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Impact of Environmental Regulation in a Small Open Economy*

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Abstract

The paper attempts to examine the impact of change in government regulation about environmental standard on the level of environmental pollution and on the level of social welfare as well as real national income in the developing economy where the manufacturing sector is unable to maintain their pollution level upto maximum permissible level of pollution imposed by the environmental authority. A fine for violation of environmental standard is imposed on the producer of the manufacturing sector. The study also shows that under some reasonable conditions there arises a favourable impact on the level of overall environmental pollution and on the level of social welfare as well as real national income due to relatively stringent government regulation about environmental standard.

Keywords: Environmental regulation, Foreign enclave, Maximum permissible level of pollution, Violation of environmental standard, Penalty for violation.

JEL classification: F10, F11, F21, F23

1. Introduction:

In recent years the relevance of environmental quality and its deterioration due to increasing global economic activity has created a huge debate of whether to achieve economic growth at the expense of environmental standards or slow down the economic activity to keep up the environmental quality. In the trade-environment literature it has been argued that as competition becomes more global, people are concerned that relatively lenient environmental regulation and loose enforcement in developing countries give them a comparative advantage in pollution intensive goods and openness to trade and foreign direct investment might harm the host country's environment. Lowering trade barrier may encourage a relocation of polluting industries from countries with strict environmental policy to those with lenient policy. As trade liberalization leads to economic growth of the economy which again leads to increase in consumption demand, population size (due to a lower death rate) and high standard of leaving, we find that more environmental discharges are generated causing greater pollution. Thus environmentalists have argued that any gains from trade liberalization would be substantially outweighed by the damage it

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would do to the environment through pollution and loss of natural resources. Sometimes developing countries may purposively undervalue the environment in order to attract the multinational firms leading to excessive environmental pollution of developing economies.

Grossman and Krueger initiated the research on trade, growth and pollution by proposing an environmental Kuznets curve (EKC) that hypothesizes an inverse-U-shaped relationship between a country's per capita income and its pollution level. The literature on EKC suggests that the per capita income levels of most of the developing countries are well below the levels associated with the turning points of most estimated EKCs. It thus implies expansion of economic activities in these countries leads to more and more environmental degradation until the turning point is reached. Perrings, Bhargava and Gupta (1995) 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 and Medium 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 large firms. However it can be argued that as the informal sectors have limited access to an Environmentally Sound Technology (EST) and as they use backward technology these firms 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 process that are "dirty" from the environment point of view. Bartone and Benavides (1993) and Kent (1991) have shown that SMEs/informal sector firms can be more pollution intensive than large firms, as they use inputs relatively inefficiently with lack of pollution control equipment and lack of basic sanitation services such as sewers and waste disposals. Blackman and Bannister (1998) and Blackman (2000) have argued that urban clusters of informal firms like brick kilns and leather tanneries can create severe pollution problems. They have stated that it is very difficult for the government to control pollution from informal sector firms, and private sector should take initiatives to control pollution of informal sector.

In the literature very few theoretical works are developed covering this aspect of informal sector. Gupta (2002) has shown that a reduction in the maximum allowable level of pollution for the formal part of the economy reduces pollution emission of the formal part of the economy, though the pollution emission of the informal part of the economy increases, under some reasonable conditions. But under some special cases, the overall pollution of the economy increases due to high emission from the unregulated informal sector.

The main motivation behind this study generates from the fact that in spite of few empirical works only a few theoretical works have been made to examine the impact of change in government regulation about environmental standard on the level of overall environmental pollution and also on the level of welfare of the economy in the presence of violation of this government regulation and the penalty imposed on the producer for violation. This idea is something new in the context of the literature on analyzing environmental pollution in a general equilibrium set up. We have also done this in this present paper. Apart from this in the present paper, unlike most of the works in the literature, we have considered domestic capital and foreign capital as imperfect substitutes and they are treated as separate inputs.

In this paper first we consider the welfare effects of change in maximum permissible level of pollution in a developing economy where the manufacturing sector is unable to maintain its pollution level upto maximum permissible level imposed by the environment authority. The violation level is detected by subtracting maximum permissible level of pollution from the total level of pollution. Fine for violation is imposed on the producers who violate this maximum permissible level of pollution. This inclusion of violation and the penalty imposed on the producer for violation is something new in the context of the literature on analyzing environmental pollution in a general equilibrium set up. The interesting results of this paper can be summarized in the following manner. In the present scenario, we explore the possibilities of welfare improvement due to reduction in maximum permissible level of pollution and it also produces a favourable impact on the level of environmental pollution.

The plan of the paper is as follows. Section 2 specifies and explains the working of the basic three-sector model. The comparative static analysis regarding the effects of change in maximum permissible level of pollution has been considered in section 3. Finally the concluding remarks are made in section 4.

2. The Model

We consider a small open economy consisting of three sectors in a Heckscher-Ohlin-Samuelson framework. All these three sectors use labour (L), which is perfectly mobile among the sectors. Domestic capital (K_D) has been considered as mobile only between manufacturing sector (M) and agricultural sector (A) but foreign capital (K_F) is specific to sector F which is called as foreign enclave. Thus both sector M and A use domestic capital and labour as inputs whereas sector F uses foreign capital and labour as inputs. As domestic capital and foreign capital are different inputs rate of return on domestic capital and foreign capital are different[11]. Here endowment of labour, domestic capital and foreign capital are exogenously given. All the markets are assumed to be perfectly competitive. Entire foreign capital income is repatriated. Due to the assumption of small open economy the economy is considered as a price taker in the world market.

We now focus on the pollution part of our model. For the sake of simplicity we have assumed in this paper that the environmental pollution occurs only through production of the various sectors. In other words, we have ignored the role of consumer in creating environmental pollution. Each sector faces a maximum permissible level of pollution generated by the pollutants for producing unit in the economy. It is assumed that pollution of the rural sector remains within the maximum allowable level. Due to adoption of environmentally sound technology by foreign enclave the pollution level of this sector is assumed to be sustained within maximum permissible level. It is only the domestic manufacturing sector which violates environmental regulation. The manufacturing sector has to pay a fine for violating the maximum permissible level of pollution. The revenue earned by the government for violation is distributed as a transfer in a lump-sum manner among the workers and domestic capitalists. All markets are assumed to be perfectly competitive. The entire foreign capital income is repatriated. Here the manufacturing sector is the import competing sector where as the foreign enclave and the agricultural sectors are assumed to

[11] Our implicit assumption is that $r_F \geq r_F^w$, where r_F^w is the exogenously given world rate of return on foreign capital. For this reason foreign capital will be invested in the small open economy but due to government control the amount of foreign capital which enters in this country is also fixed at a particular point of time. It may be noted in this connection that in many developing countries we find that the shift towards more liberalized regime is a gradual one instead of drastic shift. Drastic policy changes may lead to socio-political tension in the economy in the short run. The assumption of exogenously given foreign capital stock can thus be justified as the government directly regulates the entry of foreign capital. See Marjit (1994) for details. See also Gupta and Gupta (1998).

be sectors that produce exportable products. The product of the agricultural sector is considered as the numeraire and its price has been set equal to unity.

For specifying our model on the basis of the above assumption we use the following notations.

X_i= Quantity of o utput produced by the ith sector, i = M, A, F.

w = Common wage rate of labor in all the sectors.

r = Rate of return on domestic capital.

r_F = Rate of return on foreign capital.

P_i = Price of the product of the ith sector, i = M, A, F.

L = Fixed endowment of labor.

K_D = Fixed endowment of domestic capital.

K_F = Fixed amount of foreign capital.

a_{ji} = Quantity of jth factor for producing one unit of output in the ith sector. j = L, K and i= M, A, F (we consider variable coefficient of technology).

λ_{ji} = Proportion of jth factor used in the production of the ith sector.

$\wedge$ = Proportional change.

θ_{ji} = Share of income of jth factor (j = L, K) in the ith sector (i = M, F, A).

$\bar{Z}$ = Economy's maximum permissible level of pollution.

σ_i = Elasticity of substitution of ith sector.

α_M = Emission coefficient of the manufacturing sector.

Ω = The measure of welfare.

V_M = Violation level of manufacturing sector.
f = Rate of fine for violation.

$f.V_M$ = Total penalty for violation of manufacturing sector.

Here violation is measured by subtracting maximum permissible level of pollution from the total level of pollution. So V_M is nothing but ($\alpha_M X_M$ - $\bar{Z}$). Now total cost for violation born by manufacturing sector is the total penalty for violation. So total cost for violation per unit of production is f. ($\alpha_M X_M$ - $\bar{Z}$)/ X_M

The competitive equilibrium conditions are gives by the following equations.

$$P_M = wa_{LM} + ra_{KM} + f.(\alpha_M X_M - \bar{Z})/X_M \quad (1)$$

$$1 = wa_{LA} + ra_{KA} \quad (2)$$

$$P_F = wa_{LF} + r_F a_{KF} \quad (3)$$

The sector specificity of foreign capital is given by the following equation

$a_{KF}X_F = K_F$ (4)

Mobility of domestic capital can be expressed as

$a_{KM}X_M + a_{KA}X_A = K_D$ (5)

We specify the labor market equilibrium condition as

$a_{LM}X_M + a_{LA}X_A + a_{LF}X_F = L$ (6)

In this model we have 6 equations with six variables w, r, r_F, X_M, X_A, X_F. So the system is consistent. Due to variable coefficient technology a_{LM}, a_{KM}, a_{LA}, a_{KA} are all the functions of w and r and the factor coefficient a_{LF}, a_{KF} are the function of w and r_F. The variables P_M, P_F, $\overline{Z}$, K_F, K_D, L that are assumed to be given exogenously. Here the endogeneous variables are to be solved simultaneously and hence it is an indecomposable structure.

3. Comparative Statics:

Now we want to examine the impact of change in maximum permissible level of pollution on the level of environmental pollution as well as on the level of national welfare of our small open economy.

Totally differentiating equations (1) and (2) and after some algebraic simplification we can get [see appendix for details]

$$0 = \theta_{LM}\ \hat{w} + \theta_{KM}\ \hat{r} - \{(f\overline{Z}\ \hat{\overline{Z}})/P_MX_M)\} + \{(f.\ \overline{Z}\ \hat{X}_M)/(P_MX_M)\} \quad (1.1)$$

$$\text{or,}\quad 0 = \theta_{LA}\ \hat{w} + \theta_{KA}\hat{r} \quad (2.1)$$

Solving equations (1.1) and (2.1) by Cramer's rule and after some algebraic simplification we can get

$$\hat{w}/\hat{\overline{Z}} = G\theta_{KA}\{(\hat{X}_M/\hat{\overline{Z}}) - 1\} \quad (7)$$

$$\hat{r}/\hat{\overline{Z}} = G\theta_{LA}\{1 - (\hat{X}_M/\hat{\overline{Z}})\} \quad (8)$$

Here $|\theta| = \theta_{LA}\theta_{KM} - \theta_{LM}\ \theta_{KA}$ and $G = (f.\overline{Z}\ /\ P_MX_M)/|\theta|$ which is positive.

Since the M sector is more capital intensive comparing to the A sector so $\theta_{KM}/\theta_{LM} > \theta_{KA}/\theta_{LA}$ i.e. $(\theta_{LA}\theta_{KM} - \theta_{LM}\ \theta_{KA}) = |\theta| > 0$

Using the concept of envelope theorem (unit iso-quant) we can write from equation (3)

$$\hat{r}_F/\hat{\overline{Z}} = -(\theta_{LF}/\theta_{KF})\ G\theta_{KA}\{(\hat{X}_M/\hat{\overline{Z}}) - 1\} \quad \text{[see appendix for details]} \quad (9)$$

$$\text{Now}\ \hat{w}/\hat{\overline{Z}} - \hat{r}/\hat{\overline{Z}} = G\{(\hat{X}_M/\hat{\overline{Z}}) - 1\}$$

$$\hat{w}/\hat{\overline{Z}} - \hat{r}_F/\hat{\overline{Z}} = G(\theta_{KA}/\theta_{KF})\{(\hat{X}_M/\hat{\overline{Z}}) - 1\}$$

Taking total differentiation of equation (5) and (6) and using equations (7), (8), (9) we can get [see appendix for details]

$$\hat{X}_M / \hat{\hat{Z}} = (H\lambda_{LA} - I\lambda_{KA}) / |\Delta| \quad (10)$$

$$\hat{X}_A / \hat{\hat{Z}} = (BI - HD) / |\Delta| \quad (11)$$

where $|\Delta| = (B\lambda_{LA} - D\lambda_{KA})$

$B = \lambda_{KM} + \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G$

$D = \lambda_{LM} - \lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF}) - \lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G$

$H = \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G$

$I = -\lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G - \lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF})$

Here the values of B, H are positive and the value of I is negative but the value of D is ambiguous.

$H\lambda_{LA} - I\lambda_{KA} = \lambda_{LA}\lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{LA}\lambda_{KA}\theta_{LA}\sigma_A G$
$+ \lambda_{KA}\lambda_{LM}\theta_{KM}\sigma_M G + \lambda_{KA}\lambda_{LA}\theta_{KA}\sigma_A G + \lambda_{KA}\lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF})$

Here the value of $(H\lambda_{LA} - I\lambda_{KA})$ is positive.

So the value of $(\hat{X}_M / \hat{\hat{Z}})$ is dependent on the value of $|\Delta|$.

$(\hat{X}_M / \hat{\hat{Z}}) > 0$ if $(B\lambda_{LA} - D\lambda_{KA}) > 0$ but the value of $(\hat{X}_A / \hat{\hat{Z}})$ is ambiguous.

We have already proved that the value of $(B\lambda_{LA} - D\lambda_{KA}) > 0$ if $(\lambda_{LA}\lambda_{KM} - \lambda_{KA}\lambda_{LM}) > 0$ i.e. the M sector is more capital intensive compared to the A sector. It is only under the above sufficient condition $(B\lambda_{LA} - D\lambda_{KA}) > 0$ so that $(\hat{X}_M / \hat{\hat{Z}}) > 0$. But the value of $(\hat{X}_A / \hat{\hat{Z}})$ is ambiguous.

In order to interpret the impact of environmental regulation through the change in the maximum permissible level of pollution on the level of overall environmental pollution and on the level of real national income we need to find out the impact of that on the output levels of different sectors. A change in the maximum permissible level of pollution leads to a change in per unit cost of violation of government regulation for the manufacturing sector. This leads to change in the effective product price of manufacturing sector and hence change in factor prices. We refer to it as modified *Stolper–Samuelson type effect.* The second effect is the *Rybczynski type effect* that in turn is the outcome of change in input-output coefficients due to change in factor prices resulting from a change in the cost of violation. We can discuss these effects in the following manner.

A change in the maximum permissible level of pollution for manufacturing sector leads to a change in the levels of per unit penalty of sector M, leading to change in the effective price of this sector. This causes a *Stolper-Samuelson type effect*. This effect leads to change in factor prices. This change creates change in the levels of input-output coefficient and the degree of this change depends upon the elasticity of factor substitution. Change in the levels of input-output coefficient creates a *Rybczynski type effect.* This effect arises due to change in the demand for factors ultimately leading to excess demand or excess supply of factors. We have already explained earlier that this excess demand or excess supply of factors leads to an effect which is equivalent to change in effective factor endowment. Ultimately the impact on the levels of output of the manufacturing sector is shown in terms of equation (10).

It is only under the sufficient condition ($B\lambda_{LA}$- $D\lambda_{KA}$) >0 i.e. manufacturing sector is more domestic capital intensive compared to agricultural sector [see appendix for details] we can say that ($\hat{X}_M / \hat{\bar{Z}}$) >0. Again the values of $\hat{w} / \hat{\bar{Z}}$, $\hat{r} / \hat{\bar{Z}}$ and $\hat{r}_F / \hat{\bar{Z}}$ are dependent on the condition that whether $\hat{X}_M / \hat{\bar{Z}}$ <1 or not.

As ($H\lambda_{LA}$ - $I\lambda_{KA}$) < $|\Delta|$ [See appendix] so we can say that ($\hat{X}_M / \hat{\bar{Z}}$) < 1. So under this sufficient conditions we can also say that ($\hat{w} / \hat{\bar{Z}}$) > 0, ($\hat{r} / \hat{\bar{Z}}$) < 0 and ($\hat{r}_F / \hat{\bar{Z}}$) < 0.

As we have assumed that only the domestic manufacturing sector violates environmental regulation so the total level of environmental pollution decreases with the increase in environmental standard through decrease in the maximum permissible level of pollution imposed by the government. Thus relatively stringent government regulation about environmental standard produces a favourable impact on the level of environmental pollution.

We next consider the impact of change in maximum permissible level of pollution on the national welfare as well as real national income[12]. Now we consider quasi-concave social utility function, denoted by U that depends on consumption demand for three final goods denoted by D_A, D_M and D_F.

Thus it is shown as $U = U(D_A, D_M, D_F)$ (12)

Taking total differential of equation (12) and the using the fact (U_M/U_A) = P_M and (U_F/U_A) = P_F (where $U_A = \partial U/\partial D_A$ and $U_M = \partial U/\partial D_M$ and $U_F = \partial U/\partial D_F$) it is possible to write $d\Omega = dD_A + P_M dD_M + P_F dD_F$ (12.1)

Here $d\Omega = dU/U_A$.

Following Caves, Frankel and Jones (1996) we find that $d\Omega$ implies a measure of change in welfare measured in units of the product of sector A. Here in the absence of tariff world price is equal to domestic price.

The trade balance equation requires that

$$D_A + P_M D_M + P_F D_F = X_A + P_M X_M + P_F X_F - r_F K_F \quad (13)$$

We know that $X_A + P_M X_M + P_F X_F$ is the value of output measured at domestic price which is nothing but $wL + rK_D + f.(\alpha_M X_M - \bar{Z}) + r_F K_F$

$$X_A + P_M X_M + P_F X_F = w.L + rK_D + f.(\alpha_M X_M - \bar{Z}) + r_F K_F \quad (13.1)$$

Taking total differential of equation (13) we can get

$$dD_A + P_M dD_M + P_F dD_F = dX_A + P_M dX_M + P_F dX_F - r_F dK_F - K_F dr_F$$

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[12]The indirect welfare function of the economy depends on prices and national income. In case of a small open economy with given prices, impact on welfare will be same as impact on real national income.

Using equation (12.1) and also using equation (13.1) we get

$d\Omega = wdL + Ldw + r.dK_D + K_{D.}\, dr + f.\alpha_M dX_M - f.d\overline{Z}$

$(\hat{\Omega}/\hat{\overline{Z}}) = (I/\Omega)\,[\varepsilon_w(G\theta_{KA})\,\{(\hat{X}_M/\hat{\overline{Z}})-1\} + (1-\varepsilon_w)\,G\theta_{LA}(\{1-(\hat{X}_M/\hat{\overline{Z}})]$

$+ E(\hat{X}_M/\hat{\overline{Z}}) - J$

$= G[\varepsilon_w - \theta_{LA}]\,\{(\hat{X}_M/\hat{\overline{Z}})-1\}(I/\Omega) + E(\hat{X}_M/\hat{\overline{Z}}) - J$

Here ε_w = share of labour income in domestic factor income, $E = (f.\alpha_M X_M/\Omega)$ and

$J = f.\overline{Z}_M/\Omega.$

Here $\hat{X}_M/\hat{\overline{Z}} < 1$ as $(H\lambda_{LA} - I\lambda_{KA}) < |\Delta|$

As $(\hat{X}_M/\hat{\overline{Z}}) < 1$, $(\hat{\Omega}/\hat{\overline{Z}}_M) < 0$ if $\theta_{LA} < \varepsilon_w$ and $E(\hat{X}_M/\hat{\overline{Z}}) < J$

Here $E(\hat{X}_M/\hat{\overline{Z}}) - J$

$= (f.\alpha_M X_M/\Omega)(\hat{X}_M/\hat{\overline{Z}}) - (f.\ \overline{Z}\ /\Omega)$

$= (f\overline{Z}_M/\Omega)\{(\alpha_M\, dX_M/d\overline{Z}) - 1\}$

Now $E(\hat{X}_M/\hat{\overline{Z}}) < J$ if $(\alpha_M dX_M/d\overline{Z}) < 1$.

Here $\theta_{LA} < \varepsilon_w$ i.e. share of labour income in agricultural sector is less than the share of wage bill in domestic factor income in a developing economy and $\hat{X}_M/\hat{\overline{Z}} < 1$ as $(H\lambda_{LA} - I\lambda_{KA}) < |\Delta|$

As $(\hat{X}_M/\hat{\overline{Z}}) < 1$ and $\theta_{LA} < \varepsilon_w$, $(\hat{\Omega}/\hat{\overline{Z}}) < 0$ if $E(\hat{X}_M/\hat{\overline{Z}}) < J$

Now $E(\hat{X}_M/\hat{\overline{Z}}) < J$ if $(\alpha_M dX_M/d\overline{Z}) < 1$. i.e. change in total amount of pollution due to change in maximum permissible level of pollution is less than 1. So we can say that under the assumption that the revenue earned by the government for violation is distributed as a transfer in a lump-sum manner among the workers and domestic capitalists, a reduction in permissible level of pollution leads to a positive impact on national welfare as well as real national income under sufficient conditions that share of labour income in agricultural sector is less than the share of wage bill in domestic factor income and marginal impact of change in environmental standard on the total level of pollution is less than one. We summarise our results in the form of the following proposition.

Proposition: *A relatively stringent government regulation about environmental standard produces a favourable impact on the level of environmental pollution and on the level of social welfare as well as real national income if (i)* $(\lambda_{KM}/\lambda_{LM}) > (\lambda_{KA}/\lambda_{LA})$ *(ii)* $(\theta_{LA} < \varepsilon_w)$ *and (iii)* $(\alpha_M dX_M/d\overline{Z}) < 1$.

4. Concluding remarks:

In recent years environmental degradation is considered as one of the most important issues in the context of the developmental problems of a developing economy. Here we have assumed that environmental regulation has been imposed on the economy and only the manufacturing sector is unable to maintain their pollution level upto maximum permissible level imposed by the environment authority. A fine for violation of manufacturing sector is assumed to be imposed on the producer who violates the environmental standard imposed by the environment authority. The present paper shows the possibilities of both environmental upgradation and welfare improvement due to imposition of more stringent government regulation about environmental standard.

The present paper thus shows that strict environmental regulation may produce a very encouraging impact on the level of environmental pollution and also on the level of the national welfare as well as real national income. Thus our results show how improvement of social welfare would be possible with the improvement of environmental quality in a developing economy. Our results may encourage the policy makers who want to improve social welfare with maintaining qualitative environmental standard of the developing countries like India.

Appendix

Derivation of the expressions for ($\hat{w}/\hat{\bar{Z}}$), ($\hat{r}/\hat{\bar{Z}}$) and ($\hat{r}_F/\hat{\bar{Z}}$).

Totally differentiating equations (1) and (2) and rearranging we can get

$$\text{or, } 0 = \theta_{LM}\ \hat{w} + \theta_{KM}\ \hat{r} - \{(f\bar{Z}\ \hat{\bar{Z}})/(P_M X_M)\} + \{(f.\bar{Z}\ \hat{X}_M)/(P_M X_M)\} \tag{1.1}$$

$$0 = \theta_{LA}\ \hat{w} + \theta_{KA}\,\hat{r} \tag{2.1}$$

Now from equations (1.1) and (2.1) we can get

$$\hat{w}/\hat{\bar{Z}} = \theta_{KA}[\{f.(\bar{Z}/P_M X_M)\} - \{f(\bar{Z}/P_M X_M)(\hat{X}_M/\hat{\bar{Z}})\}]/(\theta_{LM}\,\theta_{KA} - \theta_{LA}\theta_{KM})$$

$$\hat{r}/\hat{\bar{Z}} = -\theta_{LA}[\{f.(\bar{Z}/P_M X_M)\} - \{f.(\bar{Z}/P_M X_M)(\hat{X}_M/\hat{\bar{Z}})\}]/(\theta_{LM}\,\theta_{KA} - \theta_{LA}\theta_{KM})$$

$$\therefore \hat{w}/\hat{\bar{Z}} = \theta_{KA}[f.(\bar{Z}/P_M X_M)(\hat{X}_M/\hat{\bar{Z}} - 1)]/|\theta|$$

$$\hat{r}/\hat{\bar{Z}} = \theta_{LA}[f.(\bar{Z}/P_M X_M)\{1 - (\hat{X}_M/\hat{\bar{Z}})\}]/|\theta|$$

$$\text{or, } \hat{w}/\hat{\bar{Z}} = G\theta_{KA}\{(\hat{X}_M/\hat{\bar{Z}}) - 1\}$$

$$\hat{r}/\hat{\bar{Z}} = G\theta_{LA}\{1 - (\hat{X}_M/\hat{\bar{Z}})\} \quad \text{where } G = f.(\bar{Z}/P_M X_M)/|\theta|$$

Here $|\theta| = \theta_{LA}\theta_{KM} - \theta_{LM}\theta_{KA}$

Since the M sector is more capital intensive comparing to the A sector so $\theta_{KM}/\theta_{LM} > \theta_{KA}/\theta_{LA}$ i.e. $(\theta_{LA}\theta_{KM} - \theta_{LM}\theta_{KA}) = |\theta| > 0$

Using the envelope condition (or the concept of unit isoquant) we find

$wda_{LF} + r_F da_{KF} = 0$ so that $a_{LF}\, dw + a_{KF}\, dr_F = 0$

or, $\hat{r}_F / \hat{\hat{Z}} = -(\theta_{LF}/\theta_{KF})(\hat{w}/\hat{\hat{Z}})$

$\therefore \hat{r}_F / \hat{\hat{Z}} = -(\theta_{LF}/\theta_{KF})\, G\theta_{KA}\{(\hat{X}_M / \hat{\hat{Z}}) - 1\}$

Now $\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}} = G\{(\hat{X}_M / \hat{\hat{Z}}) - 1\}$

$\hat{w}/\hat{\hat{Z}} - \hat{r}_F/\hat{\hat{Z}} = G(\theta_{KA}/\theta_{KF})\{(\hat{X}_M / \hat{\hat{Z}}) - 1\}$

Derivation of the expressions for ($\hat{X}_M / \hat{\hat{Z}}$) and ($\hat{X}_A / \hat{\hat{Z}}$).

Differentiating (5) and (6) we can get

$\lambda_{KM}\hat{X}_M + \lambda_{KA}\hat{X}_A = -\lambda_{KM}\hat{a}_{KM} - \lambda_{KA}\hat{a}_{KA}$

$\lambda_{LM}\hat{X}_M + \lambda_{LA}\hat{X}_A = -\lambda_{LF}\hat{X}_F - \lambda_{LF}\hat{a}_{LF} - \lambda_{LM}\hat{a}_{LM} - \lambda_{LA}\hat{a}_{LA}$

We know that elasticity of substitution of the ith sector can be written as

$\sigma_i = (a_{Ki} - a_{Li})/(\hat{w} - \hat{r}_i)$, here $r_A = r_M = r$ and rate of interest in foreign enclave is r_F

By applying envelope theorem (or using the concept of unit isoquant) we get from equation (2)

$wda_{LA} + rda_{KA} = 0$

$\Rightarrow \theta_{LA}\hat{a}_{LA} + \theta_{KA}\hat{a}_{KA} = 0$

$\therefore \hat{a}_{KA} = -(\theta_{LA}/\theta_{KA})\,\hat{a}_{LA}$

Now $(\hat{a}_{KA} - \hat{a}_{LA}) = -(\theta_{LA}/\theta_{KA})\,\hat{a}_{LA} - \hat{a}_{LA}$

$= -\hat{a}_{LA}\,(\theta_{LA} + \theta_{KA})/\theta_{KA}$

$= -\hat{a}_{LA}/\theta_{KA}$

Similarly by applying envelope theorem equation (1) can be written as

$\hat{a}_{KM} = -(\theta_{LM}/\theta_{KM})\,\hat{a}_{LM}$

By applying envelope theorem equation (3) can be written as

$\hat{a}_{KF} = -(\theta_{LF}/\theta_{KF})\ \hat{a}_{LF}$

$\therefore\ \hat{a}_{Li} = -\theta_{Ki}\sigma_i\,(\hat{w} - \hat{r}_i)$ and $\hat{a}_{Ki} = \theta_{Li}\sigma_i\,(\hat{w} - \hat{r}_i)$

Putting the values of $\hat{a}_{Li}$ and $\hat{a}_{Ki}$ (for i = M, A, F) we can get

$$\text{or, } \lambda_{KM}(\hat{X}_M/\hat{\hat{Z}}) + \lambda_{KA}(\hat{X}_A/\hat{\hat{Z}}) = -\lambda_{KM}\theta_{LM}\sigma_M\,(\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}}) - \lambda_{KA}\theta_{LA}\sigma_A(\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}})$$

$$\lambda_{LM}(\hat{X}_M/\hat{\hat{Z}}) + \lambda_{LA}(\hat{X}_A/\hat{\hat{Z}}) = \lambda_{LF}\sigma_F(\hat{w}/\hat{\hat{Z}} - \hat{r}_F/\hat{\hat{Z}}) + \lambda_{LM}\theta_{KM}\sigma_M\,(\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}}) + \lambda_{LA}\theta_{KA}\sigma_A\,(\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}})$$

Putting the value of $(\hat{w}/\hat{\hat{Z}} - \hat{r}/\hat{\hat{Z}})$ and $(\hat{w}/\hat{\hat{Z}} - \hat{r}_F/\hat{\hat{Z}})$ and rearranging the above two equations we can get

$$(\hat{X}_M/\hat{\hat{Z}})\{\lambda_{KM} + \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G\} + \lambda_{KA}(\hat{X}_A/\hat{\hat{Z}})\} = \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G$$

$$(\hat{X}_M/\hat{\hat{Z}})\{\lambda_{LM} - \lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF}) - \lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G\} + \lambda_{LA}(\hat{X}_A/\hat{\hat{Z}}) = -\lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G - \lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF})$$

$$\text{or, } B(\hat{X}_M/\hat{\hat{Z}}) + \lambda_{KA}(\hat{X}_A/\hat{\hat{Z}}) = H$$

$$D(\hat{X}_M/\hat{\hat{Z}}) + \lambda_{LA}(\hat{X}_A/\hat{\hat{Z}}) = I$$

where $B = \lambda_{KM} + \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G$

$D = \lambda_{LM} - \lambda_{LF}\sigma_F G(\theta_{KA}/\theta_{KF}) - \lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G$

$H = \lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{KA}\theta_{LA}\sigma_A G$

$I = -\lambda_{LM}\theta_{KM}\sigma_M G - \lambda_{LA}\theta_{KA}\sigma_A G - \lambda_{LF}\sigma_F G\,(\theta_{KA}/\theta_{KF})$

Here the values of B, H are positive and the value of I is negative but the value of D is ambiguous.

$\therefore\ \hat{X}_M/\hat{\hat{Z}} = (H\lambda_{LA} - I\lambda_{KA})/|\Delta|$

$\hat{X}_A/\hat{\hat{Z}} = (BI - HD)/|\Delta|$

where $|\Delta| = (B\lambda_{LA} - D\lambda_{KA})$

Now $H\lambda_{LA} - I\lambda_{KA} = \lambda_{LA}\lambda_{KM}\theta_{LM}\sigma_M G + \lambda_{LA}\lambda_{KA}\theta_{LA}\sigma_A G$

$+ \lambda_{KA}\lambda_{LM}\theta_{KM}\sigma_M G + \lambda_{KA}\lambda_{LA}\theta_{KA}\sigma_A G + \lambda_{KA}\,\lambda_{LF}\sigma_F G\,(\theta_{KA}/\theta_{KF})$

Here the value of $(H\lambda_{LA} - I\lambda_{KA})$ is positive.

Here the values of ($\hat{X}_M / \hat{\hat{Z}}$) is dependent on the value of $|\Delta|$.

As $|\Delta| = (B\lambda_{LA} - D\lambda_{KA}) = (\lambda_{LA}\lambda_{KM} - \lambda_{KA}\lambda_{LM}) + G[\lambda_{LA}\lambda_{KM}\theta_{LM}\sigma_M + \lambda_{LA}\,\lambda_{KA}\theta_{LA}\sigma_A$

$+ \lambda_{KA}\lambda_{LM}\theta_{KM}\sigma_M + \lambda_{KA}\lambda_{LA}\theta_{KA}\sigma_A + \lambda_{KA}\,\lambda_{LF}\sigma_F\,(\theta_{KA}/\theta_{KF})]$

We find that $(H\lambda_{LA} - I\lambda_{KA}) < |\Delta|$ so that $0 < (\hat{X}_M / \hat{\hat{Z}}) < 1$

$(\hat{X}_M / \hat{\hat{Z}}) > 0$ if $(B\lambda_{LA} - D\lambda_{KA}) > 0$ but the value of $\hat{X}_A / \hat{\hat{Z}}$ is ambiguous.

We have already proved that the value of $(B\lambda_{LA} - D\lambda_{KA}) > 0$ if $(\lambda_{LA}\lambda_{KM} - \lambda_{KA}\lambda_{LM}) > 0$ i.e. the M sector is more capital intensive comparing to the A sector.

References:

Bartone, C. R. and L. Benavides (1993): "Local Management of Hazardous Wastes from Small-Scale and Cottage Industries", *World Bank, Washington D.C. Presented at the 5th Pacific Basin Conference on Hazardous Waste, Honolulu, Hawaii,* November 8-12.

Becker, R. & Henderson, J (2000) ''Effects of Air Quality Regulation on Polluting Industries'', *Journal of Political Economy* 108: 379-421

Blackman, A. (2000): "Informal Sector Pollution Control: what policy options do we have?", *Discussion Paper 00-02-REV, Resources for the Future, Washington D.C.*

Blackman, A. and Bannister, G. J. (1998): "Community Pressure and Clean Technology in the Informal Sector: an Econometric Analysis of Propane by Tradition Mexican Brick

Eskeland, G. & Harrison, A**.** (2003), ''Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis'', *Journal of Development Economics* 70(1): 1-23

Grossman, G. M. & Krueger, A. B. 1991. "Environmental Impacts of a North American Free Trade Agreement", NBER working paper 3914, Nov. 1991.

Gupta, K. (2002): "The Urban Informal Sector and Environmental Pollution: A Theoretical Analysis"" Working Paper, No 02-006, *Centre for Environment and Development Ecnomics (CEDE), Environment Department, University of York, UK.*

Kent, L. (1991): "The Relationship between Small Enterprises and Environmental Degradation in the Developing World (with emphasis on Asia)", *US Agency for International Development, Washington, D.C.*

Leonard, J. (1988): Pollution and Struggle for the World Product, *New York: Cambridge University Press.*

Perrings, C., Bhargava, S. and Gupta, J. (1995): "The Transfer of Environmentally Sound Technology to Small and Medium Scale Enterprices in Developing Countries: A Survey of the Issues." *Paper prepared for UNCTAD, Geneva.*

Person, C. (1987): "Multinational corporation, Environment and the Third World, Durham": *Duke University.*