Chapter 2
Accumulation of Capital for Pollution Abatement and Immiserizing Growth—A Theoretical Result for Developing Economies

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1 Introduction

In an open economy, when growth is driven by factor accumulation, the economy gains by way of expansion of domestic income at constant terms of trade (TOT), but the post-growth equilibrium international TOT may go against the growing nation if its growth is concentrated heavily in its exportable sector (ultra-export-biased growth), and the level of national welfare of the growing economy in the post-growth scenario may turn out to be less than its pre-growth scenario, if the loss in TOT is stronger than the income gains due to growth for such an economy. This is the phenomenon of *immiserizing growth* as coined by Bhagwati (1958). In the standard Heckscher–Ohlin framework for an open economy, the results of changes in welfare gains and losses due to factor accumulation hold true when the international equilibrium remains stable both before and after growth and there is free trade between nations and the markets are perfectly competitive.

Concerns for the environment in an economy have received articulated attention by economic analysts in recent years, who point to the various forms of externalities that pollution or environmental degradation of any form emits either through consumption or through production. These externalities have opened up the cases for different forms of domestic distortions and the trade interventions and environmental interventions reflecting alternative forms of lobbying by the interested group, and the scope for devising an optimum framework for resolving such conflicts. Under the new era of climate change, it is interesting to ask whether global environmental problems such as global warming and climate changes could be tackled by a shift of capital from developed to developing nations. The developed nations have already entered into a process of adopting eco-friendly technologies, particularly the economies of the European Community. The USA, being the highest contributor of global warming, had not ratified the Kyoto Protocol which requires that the countries must reduce its carbon emission below the 1990 level. Thus, there is room for

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improvement within the developed economies from an environmental perspective, but that has to be accompanied with loss in production. But the damages that have been made to the environment due to the process of rapid industrialization in developed countries are irrevocable as far as climate changes are concerned. However, any further damage can be prevented through international cooperation, and one such area of cooperation is to allow for movement of foreign capital into developing countries for abatement of pollution. We shall use a two-sector general equilibrium framework for an open economy with environmental pollution acting as an externality to examine the conditions of *immiserizing* growth in developing countries under two situations: (1) domestic capital accumulation for pollution abatement purposes and (2) foreign capital accumulation for pollution abatement purposes.

From the developing country's perspective, the driver for the companies may be earning carbon credits without diverting or less diverting the resources away from production. This would lead to a steady growth process of the emerging economies. However, the question that remains unanswered is the welfare aspect in terms of using foreign capital for carbon emission purposes and using domestic capital for the same purpose. This chapter is limited to this comparative study of conditions for immiserizing growth patterns through trade when domestic and foreign capital is used for pollution abatement purposes. The environmental distortion is expressed as the cost borne by the society to combat the problems of pollution. We keep the analysis simple in terms of general equilibrium model of international trade with full employment of resources as developed among others by Kemp (1969) and Hazari and Sgro (1983).

In case of domestic labour and capital accumulation, we observe what would be the conditions that are needed for welfare improvement in the economy. When the Rybczynski result is valid, then capital accumulation in the economy would lead to welfare gain only when expansion of capital-intensive sectors and improvement in TOT are larger than the contraction of labour-intensive sectors and the loss due to degradation of environmental quality. When the Rybczynski result does not hold, then, under the Marshall–Lerner condition, the economy faces a net welfare loss as the contraction of capital-intensive sectors and deterioration in TOT adds to the loss due to contraction of labour-intensive sectors and degradation of environmental quality. In this case, it is to be noted that environmental degradation, to a large extent, could not be overcompensated by any production gains or gains in TOT. This leads to immiserizing growth. The best policy to avoid immiserizing growth, in this case, is to impose environmental tax and to give production subsidy to the capital-intensive sectors such that TOT also moves in favour of the domestic country. In the case of labour accumulation, we find a different story when the Rybczynski result does not hold good; there would be undoubtedly a welfare gain. Thus, an economy may improve when the accumulation of factor, which generates less environmental degradation, would lead to welfare gains. Even if the factor is more pollution intensive, then also the economy gains from its accumulation provided the impact on environmental quality is not so considerable. However, immiserizing growth would be inevitable when the second sector contracts more unless environmental tax is imposed on sector I and a subsidy is given to sector II.

When domestic and foreign capital accumulation for pollution abatement purposes are adopted by the country separately, then by comparing the two results it is

inferred that an economy's welfare improves more when the economy invites foreign capital for pollution abatement purposes rather than siphoning away part of domestic capital for such purposes. However, a prerequisite to the foreign capital accumulation for pollution abatement is that the Marshall–Lerner condition should be satisfied. However, this is a necessary condition but not a sufficient condition as welfare improvement also depends on the utilization capacity of foreign capital and the rate of interest at which foreign capital is being provided. In this context, it is to be noted that international cooperation among countries for common interests of improving the environment requires that developing countries be provided financial assistance by the developed countries to meet the international environmental standards. Financial assistance in the form of foreign capital for pollution abatement at low interest rates could improve the welfare of least developed countries (LDCs), both in terms of environmental quality and in terms of net production gain. Foreign capital technologies are assumed to be environment saving. However, if the interest rates were too high to be repatriated by the gains in TOT and production, then immiserizing growth would take place. The best policy is a tax policy. Not only should an environmental tax be imposed but also a production tax on both the sectors should be imposed. When TOT moves against the country, then immiserizing growth could be avoided by imposing environmental tax on the price of sector I only. Domestic capital accumulation for pollution abatement in developing countries would siphon off the domestic capital resources, which could otherwise be used in the production process. The Rybczynski theorem's validity would lead to immiserizing growth when contraction of a labour-intensive sector becomes more than the improvement in environmental quality and expansion in a capital-intensive sector taken together. Then the best policy to overcome such distortion is to impose environmental tax and to provide production subsidies to both the sectors with the proceedings of the tax.

The plan of the present chapter is as follows. Section 2 describes the model. Section 3 describes the effects of accumulation of domestic factors. Section 4 analyses the effects of introducing foreign capital in the model, and the conditions for immiserizing growth. Section 5 explains how the country is benefited if it utilizes foreign capital instead of its own capital for pollution abatement. Section 6 contains the concluding remarks.

2 The Model

The impact of capital accumulation on the welfare of an economy may lead to immiserizing growth in the presence of some externality. In the present chapter, the possibility of immiserizing growth in the presence of environmental resource as a factor of production is checked, firstly, when capital accumulation occurs domestically with a part being used for the purpose of pollution abatement, and secondly, when foreign capital is introduced in the model only for the purpose of pollution abatement.

The model developed here is a simple general equilibrium Heckscher–Ohlin model of trade with environment as the third factor of production. Including Meade-

type production externality, the changes in the model have been observed in the existing literature of international trade. Unlike Judith Dean (1999) and Ramon Lopez (1994), weak separability between environmental resource and conventional factors of production is not assumed.

The production function is defined as follows:

$$X_i = F(K_i, L_i, E_i), \text{ where}$$

K_i Capital input of the ith sector,
L_i Labour input of ith sector,
E_i Environmental resource of the ith sector and
X_i Output level of the ith sector.

The following assumptions are made about the above production function:

1. It follows constant returns to scale. Thus, the production function can be written as follows:

$$X_i = L_i f(k_i, e_i), \tag{2.1}$$

where k_i is the capital–labour ratio and e_i is the environmental resource and labour ratio.

2. The assumptions on the marginal productivity functions may be stated as follows: The marginal productivity of labour is

$$\frac{\partial X_i}{\partial L_1} = f_i - k_i f_{ik_i} > 0, \tag{2.2}$$

where $f_{ik_1} = \frac{\partial X_i}{\partial k_i}$.

The marginal productivity of capital is

$$\frac{\partial X_i}{\partial K_i} = f_{ik_1} > 0. \tag{2.3}$$

The marginal productivity of environmental resource is

$$\frac{\partial X_i}{\partial E_i} = f_{ie_1} > 0. \tag{2.4}$$

The analysis has been carried out in an open economic framework. The home country is assumed to be labour-abundant compared to the foreign country, which is capital-abundant. Commodity 1 is assumed to be more labour-intensive, and commodity 2 is assumed to be more capital-intensive. Thus, (1) $L_1 > L_2$ and (2) $K_1 < K_2$. Thus, country 1 will export commodity 1 and import commodity 2. We also assume that there is a difference in the pre-trade price ratios of the two countries, such that $\left(\frac{p_2}{p_1}\right)_1 > \left(\frac{p_2}{p_1}\right)_2$, where p_1 and p_2 are prices of commodities 1 and 2. Commodity 2 is assumed to use more environmental resources compared to commodity 1. Production

of commodity 2 creates more pollution than commodity 1 as commodity 2 is capital-intensive and commodity 1 is labour-intensive. Thus, we assume that the capital technologies in the countries are such that more pollution is created by the use of capital in both the countries. Thus, $E_1 < E_2$.

The balance of trade (BoT) equilibrium is

$$B_1 = pM_2, \tag{2.5}$$

where

B_1 is the export of commodity 1, $B_1 = X_1 - C_1$,
M_2 is the import level of commodity 2, $M_2 = C_2 - X_2$,
p is the relative price level of importable, $p = \frac{p_2}{p_1}$ and
p_1 and p_2 are prices of commodities 1 and 2.

The social welfare function is defined as follows:

$$W = W(C_1, C_2, E), \tag{2.6}$$

where

C_1 is the domestic consumption level of commodity 1,
C_2 is the domestic consumption level commodity 2 and
E is the level of environmental quality.

Competition prevails in all markets. Thus, wage rate w and rental rate r appear exogenous to the model and are expressed in terms of commodity 1. Thus, we can conclude, w equals the marginal productivity of labour and r equals the marginal productivity of capital. Two equations are, thus, obtained:

$$w = f_1 - k_1 f_{1k_1} - e_1 f_{1e_1} = p(f_2 - k_2 f_{2k_2} - e_2 f_{2e_2}), \tag{2.7}$$

$$r = f_{1k_1} = p f_{2k_2}. \tag{2.8}$$

From the above specification of the model, it could be observed what the general equilibrium condition holds, i.e. whether the autarky TOT is tangent to the production possibility curve (PPC) at autarky equilibrium.

Slope of the PPC is defined by $\frac{dX_1}{dX_2}$, and the slope of the TOT line is $(-p)$, which is nothing but $\left(-\frac{p_2}{p_1}\right)$.

From the marginal productivity of labour, capital and environmental resource conditions, we obtain

$$\frac{dX_1}{dX_2} = -\frac{p(1+\alpha_1)}{(1+\alpha_2)} = -p\gamma, \tag{2.9}$$

where $\alpha_i = \frac{f_{ie_i} dE_i}{F_i K_i dK_i + F_i L_i dL_i}$ and $\gamma = \frac{1+\alpha_1}{1+\alpha_2}$. Since capital intensive sector is assumed to be more environmental resource-intensive, we assume $\alpha_1 < \alpha_2$. Thus, $\left|\frac{dX_1}{dX_2}\right| < p$. Therefore, we see from Fig. 2.1 that at equilibrium the TOT TT′ is intersecting the PPC PP′.

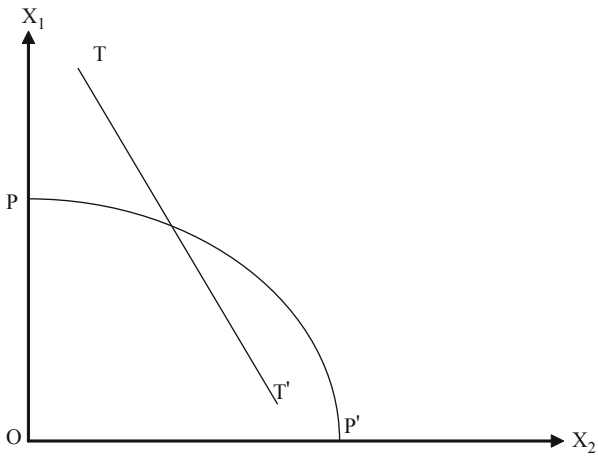

Fig. 2.1 Initial equilibrium

3 Conditions for Immiserizing Growth in Case of Domestic Factor Accumulation

To analyse the conditions of immiserizing growth under domestic factor accumulation, under the model presented in Sect. 1, only the effect of capital accumulation in the economy is noticed in this chapter, as our main objective of the study has been capital accumulation for the pollution abatement purpose. Therefore, in this chapter we ignore effects of the second factor, i.e. labour accumulation and concentrate only on effects of capital accumulation, K_D.

We define welfare function, $W = W(C_1, C_2, E)$ from Eq. (2.6). Taking total differentials,

$$dW = W_1 dC_1 + W_2 dC_2 + W_3 dE.$$

Dividing both sides by W_1 we get

$$\frac{dW}{W_1} = \frac{W_1 dC_1 + W_2 dC_2}{W_1} + \frac{W_3 dE}{W_1} = \frac{dC_1 + p dC_2 + W_3 dE}{W_1}, \tag{2.10}$$

where $p = p_2/p_1$.

From budget constraint, we know that $(X_1 + pX_2) = (C_1 + pC_2)$.

Taking total differential, we get $dX_1 + pdX_2 + X_2 dp = dC_1 + pdC_2 + C_2 dp$

or
$$dC_1 + pdC_2 = dX_1 + pdX_2 - M_2 dp, \tag{2.11}$$

where $M_2 = C_2 - X_2$.

Putting Eq. (2.11) in Eq. (2.10), we get

$$dW/W_1 = dX_1 + pdX_2 - M_2 dp + (W_3/W_1)dE.$$

Differentiating with respect to K, capital accumulation,

$$(1/W_1)(dW/dK) = dX_1/dK + p(dX_2/dK) - M_2(dp/dK) + (W_3/W_1)(dE/dK). \tag{2.12}$$

Now from the Rybczynski result, in the presence of environmental resource as a factor of production, it is observed that X_1 decreases with the increase in capital endowment:

$$dX_1/dK = (f_1 - e_1)(dL_1/dK) + f_1 e_1(dE_1/dK) < 0.$$

Effects on X_2 are ambiguous as $dX_2/dK = (f_2 - e_2)(dL_2/dK) + f_2 e_2(dE_2/dK)$, and

$$dX_2/dK \quad \text{will be } > 0 \qquad \text{if} \qquad |(f_2 - e_2)(dL_2/dK)| > |f_2 e_2(dE_2/dK)|.$$

The changes in the TOT could be obtained as follows:

Differentiating the balance of payments equilibrium equation with respect to capital endowment, K, we get

$$\frac{dp}{dK} = \frac{p\dfrac{\partial M_2}{\partial K}}{(\eta_x + \eta_m - 1)M_2}, \tag{2.13}$$

where η_x and η_m are the import elasticities of the two countries.

M_2 is defined[1] as $M_2 = D_2(p, Y) - X_2(p, Y)$,

where D_2 is the domestic demand of the second commodity and X_2 is total output level of the second commodity.

Thus, initially p remaining constant, the partial derivative of M_2 with respect to K is $\frac{\partial M_2}{\partial K} = \frac{\partial D_2}{\partial Y}\frac{dY}{dK} - \frac{\partial X_2}{\partial K}$, and using Eq. (2.9),

$$\frac{dY}{dK} = \frac{dX_1}{dK} + p\frac{dX_2}{dK} = p(1-\gamma)\frac{dX_2}{dK}.$$

Then $\frac{\partial M_2}{\partial K} = [pm_h(1-\gamma) - 1]\frac{dX_2}{dK}$,

where m_h is the marginal propensity to consume, $\frac{\partial D_2}{\partial Y}$.

Thus, $\frac{dp}{dK} = \frac{p[pm_h(1-\gamma)-1]}{(\eta_x+\eta_m-1)M_2}\frac{dX_2}{dK}$. For simplicity, initially we put $p = 1$. Then

$$\frac{dp}{dK} = \frac{m_h(1-\gamma) - 1}{(\eta_x + \eta_m - 1)M_2}\frac{dX_2}{dK}. \tag{2.14}$$

According to Marshall–Lerner condition, the sum of import elasticities is greater than unity and both γ and m_h are less than unity.[2] Thus, from the above equation, we get that if the production of X_2 increases (decreases), then the TOT would move in favour of (against) country 1.

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[1] This definition is obtained from B. Hazari (1983) where the domestic demand is a function of price and income and the production of importables is also a function of price and income level.

[2] $\gamma < 1$, by assumption as $\alpha_1 < \alpha_2$. m_h is the mpc which is less than unity.

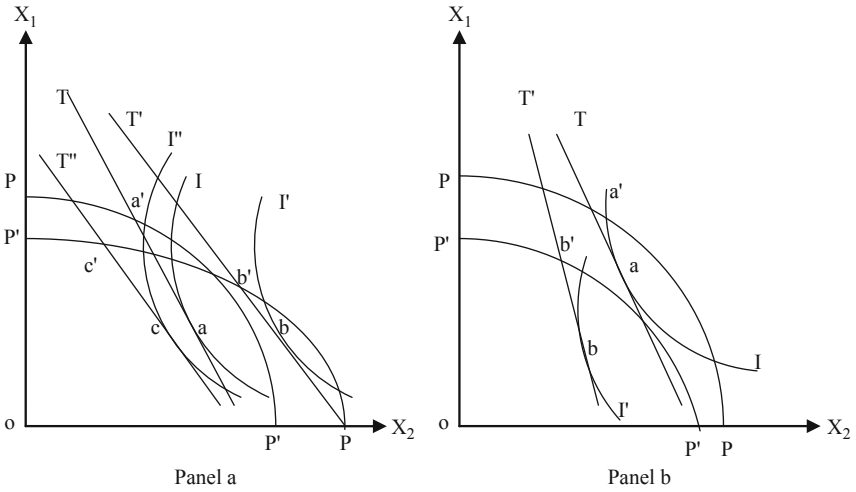

Fig. 2.2 Depicting conditions of immiserizing growth under domestic capital accumulation

As production of import sector rises (X_2), then $p = p_2/p_1$ will fall. Therefore, TOT will move in favour of the home country. Now E will fall as more capital is accumulated.

Therefore, $(dE/dK) < 0$.

Thus,

$$(1/W_1)(dW/dK) = dX_1/dK + p(dX_2/dK) - M_2(dp/dK) + (W_2/W_1)(dE/dK) > 0,$$

only when $\quad dX_1/dK + (W_1/W_2)(dE/dK) \,|<|\, p(dX_2/dK) - M_2(dp/dK)|.$

So if this condition is satisfied, the country will improve its welfare with capital accumulation. Thus, condition of immiserizing growth is

$|dX_1/dK + (W_1/W_2)(dE/dK)| > |p(dX_2/dK) - M_2(dp/dK)|$. This is depicted in Fig. 2.2a.

From Fig. 2.2a, we observe that initial TOT, T, intersects initial PPC, PP, at a′ and is tangent to the initial indifference curve at point a. Welfare will improve with capital accumulation when falling TOT, T′, intersects PPC, P′P′, at point b′. However, if the falling TOT shows a large deterioration along with environmental degradation, then immiserizing growth condition is captured at point c where welfare reduces to I″ from I and the TOT, T″ intersects PPC at point c′.

If $dX_2/dK < 0$, i.e. if $|(f_2 - e_2)(dL_2/dK)| < |f_2 e_2(dE_2/dK)|$, then when both X_1 and X_2 will fall, the country's export supply falls and import demand rises. TOT will move against the country under the Marshall–Lerner condition. In that case, $(1/W)(dW/dK) < 0$, as each term in Eq. (2.12) becomes negative. Thus, if the Rybczynski theorem (Reference Appendix) is not valid for the capital-intensive sector, then capital accumulation leads to immiserizing growth. This is shown in Fig. 2.2b, where immiserizing growth is captured by the shift of welfare indifference curve from I to I′. Here PPC moves from PP to P′P′. The best policy to avoid immiserizing growth would be to impose environmental tax and give production

subsidies to the sectors to implement environment-friendly technology in order to expand production of both the sectors.

If the Rybczynski theorem is valid, then in the presence of the environmental resource factor, welfare improves by domestic capital accumulation only when the expansion in the capital-intensive sector and improvement in the TOT is more than the absolute contraction of the labour-intensive sector and deterioration in environmental quality. Under the Marshall–Lerner condition, there would be immiserizing growth if the Rybczynski theorem were not valid.

4 Effects of Foreign Capital Introduced in the Economy for Pollution Abatement Purposes

In the earlier sections, capital available in the economy is the domestic capital, K. When foreign capital is introduced in the economy, then total capital K is divided into two parts—domestic capital K_{D} and foreign capital K_{F}. Foreign capital can only be used for pollution abatement purposes. Domestic capital is used for production purposes. Then the question arises whether the economy's welfare gains due to pollution reduction leading to more production would be wiped out by the welfare losses due to deterioration in TOT and repatriation of foreign capital. Thus, the economy would have either a net gain or a net welfare loss.

The production function is rewritten as $X_i = F_i(K_{Di,}\ Li,\ E_i) = L_i f_i(k_{Di,}\ e_i)$. Assumption: Foreign capital invested for pollution abatement is partly or fully absorbed by the society, $dE = \theta dK_F (0 < \theta \leq 1)$. Environmental quality is partially or fully improved according to the economy's utilization capacity of foreign capital for pollution abatement purposes. Thus, θ is defined as the parameter for utilization capacity.

4.1 Effect on Output Levels

Differentiating the production function with respect to K_F,

$dX_1/dK_F = f_1 e_1 (dE_1/dK_F)$.

Similarly, $dX_2/dK_F = f_2 e_2 (dE_2/dK_F)$.

The effects of improvement in environmental quality on the employment of environmental resources by the sectors are positive, as productivity of environmental resources is enhanced as these resources become less pollution generating. Thus, $\frac{dE_1}{dK_F} > 0$, $\frac{dE_2}{dK_F} > 0$,

$$\therefore \frac{dX_1}{dK_F} = L_1 f_1 e_1 \left(\frac{dE_1}{dK_F}\right) > 0 \tag{2.15}$$

$$\frac{dX_2}{dK_F} = L_2 f_2 e_2 \left(\frac{dE_2}{dK_F}\right) > 0 \tag{2.16}$$

Therefore, gains from trade due to production should increase as the export sector expands and the import sector's expansion reduces imports.

4.2 Effects of Foreign Capital Growth on Balance of Trade (BoT) Equilibrium

BoT equilibrium Eq. (2.5) is rewritten as

$B_1 = pM_2 + iK_F$.

Thus, from BoT equilibrium, we can infer that trade surplus in the economy should cover the interest payments on capital account, i.e. capital deficit of iK_F. Another way to interpret the changes in BoT equilibrium is that total production must exceed total consumption to cover the interest payments to the foreign country. Whether the country's trade balance improves or deteriorates with the import of foreign capital can be checked in the following way. Trade balance will improve only when

$$\left(\frac{dB_1}{dK_F}\right) \geq \left[\frac{d(pM_2 + iK_F)}{dK_F}\right]$$

or

$$\frac{dB_1}{dp}\frac{dp}{dK_F} \geq p\frac{\partial M_2}{\partial K_F} + p\frac{\partial M_2}{\partial p}\frac{dp}{dK_F} + M_2\frac{dp}{dK_F} + i \tag{2.17}$$

Dividing throughout by $M_2(dp/dK_F)$ we get,

$$(\eta_m + \eta_x - 1) \geq \eta_m + i,$$

or $\eta_x \geq i + 1$, where η_m is the import elasticity of demand for the second commodity and η_x is the elasticity of exports.

The balance of trade would only improve when the difference between the export elasticity and rate of interest, at which the home country is borrowing foreign capital, is greater than unity.

4.3 Effects on National Income

National income in terms of exportable is defined as $Y = X_1 + pX_2$. Out of this national income, foreign capital, which is taken only for the purpose of pollution abatement, has to be repaid to the foreigners in terms of interest payments, iK_f. Thus, national income should be defined as, $Y = X_1 + pX_2 - iK_F$. So, TOT remaining constant, the partial effect on national income is, using Eq. (2.9),

$\frac{\partial Y}{\partial K_F} = \frac{\partial X_1}{\partial K_F} + p\frac{\partial X_2}{\partial K_F} - i = p(1-\gamma)\frac{\partial X_2}{\partial K_F} - i$. Thus, national income would rise only if the gains from production are greater than the rate of interest at which the foreign capital is repatriated.

4.4 Effects on TOT

From Eq. (2.17), $\frac{dp}{dK_F} = \frac{p(\partial M_2/\partial K_F)+i}{(\eta_x+\eta_m-1)M_2}$,

M_2 is defined as $M_2 = D_2(p, Y) - X_2(p, Y)$.

Thus, initially p remaining constant, the partial derivative of M_2 with respect to K_F is $\frac{\partial M_2}{\partial K_F} = \frac{\partial D_2}{\partial Y}\frac{dY}{dK_F} - \frac{\partial X_2}{\partial K_F}$,

or $\frac{\partial M_2}{\partial K_F} = m_h[p(1-\gamma)-1]\frac{dX_2}{dK_F} - m_h i$. Thus, initially putting $p = 1$, for simplicity,

$$\frac{dp}{dK_F} = \frac{(m_h(1-\gamma)-1)\frac{dX_2}{dK_F} + (1-m_h)i}{(\eta_x+\eta_m-1)M_2}. \tag{2.18}$$

Under the Marshall–Lerner condition, the change in TOT remains ambiguous as $m_h < 1$, $\gamma < 1$ and $\frac{dX_2}{dK_F} > 0$. This implies that the second term in the numerator is positive while the first term is negative. Thus, TOT will move in favour of the home country (country 1) with foreign capital introduced in the economy for pollution abatement, only if $\left|(m_h(1-\gamma)-1)\frac{dX_2}{dK_F}\right| > |(1-m_h)i|$. If this condition is not satisfied, then the TOT moves against the country.

4.5 Conditions for Immiserizing Growth Under Foreign Capital (K_F) Accumulation

In the basic model, we have defined social welfare function, $W = W(C_1, C_2, E)$. The main objective of this exercise is to observe the effects of foreign capital invested for the purpose of pollution abatement only on the level of social welfare:

$W = W(C_1, C_2, E)$.

Taking total differential and dividing both sides by W_1, we get,

$$\begin{aligned} dW/W_1 &= dC_1 + (W_2/W_1)dC_2 + (W_3/W_1)dE \\ &= dC_1 + pdC_2 + (W_3/W_1)dE. \end{aligned} \tag{2.19}$$

From Balance of Payments (B.O.P.) equilibrium condition, we know that,

$$(X_1 + pX_2) - (C_1 + pC_2) = iK_F,$$

or $$(C_1 + pC_2) = X_1 + pX_2 - iK_F,$$

or $$dC_1 + pdC_2 + C_2dp = dX_1 + pdX_2 + X_2dp - idK_F,$$

or $$dC_1 + pdC_2 = dX_1 + pdX_2 - M_2dp - idK_F. \tag{2.20}$$

Combining Eqs. (2.19) and (2.20),

$$(dW/W_1) = dX_1 + pdX_2 - M_2dp - idK_F + (W_3/W_1)dE.$$

Therefore,

$$\begin{aligned}(1/W_1)\,(dW/dK_F) &= dX_1/dK_F + p\,(dX_2/dK_F) - M_2\,(dp/dK_F) - i \\ &\quad + (W_3/W_1)\,(dE/dK_F) \\ &= dX_1/dK_F + p\,(dX_2/dK_F) - M_2\,(dp/dK_F) - i \\ &\quad + (W_3/W_1)\,\theta,\end{aligned}$$

as $dE = \theta dK_F$.

Now, $dX_1/dK_F + pdX_2/dK_F > 0$, as from Eqs. (2.19) and (2.20), dX_1/dK_F and $dX_2/dK_F > 0$.

From Eq. (2.18), dp/dK_F is ambiguous. Now let us first assume $dp/dK_F < 0$, i.e. it moves in favour of the country.

Under this condition, $dX_1/dK_F + p(dX_2/dK_F) - M_2(dp/dK_F) > 0$.

But welfare will increase only when $(1/W_1)(dW/dK_F) > 0$, i.e. $dX_1/dK_F + p(dX_2/dK_F) - M_2(dp/dK_F) + (W_3/W_1)\,\theta > i$. So gains from production increase and improvement in TOT under the Marshall–Lerner condition should be greater than the rate of interest, which the home country pays the foreign country by using the foreign capital for the purpose of pollution abatement. If this condition is not satisfied, then that leads to immiserizing growth. This is described with the help of Fig. 2.3a.

From Fig. 2.3a, the initial PPC, PP, intersects the initial TOT line, T, at a′. The initial consumption takes place at point a where the T is tangent to the welfare indifference curve I. With the initiation of pollution abatement with foreign capital, the PPC shifts to P′P′ from PP. The TOT, T, shifts to T′ becoming flatter. There would be an overall improvement if

$$dX_1/dK_F + p(dX_2/dK_F) - M_2(dp/dK_F) + (W_3/W_1)\theta > i.$$

This improvement is depicted in the figure by the shift of I to a higher indifference curve I′. But if the above condition is not satisfied, i.e.

$$dX_1/dK_F + p(dX_2/dK_F) - M_2(dp/dK_F) + (W_3/W_1)\theta < i,$$

then, the country would suffer an immiserizing growth, in spite of the expansion in production sectors. The interest payments to the foreigners become so high that it undermines the improvement of production. The TOT also shifts to the left to T″ as interest is high, but is flatter due to the expansion of sectors. The welfare is reduced, shown by the shift of the indifference curve to I″. An environmental tax coupled with production tax should be imposed, such that the PPC shifts to P″P″ and TOT line shifts to T‴, leading to a rise in welfare level to I‴. So the Marshall–Lerner condition alone cannot ensure the country's welfare improvement. The rate of interest at which the foreign capital is repatriated plays an important role in this context. The rate of absorption of foreign capital, θ, by the economy for pollution abatement also plays a major role. Higher the rate of absorption, higher the improvement in environmental quality will be. Therefore, welfare of the economy increases.

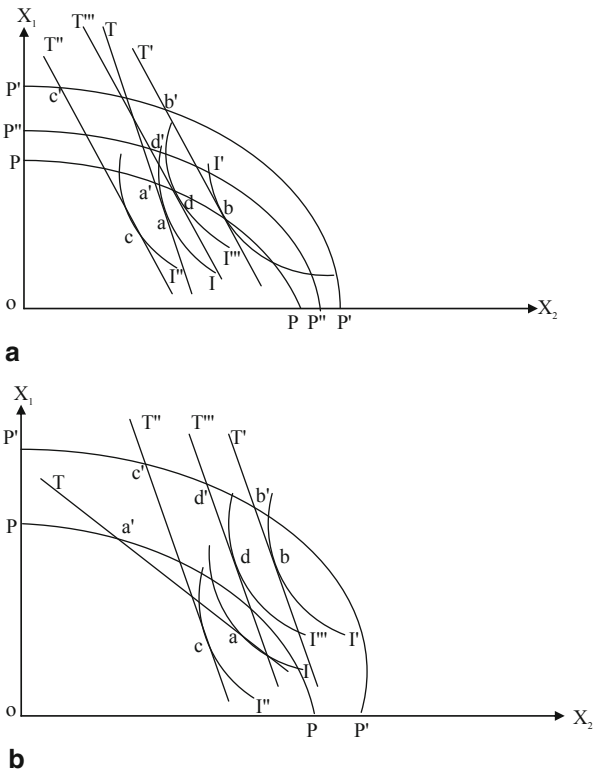

Fig. 2.3 Conditions of immiserizing growth with foreign capital for pollution abatement

If $dp/dK_F > 0$, then the condition for immiserizing growth would be $dX_1/dK_F + p(dX_2/dK_F)M_2(dp/dK_F) + (W_3/W_1)\theta < i + M_2(dp/dK_F)$. This is depicted in Fig. 2.3b.

Welfare improvement is shown by the shift of welfare indifference curve from I to I′. However, immiserizing growth is shown by a shift to I″. This could be avoided by reducing TOT. This could be brought about by imposing an environmental tax on the price of sector I, such that the TOT line shifts to the right. On the same PPC, P′P′, the new TOT line, T‴, is flatter than the TOT line, T″, indicating a fall in TOT, thereby shifting the production point to d′ from c′. Thus, effects on TOT becomes one of the major criteria for welfare improvement when foreign capital is introduced in the economy for pollution abatement purposes, along with the rate of interest at which foreign capital is being repatriated.

5 Effects of Domestic Capital for Pollution Abatement Purposes

In Sect. 3 of this chapter, foreign capital for pollution abatement purposes was introduced in the model and how the economy may become better off both in TOT and environmental improvement was analysed, and it was observed that an economy's

welfare improves if it is able to repatriate the foreign capital from production and trade improvement due to pollution abatement. However, it would be interesting to observe whether welfare improves more in the case of domestic capital being utilized for pollution abatement or foreign capital being used for the same.

For the analysis, we have introduced some simple changes in the model. Domestic capital is now used for two purposes: (1) production and (2) pollution abatement. Thus, total capital endowment, K, in the economy is divided into two parts—K_p, part of total capital used for production purposes, and $K_{a,}$ for pollution abatement purposes. Thus, $K = K_a + K_p$.

Assumptions:

1. α part of total capital is used in pollution abatement purpose.
2. μ is the rate of utilization of capital for pollution abatement purposes.

The production function is rewritten as $X_i = F_i(K_{pi}, Li, E_i) = L_i f_i(k_{pi}, e_i)$.

If there is domestic capital accumulation, i.e. if there is an increase in the endowment of domestic capital, then in order to observe the welfare effects, we have to observe the following effects.

5.1 Effects on Output Levels

At first, we try to observe the effects on labour and capital inputs of both the industries. We rewrite the capital endowment equation as follows:

$$\begin{aligned} K &= K_a + K_p \\ &= K_a + K_{p1} + K_{p2}, \qquad \text{where } K_{pi} = \text{capital input in the i}^{\text{th}} \text{ industry} \\ &= k_1 L_1 + k_2 L_2 + K_a \end{aligned}$$

Change in total capital endowment on labour inputs and environmental resources of the industries—

$$dL_1/dK = -(1-\alpha)/(k_2 - k_1),$$

and

$$dL_2/dK = -(1-\alpha)/(k_2 - k_1), \tag{2.21}$$

$$dE/dK = (dE/dK_a)(dK_a/dK) = \alpha\mu. \tag{2.22}$$

dE_1/dK and dE_2/dK are assumed to be positive as improvement in environmental quality has positive effects on the employment of environmental resources, which now have greater productivity.

Using the Rybczynski result (Reference Appendix), we obtain the effects on output levels as follows:

$$(dX_i/dK) = (f_i - e_i)(1-\alpha)(dL_i - dk) + f_i e_i (dE_i/dK).$$

Thus,

$$(dX_1/dK) = -(f_1 - e_1)(1-\alpha)/(k_2 - k_1) + f_1 e_1 (dE_1/dK), \tag{2.23}$$

$$(dX_2/dK) = (f_2 - e_2)(1-\alpha)/(k_2 - k_1) + f_2 e_2 (dE_2/dK). \tag{2.24}$$

The capital-intensive sector expands unambiguously as there is an increase in the productive capital and environmental resource due to domestic capital accumulation. The contraction of the labour-intensive sector due to domestic capital accumulation cannot be unambiguously determined. However, contraction in the labour-intensive sector due to the increase in productive capital endowment in the economy should be more than its expansion due to increase in the environmental resource, which is a result of the improvement in environmental quality as part of the domestic capital being used for the purpose of pollution abatement. If the cost–benefit approach is taken into consideration, then pollution abatement cost should be lower than the production cost. Hence, $(\alpha < 1-\alpha)$, the part of the domestic capital used for the pollution purpose should be less than the part used for production purpose, such that the cost incurred for pollution abatement does not exceed the benefits derived. In such a situation, the Rybczynski result would also hold for the labour-intensive industry.

5.2 *Effects on TOT*

From Eq. (2.14),

$$\frac{dp}{dK} = \frac{m_h(1-\gamma) - 1}{(\eta_x + \eta_m - 1)M_2} \frac{dX_2}{dK}.$$

Following the Rybczynski result, the capital-intensive sector will expand and the labour-intensive sector will contract due to domestic capital accumulation. Then the import demand will fall as the importable capital-intensive sector expands. As a result, the price of imported commodity in the world market will fall. However, due to the contraction of labour-intensive sector, export supply will fall, raising the price of exports in the world market. As a result, the TOT ($\mathrm{p} = \frac{p_2}{p_1}$) will move in favour of the country.

5.3 *Conditions for Immiserizing Growth Under Domestic Capital (Kp + Ka) Accumulation*

We obtain the condition where the welfare changes are positive. This is done as follows:

$$(1/W_1)(dW/dK) = dX_1/dK + p(dX_2/dK) - M_2(dp/dK) + (W_3/W_1)(dE/dK).$$

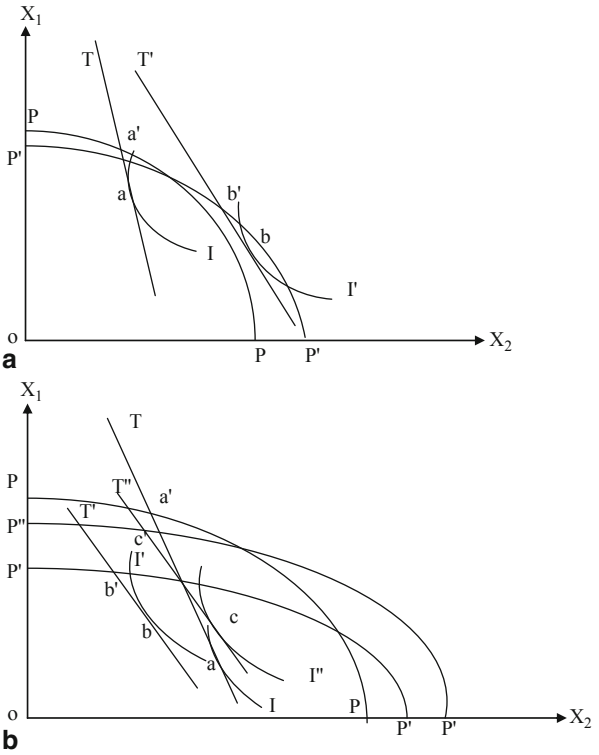

Fig. 2.4 Conditions of immiserizing growth under domestic capital for pollution abatement purpose

The first term on the right-hand side is only negative. Other terms are positive. Thus, the condition for immiserizing growth is derived as follows:

$(1/W_1)(dW/dK) > 0$ is the condition for immiserizing growth. This implies,

$p(dX_2/dK) - M_2(dp/dK) + (W_3/W_1)(dE/dK)| > dX_1/dK|$. This implies that absolute decrease in output level of labour-intensive export sectors should be less than the increase in output level of the capital-intensive sectors and the positive TOT effect. This improvement in welfare is shown in Fig. 2.4a.

Improvement in TOT and environmental quality and expansion in capital-intensive sectors should overcompensate for the loss of welfare due to contraction of labour-intensive sectors. Welfare rises from I to I′ and TOT moves from line T to T′. The PPC would shift from PP to P′P′.

However, if the shift of PPC is such that there is a little expansion in TOT and capital-intensive sector, while contraction of the labour-intensive sector is more, then PPC shifts to P′P′ as shown in Fig. 2.4b.

The TOT line becoming flatter shifts to T′ from T and there is a welfare loss shown by the shift of welfare curve from I to I′. This is a case for immiserizing growth. If an environmental tax is imposed and by these proceedings if a production subsidy is given to both the sectors, then contraction of labour-intensive sectors would be less and expansion of capital-intensive sectors would be more. The PPC would shift to P″P″. TOT would shift up to T″T″ as a result of the expansion of capital intensive sector.

5.4 A Comparative Study of Foreign Capital and Domestic Capital for Pollution Abatement Purposes and its Implications on Carbon Credits

The studies mentioned earlier have observed the conditions of immiserizing growth if foreign capital and domestic capital are used for pollution abatement purposes. Comparing the two studies, it is inferred that if the world rate of interest is sufficiently low, then a country will be better off if the economy opts for foreign capital for pollution abatement and does not waste its domestic resources. Even if the domestic capital is used, then production expands through the use of eco-friendly technologies that lead to less wastages and improvement in environmental quality. However, welfare improvement is realized when contraction in labour-intensive export sector is less than the expansion in the capital-intensive import sector. The implication here is that a production subsidy is to be given to the labour-intensive sector, and a tax is to be collected from the capital-intensive sector when a part of the gains of adopting eco-friendly technology is siphoned off from the capital-intensive sector and distributed to the labour-intensive sector. There is no doubt that such a redistribution will increase national welfare, but that itself provides a disincentive to the capital-intensive sector of the economy. Therefore, resource diversion and redistribution of gains is neither sustainable nor justified.

If the rate at which foreign capital is repatriated back is kept low, then, however, a higher rate of foreign capital repatriation may be detrimental to the growth and welfare process of the economy. In the example of carbon emissions and carbon credit, use of foreign capital in developing nations may be an ideal strategy wherein the rate of foreign capital repatriation is very low, and, on the other hand, the foreign capital is compensated by the earning of carbon credits, the trading that involves full return on such capital investment. Under such a framework, it seems that foreign capital investment in environmental projects in developing economies may benefit both developed and developing economies, rather than addressing the problem of climate change individually with their respective domestic resources.

6 Conclusion

The chapter had theoretically analysed two different conditions of immiserizing growth under foreign capital and domestic capital used for pollution abatement purposes. The entire theoretical analysis is based on a two-country model. However, it may be extended to a multi-country case. It is better for a developing nation to opt for foreign capital for pollution abatement purposes. In such a case, the benefits gained both economically and environmentally would be higher than the costs. The resources may be used for production purposes rather than being diverted from production sector to undertake expensive eco-friendly projects. However, environmental quality is also improved in the process. However, such initiatives from foreign counterparts need international cooperation. The entire explanation of growth has been based on welfare analysis in terms of environmental quality improvement and BoT situation

of a country, which in turn explains gains from trade in terms of TOT and output expansion. It has been shown that a redistribution of gains from trade from polluting capital-intensive sector, that adopts eco-friendly technology, to labour-intensive sector as production subsidy may prevent immiserizing growth in case domestic capital is used for production purpose. However, using foreign capital for improving the environment is a better choice provided the rate of absorption of such foreign capital by the domestic economy is high and rate of repatriation is low.

This model can also explain the theoretical basis of carbon credit earning by developed economies by undertaking green business projects in developing economies by which both economies may be beneficial in terms of economy and environment. The benefits acquired through Clean Development Mechanism of the Kyoto Protocol can also be analysed by this model. Through international cooperation, further damages to the environment and climate change threats can be prevented in the world economy as a whole. This chapter is limited in its theoretical assumptions of a neoclassical general equilibrium set-up. Further extension of the model may be feasible to explore the intergenerational gains from cooperation in a dynamic set-up.

References

Bhagwati J (1958) International trade and economic expansion. American Economic Review 48(5):941–953

Chatterjee B (2000) Environment, trade and globalization—emerging issues and policy options. N.K. memorial lecture delivered at the 4th annual conference of Economic Association of Bihar, Patna. May 28:2000

Chatterjee B, Karmakar AK (1995) Environment and development in an open economy. IEA Conference Volume. Gwalior, December 1995

Chatterjee B, Sen R (2001) Environment standards, WTO and the Indian economy. In: Chadda GK (ed) WTO and the Indian Economy. Deep and Deep, New Delhi

Chichilnisky G (1994) North–south trade and the global environment. Am Econ Rev 84(4):851–873

Copeland BR, Taylor MS (1994) North-south trade and the environment. Q J Econ 109(3):755–787 (August 1994)

Copeland BR, Taylor MS (1997) A simple model of trade, capital mobility, and the environment. NBER Working Paper Series, vol 5898. National Bureau of Economic Research, Cambridge

Dean J (1992) Trade and environment: a survey of the literature. In: Low P (ed) International trade and the environment. World Bank Discussion Papers, vol 159. World Bank, Washington D.C.

Dean J (1999) Testing the impact of trade liberalization on the environment. In: Fredriksson P (ed) Trade, global policy and the environment. World Bank Discussion Papers, vol 402. World Bank, Washington, D.C., pp 55–63

Hazari BR, Sgro PM (1975) Theorems on immiserising (normal growth) in the non-traded goods and wage differentials framework. Southern Econ J 41:515–519

Hazari BR, Sgro PM (1976) Some notes on technical progress in the framework of factor market imperfections and non-traded goods. Aust Econ Pap 25(March):1–43

Hazari BR, Sgro PM (1983) International trade theory in a two country general equilibrium model with traded intermediate goods, Vol 2, published by School of Economics, La Trobe University

Kemp MC (1969) The pure theory of international trade and investment. Prentice Hall, Englewood Cliffs

Kolstad CD (2010) Environmental economics. Oxford University Press, New York

Lopez R (1994) The environment as a factor of production: the effects of economic growth and trade liberalization. J Environ Econ Manag 27:163–184

World B (1992) World development report. World Bank, Washington D.C