha,\Omega}|$

Proposition 1: *Pollution control in the form of reduction in maximum allowable pollution in a small open economy may increase the emission of pollutants from the polluting manufacturing sector. In fact under the condition* $|e_{Y,\Omega}| > |e_{\alpha,\Omega}|$, *a reduction in maximum allowable pollution leads to an increase in emission of pollutants in such an economy.*

Now we examine the impact of an increase in emission tax rate β on the pollution level.

An increase in β leads to a reduction in the effective price of Y i.e., a reduction in the level of $[P_Y - \beta\alpha(\Omega)] = P_Y^*$. Given $\bar{w}$, from equation (1) we find that reduction in P_Y^* causes a fall in r.

Again, given the price of the product of the agricultural sector, from equation (1) we find that a fall in r causes a rise in w. So an increase in β causes both ($\bar{w}$/r) and (w/r) to rise, though it causes no change in ($\bar{w}$/R). It causes both a_{KY} and a_{KX} to increase on one hand and a_{LY} along with a_{LX} to fall on the other. However, as there is no changes in the level of ($\bar{w}$/R) we find that an increase in β causes no change in the levels of a_{KZ} and a_{LZ}. Increase in the levels of a_{KY} and a_{KX} means there is a rise in the demand for traditional capital, for initial of X and Y, and therefore a fall in the effective supply of K_T. Again reduction in the levels of a_{LY} and a_{LX} means there is a reduction in the demand for labour, for initial of X, Y and Z (and also for given a_{LZ}. It means an increase in the effective supply of labour available for sectors 'x 'and 'y' It is to be noted that as Z remains unchanged due to an increase in β, the demand for labour in sector z also remains unchanged due to an increase in β. Hence the ultimate outcome is the operation of a *'Secondary Rybczynski type effect'*. Increase in effective supply of labour and reduction in effective supply of capital causes the capital-intensive sector 'y' to contract and the labour-intensive sector 'x' to expand. In other words , Y falls and X increases due to an increase in β.

Thus the effect on total emission of pollutants from the polluting sector is given by

$$(dE/d\beta) = \alpha\,(dY/d\beta) \qquad (8)$$

As (dY/d β) <0 we can conclude unambiguously (dE/d β)< 0.In other words, an increase in emission tax rate reduces the level of emission of pollutants in the economy. We summarize our results in the form of the following proposition.

Proposition 2: *Pollution control in the form of an increase in the rate of emission tax on the polluting manufacturing sector in a small open economy is successful in reducing the pollution generated from this sector as well in reducing the total pollution of such an economy.*

On the basis of the above discussion we may conclude that an improvement in environmental standard is not successful in reducing the pollution whereas an increase in emission tax rate reduces unambiguously the level of pollution in the context of our general equilibrium framework.

Next we would study the impact of a change in maximum allowable pollution on social welfare. We consider a quasi-concave social utility function, u, which depends on consumption demand of the three final goods, (D_X, D_Y and D_Z) and the level of emission E. It is also assumed that an increase in the level of pollution causes a negative externality on social welfare.

Thus u = u (D_X, D_Y, D_Z, E) (9)

Here u_x>0, u_y >0, u_z>0 and u_E<0.

Considering dV = (d u /u_x) as a measure of change in welfare measured in units of the product of sector 'x' we can write

$$dV = dD_X + P_Y dD_Y + P_Z dD_Z - \rho dE \quad (10)$$

Where $(u_E/u_x) = -\rho$, (given ρ>0)

ρ is the real social cost per unit of pollution

The budget constraint facing the economy (the trade balance condition) is given by

$$D_X + P_Y D_Y + P_Z D_Z = X + P_Y Y + P_Z Z \quad (11)$$

or, $D_X + P_Y D_Y + P_Z D_Z = wL + (\bar{w} - w)(a_{LY}Y + a_{LZ}Z) + rK_T + RK_G(\Omega) + \beta E$ (12)

In equation (12) we assume that the tax revenue βE is distributed in a lump sum manner among the capitalists and the workers.

Taking the total differential of equation (12) and using equation (10) we can write after some algebraic manipulation the following equation

$$dV + \rho dE = Ldw + (\bar{w}\text{-}w)(a_{LY}dY + Yda_{LY} + a_{LZ}\,dZ) - (a_{LY}Y + a_{LZ}Z)dw + K_T dr$$

$$+ RK_G'\,d\Omega + \beta dE$$

or, $$V\hat{V} = w\,\hat{w}\,[L - (a_{LY}Y + a_{LZ}Z)] + (\bar{w}\text{-}w)L[\,\lambda_{LY}\hat{Y} + \lambda_{LY}\sigma_Y\,\theta_{KY}\,\hat{r} + \lambda_{LZ}\,\hat{Z}\,]$$

$$+ r\,K_T\,\hat{r} + \Omega\,RK_G'\,\hat{\Omega} + E(\beta\text{-}\rho)\,\hat{E} \quad (13)$$

where θ_{ij} is the share of ith input (in value terms) in the product of the jth sector (in value terms), σ_Y is the elasticity of factor substitution in the 'y' sector,λ_{ij} is the share of ith factor(in physical terms) in the jth sector in the total factor endowment of that sector.

From equation (1) using the envelope condition we get

$$\hat{w} = -(\theta_{KX}/\theta_{LX})\,\hat{r} \quad (14)$$

Again from equation (2) using the envelope condition we get

$$\hat{r} = -(\varepsilon_1/\theta_{KY}) \quad (15)$$

wher.e $\varepsilon_1 = \pi\varepsilon$, $\pi = (\beta\alpha\,/\,P_y)$ is the share of emission tax (for unit level of output)in the price of the product of the polluting sector and $\varepsilon = \alpha^{/}(\Omega/\alpha)$ is the elasticity of emission coefficient with respect to maximum allowable pollution. As $\varepsilon > 0$ and $\pi > 0$ we have $\varepsilon_1 > 0$

Finally from equation (5) we get

$$\hat{Z} = e_{KG\Omega}\,\hat{\Omega} \quad (16)$$

where $e_{KG\Omega} = (\Omega K_G'/K_G) < 0$ is the elasticity of green capital with respect to maximum allowable pollution.

Using equations (14), (15) and (16) and after some algebraic manipulations we can rewrite equation (13) as

$V(\hat{V}/\hat{\Omega}) = (\epsilon_1 r/\Theta_{KY})(a_{KX}X - K_T) + (\bar{w}\text{-}w)L[\lambda_{LY}(\hat{Y}/\hat{\Omega}) + \lambda_{LY}\sigma_Y\ \Theta_{KY}(\hat{r}/\hat{\Omega}) + \lambda_{LZ}e_{K_G,\Omega}]$

$$+\Omega R K_G' + E(\beta\text{-}\rho)(\hat{E}/\hat{\Omega}) \quad (17)$$

Change in welfare can be shown as the sum total of four effects viz. factor-income effect given by$[(\epsilon_1 r/\Theta_{KY})(a_{KX}X - K_T)]$, labour reallocation effect given by $(\bar{w}\text{-}w)L[\lambda_{LY}(\hat{Y}/\hat{\Omega}) + \lambda_{LY}\sigma_Y\ \Theta_{KY}(\hat{r}/\hat{\Omega}) + \lambda_{LZ}e_{K_G,\Omega}]$, green capital effect given by $\Omega R K_G'$ and emission effect given by $E(\beta\text{-}\rho)(\hat{E}/\hat{\Omega})$. As we find $a_{KX}X < K_T$, $e_{KG\Omega} < 0$ and both $(\hat{Y}/\hat{\Omega})$ and $(\hat{r}/\hat{\Omega})$ are negative we conclude that the factor-income effect, labour reallocation effect and the green capital effect are negative. Here only the sign of emission effect is indeterminate. We know that $(\hat{E}/\hat{\Omega}) < 0$ if $|e_{Y,\Omega}| > |e_{\alpha,\Omega}|$. Thus if $\beta > \rho$, emission effect is negative so that a reduction in maximum allowable pollution increases welfare.

We now consider the expression for change in welfare as a result of an increase in emission tax rate. We follow the same procedure as that of the earlier case where we have considered the impact of reduction in maximum allowable pollution on social welfare and after some simplification we can write equation (12) as

$V(\hat{V}/\hat{\beta}) = (\hat{r}/\hat{\beta})r[K_T - a_{KX}X] + L(\bar{w}\text{-}w)[\lambda_{LY}(\hat{Y}/\hat{\beta}) + \lambda_{LY}\sigma_Y\ \Theta_{KY}(\hat{r}/\hat{\beta})]$

$$+ \alpha Y(\beta - \rho)[(\beta / (\beta\text{-}\rho)) + (\hat{Y}/\hat{\beta})] \quad (18)$$

Therefore change in welfare is the sum total of factor income effect, labour reallocation effect and emission effect.

Once again the sign of emission effect is indeterminate. Other two effects are negative. Under the sufficient condition $\beta > \rho$ and $|(\hat{Y}/\hat{\beta})| > [\beta / (\beta - \rho)]$ we find that emission effect is negative so that an increase in emission tax rate reduces welfare.

Proposition 3: *Pollution control in the form of a reduction in maximum allowable pollution improves welfare whereas pollution control in the form of increase in emission tax rate reduces welfare under some reasonable sufficient conditions.*

4 Extensions of the Model

Suppose we assume that the two manufacturing sectors (polluting and non-polluting) are located in the urban area and the agricultural sector is located in the rural area. As in the basic model the manufacturing (urban) wage rate is assumed to be fixed at a level, $\bar{w}$, much higher than the agricultural (rural) wage rate, w. We consider Harris-Todaro (1970) type of migration mechanism from the rural area to the urban area. So equation (19) is added to our basic model that we refer to as the migration-equilibrium condition and write it as follows:

$$\bar{w} = (1+\mu)w \quad (19)$$

μ is the urban unemployment rate [$\mu = (U/(a_{Ly}Y + a_{Lz}Z))$, where U is the level of urban unemployment].

The allocation of labour force among various sectors is modified as follows:

$$[a_{Ly}(\bar{w}/r)\, Y + a_{Lz}(\bar{w}/R)\, Z](1+\mu) + a_{Lx}(w/r)X = L \quad (6')$$

The working of the extended model is similar to that of the basic model. In the extended model μ is determined from equation (19).

We also modify the capital-intensity condition of the basic model as follows:

$$(a_{Ky}/a_{Ly}(1+\mu)) > (a_{Kx}/a_{Lx})$$

It implies that sector 'y' is more capital-intensive than sector 'x' in *'employment-adjusted terms'*.[3] It is to be noted that $(a_{Ky}/a_{Ly}(1+\mu)) > (a_{Kx}/a_{Lx}) \Rightarrow (a_{Ky}/a_{Ly}) > (a_{Kx}/a_{Lx})$

[3] See Khan(1982) for details.

The major results of the model remain unaltered even when the model is extended with unemployment. We have only the additional effect on urban unemployment as a result of changes in pollution control instruments.

A reduction in maximum allowable pollution reduces w. It implies an increase in the urban unemployment rate,μ, from equation (19). Again reduction in Ω raises 'r'. From section 3 we have found that a reduction in Ω increases the values of both Y and Z. Even in the presence of urban unemployment this result is valid and we are not repeating the explanations behind the results here. As $\bar{w}$ is given, we find that ($\bar{w}$/r) falls implying an increase in $a_{Ly}(\bar{w}/r)$ causing an increase in $a_{Ly}Y$. It is to be noted that though $a_{Lz}(\bar{w}/R)$ is independent of changes in Ω, a reduction in Ω causes an increase in Z so that $a_{Lz}Z$ increases. Increase in urban unemployment rate, μ, along with increase in urban employment, $(a_{Ly}Y+a_{Lz}Z)$, causes increase in the level of urban unemployment $U=\mu(a_{Ly}Y+a_{Lz}Z)$.

In case of an increase in emission tax rate we find that the opposite things happen. Increase in β raises w, reduces r, reduces μ, reduces Y (causes no change in the levels of a_{Lz} and Z) and also reduces $a_{Ly.}$ Thus the level of urban unemployment falls as a result of increase in β.

Proposition 4: *Pollution control in the form of a reduction in maximum allowable pollution increases the level of urban unemployment whereas pollution control in the form of increase in emission tax rate reduces the level of urban unemployment.*

The welfare implications are similar to those of the earlier model. The only difference is that here we have an additional unemployment effect. So to get the same welfare implications we need to modify marginally the sufficient conditions.

5. Concluding Remarks

In the present paper we thus find that the effects of pollution control creates a bunch of tradeoff in front of the policy makers. To be more specific, first we consider the effects of pollution control in the form of reduction in maximum allowable pollution. Such a measure may increase pollution generated from the polluting sector. In fact it increases pollution under some reasonable conditions. Apart from this, such a measure improves welfare under some sufficient conditions. Finally if Harris-Todaro (1970) type urban unemployment is introduced in this model, we find that such a measure increases urban unemployment. Next we consider the effects of pollution control in the form of increase in emission tax. Such a measure reduces pollution generated from the polluting sector though it reduces welfare under some sufficient conditions. However, increase in emission tax reduces urban unemployment. So from the point of view of pollution control increase in emission tax is better compared to reduction in maximum allowable pollution as a pollution control measure. Interestingly, if the objective of the policy makers is to improve social welfare reduction in maximum allowable pollution appears to be a better measure compared to increase in emission tax rate. Finally from the point of view of reduction in urban unemployment increase in emission tax rate is a superior measure compared to reduction in maximum allowable pollution. Thus on one hand there is a trade off in front of the policy makers between tax and standard from the point of view of reducing pollution and improving social welfare on one hand and from the point of view of reducing urban unemployment and improving social welfare on the other.

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