# Production network and emission control targets-theoretical approach

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# Production Network and Emission Control Targets-Theoretical Approach

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**Abstract:** By spurring trade, the level of income and consumption and production increase, which consequently causes a more polluted environment. As global economic integration escalates, the possibility of contention becomes more translucent. The foundation of this article is based on the Ricardian model regarding consumption and production pollution function in six scenarios depending on Autarky or trade situation. There is also a difference in the relative labour size of countries. Also, pollution tightness can clarify whether there are any concerns about climate change regarding the production pollution function and consumption pollution function. The theoretical approach proves that unemployment does not occur when we have no concerns about climate change and this tightness of pollution would not impact the level of production and consumption. The emission intensity, relative labour size and tightness of pollution targets are the key elements discussed in both Autarky and trade. The critical point about trade is that it enters specialization, and the home country only produces good 1 and the foreign country only produces good 2. The main finding of this paper, based on a simple theoretical approach, is about the impact of one unit change in relative labour size regarding pollution tightness with respect to the labour force of both home and foreign countries is provided at the end.

**Keywords:** environmental pollution, international trade, production, consumption, economic growth

## 1 Introduction

The relationship between economic activities and the environment is an important and complex issue. Pressure on the environment through human activities is one of the significant global issues that many countries face. This is important not only from an environmental point of view but also from an economic point of view because

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economic activities may affect the well-being and long-term life of human beings. In recent decades, environmental hazards and harms have become more apparent. These damages are due to economic factors and factors such as employment, investment, energy consumption, industrial activities, and economic growth. Many environmental effects and consequences occur during higher economic growth in countries. So that with the increase in the volume of economic activities and the expansion of economic factors of businesses, the adverse effects of environmental pollution increase. Environmental damage along with the development and growth of business activities has caused a conflict between the benefits of higher economic growth and environmental degradation.

Given the foregoing, this paper provides a conceptual framework of the relationships between producers, economic elements of business and environmental changes regarding consumption and production pollution function in trade. Considering the inevitable impact of environmental pollution caused by economic activities on economic growth, it is essential to know the different policies to analyse the effects of change in various parameters and variables (Michail and Melas 2022). On the other hand, a review of the environmental economics literature indicates that economic growth, industry investment, trade openness, and employment all affect the quality of the environment. Therefore, this paper raises two related research questions:

1. What is the sensitivity of business economic factors? (What will be the impact on the labour adjustment with respect to the changes in relative labour size and pollution tightness? And how will the effects under autarky and trade scenarios on comparing consumption and production pollution function?)
2. What are the key elements influencing production pollution function and consumption pollution function in Autarky and trade?

An ongoing subject of debate is the relationship between trade and environmental policy. International trade is a powerful tool for achieving better environmental results, but it may also worsen existing environmental issues. In this paper, we compiled a concise summary of current advances in the trade and environmental literature in which policy implications are discussed. For instance, Hussain and Dey (2021) and Hu et al. (2022) have both reviewed topics related to trade and environment, as well as Copeland and Taylor (2004), Neary (2006), Cherniwchan et al. (2017), Ashraf et al. (2021), Borsatto and Amui (2019), Cole et al. (2021), and Yao et al. (2019). Trade has a significant impact on the environment in a variety of ways. Trade impacts pollutant emissions and the long-term viability of renewable resources because it alters consumption and production levels and mixes. Production practises influenced by the imports of intermediate products and capital, which impact pollution levels. Emission intensities are also affected by trade-induced technology transfer. Different sections of a country's economy are affected by trade differently, which might raise or decrease environmental strain. Firms are also impacted in diverse ways. Some enterprises grow, and others shrink; new businesses arrive, and others depart. Environmental consequences are affected by all these factors. The demand for transportation, which impacts pollution emissions, influences the development of new species, as well as the political process that influences environmental policy adoption and enforcement. Trade also has a direct impact on trade patterns.

Emission levels may be broken down into three categories: size (the total amount of economic activities), using the emission intensity technique and the percentage of economic production devoted to specific activities (Ishikawa and Okubo 2011; Ansari and Babu 2018). If the quantity of production stays constant, the emission intensity will remain constant, and increasing output leads to an increase in emissions. Even if the quantity and intensity of emissions remain constant, a change in production away from clean sectors and toward polluting ones will result in more pollution. Furthermore, if the total output is maintained, the same pollution would be reduced if more environment-friendly industrial methods were adopted. All three of these market aspects have a direct bearing on emissions of greenhouse gases. According to various hypotheses and empirical evidence, trade may boost individual income and economic growth. However, extant scholar also shows that the demand for environmental quality rises with wealth. A better standard of living may lead to more strict environmental regulations that cut emissions (a technique effect). Pollution levels might rise or fall as a result. Ansari and Babu (2018) publication sparked a vast body of work on the environmental Kuznets curve (EKC). When determining how economic expansion affects the environment, this study looked at the interactions between size, method, and composition impacts.

Studies have shown that economic development has different consequences depending on various circumstances, including the availability of resources and whether the economy favours clean or filthy businesses (a composition effect).

Given the foregoing, it is difficult to separate the consequences of globalisation on the environment from those of economic expansion, which is a dilemma for environmentalists. In the research on trade and the environment, trade influences environmental outcomes because economic development is not the predominant factor. With this assumption, this paper will focus on whether the growth path of the autarky economy is more or less polluting than the open economy. The paper will therefore conceptually elucidate two main pathways by which international trade might result in distinct kinds of environmental consequences from development, as trade and growth both produce scale effects.

# 2 Ricardian Model

The determination of the pattern of international trade under uncertainty has been the subject of several recent investigations. Early writers on this topic studied situations in which opportunities for the international sharing of risk are absent and found that trade need not follow comparative cost advantage and the Heckscher-Ohlin theorem does not hold. It has been proven that, if industry-specific uncertainties are perfectly correlated across countries, then 'specialization according to comparative advantage' does explain the pattern of trade in securities in a Ricardian-type model.

The general form of simple production function can be defined as $X = L_X/a_X$, $Y = L_Y/a_Y$ where $a$ and $b$ are labourers per unit of output or hours of work per unit of output. Here, $1/a_X$ and $1/a_Y$ give outputs per labour unit. We can define the parameters and variables as follows:

Parameters:
$a_i$ : *Unit labor costs for good i*
$z_i$ : *labor productivity for good i*
$\theta_i$ : *Utlity function for good i*
$P_i$ : *Price for good i*
Variables:
$L$ : *labor*
$y$ : *Production*
$C$ : *consumption*

According to the basic Ricardian model, and by the implementation of Lagrangian technique in a set of equations, we can reach the following results:

$$\begin{cases} wL = p_1c_1 + p_2c_2 \\ \dfrac{\theta_1}{c_1} = \lambda p_1 \\ \dfrac{\theta_2}{c_2} = \lambda p_2 \end{cases} \rightarrow c_1 = \frac{wL}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) = \frac{1}{a_1}L\left(\frac{\theta_1}{\theta_1+\theta_2}\right), c_2 = \frac{1}{a_2}L\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \quad (1)$$

The results from equation (1) are the basic structure of our model.

## 2.1 Autarky

Autarky is based on an economic system of self-sufficiency and constrained trade. A nation is in an actual state of Autarky if it has a closed economy, which suggests that it does not engage in worldwide trade with other countries. When this term is applied to countries, it will describe a nation that survives without international trade. We call it a closed economy if it willingly refuses to trade with other countries.

No country is in a total state of Autarky in today's global trade. Even North Korea (DPRK) has trade agreements with China and Vietnam. The main reason we study Autarky is to provide a baseline scenario to emphasize the advantages of trade, and the necessity of trade between countries. Through trade, countries can gain profits, which they could not achieve in Autarky.

Each of the production-based pollution functions for two goods, in equations (2) and (3), has a direct relation with the amount of pollution per unit of output (economic size scale) and the productivity of the labour force. Moreover, access to more reliable technology can contribute to higher emissions produced by each good. When the utility of a good one is increased, and the preference towards good two decreases, the total amount of emission for good one will be increased.

Here, the total amount of emission ($E_1^Y, E_2^Y$) is a function of emission intensity ($e_1^Y, e_2^Y$) and the amount of production ($Y_1, Y_2$). Indeed, emission intensity, technological factors, productivity, and the preference towards a similar good can increase the total amount of emission.

$$E_1^Y = e_1^Y.Y_1 = e_1^Y.\frac{1}{a_1}L\left(\frac{\theta_1}{\theta_1+\theta_2}\right) = e_1^Y z_1.L\left(\frac{\theta_1}{\theta_1+\theta_2}\right) \tag{2}$$

$$E_2^Y = e_2^Y.Y_2 = e_2^Y.\frac{1}{a_2}L\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = e_2^Y.z_2.L\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \tag{3}$$

According to equation (4), the total amount of production-based pollution function can be achieved by the summation of production-based pollution functions for both goods. Labour amount, the productiveness of each good, and the preference and utility of each good directly impact the total amount of emission produced for goods 1 and 2.

$$E^Y = E_1^Y + E_2^Y = \left(\frac{L}{\theta_1+\theta_2}\right)\left(\frac{e_1^Y.\theta_1}{a_1} + \frac{e_2^Y.\theta_2}{a_2}\right) = \left(\frac{L}{\theta_1+\theta_2}\right)(e_1^Y.\theta_1.z_1 + e_2^Y.\theta_2.z_2) \tag{4}$$

Since under Autarky, the amount of consumption is equal to the total output (production), we can reach similar results for consumption output for each good. In the set of equations (5) and (6), we have $C = Y$.

$$E_1^C = e_1^C.C_1 = e_1^C.Y_1 = e_1^C.\frac{1}{a_1}L\left(\frac{\theta_1}{\theta_1+\theta_2}\right) = e_1^C.z_1L\left(\frac{\theta_1}{\theta_1+\theta_2}\right) \tag{5}$$

$$E_2^C = e_2^C.C_2 = e_2^C.Y_2 = e_2^C.\frac{1}{a_2}L\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = e_2^C.z_2L\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \tag{6}$$

According to equation (7), the total amount of consumption-based pollution function can be derived by the summation of consumption-based pollution functions for both goods. Labour amount, the productiveness of each good, and the preference and utility of each good directly impact the total amount of emission consumed for goods 1 and 2.

$$E^C = E_1^C + E_2^C = \left(\frac{L}{\theta_1+\theta_2}\right)\left[\frac{\theta_1}{a_1}.e_1^C + \frac{\theta_2}{a_2}.e_2^C\right] = \left(\frac{L}{\theta_1+\theta_2}\right)\left[\theta_1.e_1^C.z_1 + \theta_2.e_2^C.z_2\right] \tag{7}$$

According to equation (8), the total consumption and production emissions can be generated. Allocated labour amount, preference towards using these products, the productivity of each good, and emission intensity can directly impact the total amount of emission.

$$\begin{aligned} E^T = E^Y + E^C &= \left(\frac{L}{\theta_1+\theta_2}\right)\left(\left(\frac{e_1^Y.\theta_1}{a_1} + \frac{e_2^Y.\theta_2}{a_2}\right) + \frac{\theta_1}{a_1}.e_1^C + \frac{\theta_2}{a_2}.e_2^C\right) \\ &= \left(\frac{L}{\theta_1+\theta_2}\right)\left(\frac{\theta_1}{a_1}.\left(e_1^Y + e_1^C\right) + \frac{\theta_2}{a_2}.\left(e_2^Y + e_2^C\right)\right) \\ &= \left(\frac{L}{\theta_1+\theta_2}\right)\left(\theta_1.z_1.\left(e_1^Y + e_1^C\right) + \theta_2.z_2.\left(e_2^Y + e_2^C\right)\right) \end{aligned} \tag{8}$$

## 2.2 Trade

When economic liberalization happens, two countries start to trade and specialization occurs ($Y_{1F} = Y_{2H} = 0$). This means that the production function for good 1 in a foreign country and good 2 in the home country equals zero.

In this regard, in the home country, the production-based pollution for a good one can be easily determined by labour and productivity (L.Z) and pollution per unit of output. Hence, the production-based pollution amount has no relation with the volume of trade and income.

$$Y_1^H = e_1^Y.\left[\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right)\right]$$

$$\begin{aligned} E_1^{Y,H} = e_1^Y.Y_1^H = e_1^Y.\left(C_1^H + C_1^F\right) &= e_1^Y.\left[\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right)\right] \\ &= e_1^Y\left(\frac{L^H}{a_1^H} + \frac{L^F}{a_1^F}\right)\left(\frac{\theta_1}{\theta_1+\theta_2}\right) = e_1^Y\left(\frac{L^H}{a_1^H}\right) = e_1^Y L^H z_1^H \end{aligned} \tag{9}$$

$$E_2^{Y,H} = 0 \tag{10}$$

Equation (11) shows the production-based pollution for the home country, which can be resulted of the summation of equations (9) and (10).

$$\begin{aligned} E^{Y,H} &= E_1^{Y,H} + E_2^{Y,H} = e_1^Y.Y_1^H + e_2^Y.Y_2^H = e_1^Y.\left(\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right)\right) \\ &= e_1^Y\left(\frac{L^H}{a_1^H} + \frac{L^F}{a_1^F}\right)\left(\frac{\theta_1}{\theta_1+\theta_2}\right) = e_1^Y\left(\frac{L^H}{a_1^H}\right) = e_1^Y L^H z_1^H \end{aligned} \tag{11}$$

Equations (12) and (13) show that unlike production-based pollution, consumption-based pollution is not constant and is dependent on the preferences of goods, prices, and the amount of consumption.

$$E_1^{C,H} = e_1^C.C_1^H = e_1^C.\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) \tag{12}$$

$$E_2^{C,H} = e_2^C.C_2^H = e_2^C.\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \tag{13}$$

Equation (14) represents the consumption-based pollution for the home country, resulting from the summation of equations (12) and (13).

$$\begin{aligned} E^{C,H} &= E_1^{C,H} + E_2^{C,H} = e_1^C.\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^C.\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \\ &= w^H L^H\left(\frac{1}{\theta_1+\theta_2}\right)\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) \end{aligned} \tag{14}$$

The total amount of consumption and production emission can be generated according to equation (15). It is obvious that allocated labour amount, preference towards using these products, the productivity of each good, and emission intensity can have a direct impact on the total amount of emission.

$$E^H = E^{Y,H} + E^{C,H} = e_1^Y L^H z_1^H + w^H L^H\left(\frac{1}{\theta_1+\theta_2}\right)\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) \tag{15}$$

The results of equations (16) and (17) show that since a foreign country does not produce good 1, its production-based pollution is zero. The total amount of production-based pollution for a foreign country is for good 2 which is only dependent on the output of emission intensity, labour, and their productiveness.

$$E_1^{Y,F} = 0 \tag{16}$$

$$E_2^{Y,F} = e_2^Y.Y_2^F = e_2^Y.\left(C_2^H + C_2^F\right) = e_2^Y.\left[\left(\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right)\right)\right]$$
$$= e_2^Y\left(\frac{L^H}{a_2^H} + \frac{L^F}{a_2^F}\right)\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = e_2^Y\left(\frac{L^F}{a_2^F}\right) = e_2^Y.L^F.z_2^F \tag{17}$$

Similarly, in a foreign country, equation (18) represents the production-based pollution for a foreign country which can be resulted in the summation of equations (16) and (17).

$$E^{Y,F} = E_1^{Y,F} + E_2^{Y,F} = e_1^Y.Y_1^F + e_2^Y.Y_2^F = e_2^Y.\left(\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right)\right)$$
$$= e_2^Y\left(\frac{L^H}{a_2 H} + \frac{L^F}{a_2^F}\right)\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = e_2^Y.L^F.z_2^F \tag{18}$$

Equations (19) and (20) show that unlike production-based pollution, consumption-based pollution is not constant and is dependent on emission intensity, the preferences of goods, prices, and the amount of consumption. Hence, the consumption-based pollution is dependent on the level of creating pollution for both goods and income of foreign country.

$$E_1^{C,F} = e_1^C.C_1^F = e_1^C.\frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) \tag{19}$$

$$E_2^{C,F} = e_2^C.C_2^F = e_2^C.\frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) \tag{20}$$

Equation (21) represents the consumption-based pollution for a foreign country which can be the result of the summation of equations (19) and (20).

$$E^{C,F} = E_1^{C,F} + E_2^{C,F} = e_1^C.\frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^C.\frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right)$$
$$= w^F L^F\left(\frac{1}{\theta_1+\theta_2}\right)\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) \tag{21}$$

In a foreign country, the total amount of consumption and production emissions can be generated according to equation (22). It is obvious that allocated labour amount, preference towards using these products, the productivity of good 2, and emission intensity can have a direct impact on the total amount of emission.

$$E_F^T = E^{Y,F} + E^{C,F} = e_2^Y.L^F.z_2^F + w^F L^F\left(\frac{1}{\theta_1+\theta_2}\right)\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) \tag{22}$$

## 3 Two-Country Equilibrium

Now, we can consider the ways in which countries may face global emission constraints; and how such constraints will have an impact on their economic structures and actual emissions. Here, we have $\overline{P}^Y$ the production pollution level, $\overline{P}^C$ the consumption pollution level, and $\overline{P}^{Y+C}$ as the total pollution level. We assume that countries are binding, which means that they try to have the emission below $\overline{P}^Y$ the production pollution level, $\overline{P}^C$ the consumption pollution level, and $\overline{P}^{Y+C}$ the total pollution level. We can conclude because of global constraints, we can reduce the number of working people, and some of them may end up being unemployed to reduce production and enhance pollution. In fact, under autarky, both countries are fully employed. To engage in global production, both countries need to change their employment level and reduce the pollution-related workforce. In this regard, knowing how many individuals should be sacked is important.

The critical issue here is the fact that we are facing two situations.

The first one is related to an ideal world (non-binding) in which we do not need to change in the amount of production and consumption. In this scenario, there is no climate crisis. In this case, the level of production and consumption is at its acceptable amount. In terms of mathematics, all the equations for consumption and production functions are not binding in this situation. This is the case in which we have $\overline{P}^Y = P^Y$ ($P^Y$ is the production pollution function without emission constraints) and we do not have to do anything about to change our behaviour towards reducing pollution.

The second one is related to the situation where the target value for consumption and production functions is lower than the actual equilibrium emission. Here, we have: $\overline{P}^Y < P^Y$, and scaling down production becomes essential. The key element here is that for instance for production function, we have: $\overline{P}^Y = \beta P^Y, \beta < 1$. In this case, the world must make some sacrifices in their labour force. However, if the size of the labour force in two countries is equal, the sacrifice is shared equally. But if the size of countries' labour force is different, they should sacrifice proportionally. The intuition here is that the more polluting country must have more sacrifices; and when the world is facing tight binding constraints, countries should scale down their production or consumption level. We can also consider the emission regarding the relationships between industries by defining $e_2^Y = \gamma . e_1^Y, \gamma < 1$ to consider which industry should sacrifice more. Indeed, the cleaner country should have less adjustment and sacrifice of its labour force. Throughout all scenarios we have $L^{*H}$ (home country) and $L^{*F}$ (foreign country), which show the equilibrium labour force. They are lower than the actual labour force, $L^H$ (home country) and $L^F$ (foreign country), which show the equilibrium labour force. The gap ($L^H - L^{*H}$, $L^F - L^{*F}$) shows unemployment in each country. Besides, to resort to simplicity, we can consider $\theta_1 + \theta_2 = 1$ under both Autarky and trade.

## 3.1 Autarky-Production Pollution Function

$$E_1^{Y,H} + E_2^{Y,H} + E_1^{Y,F} + E_2^{Y,F} = \overline{P}^{Y,H} + \overline{P}^{Y,F} = \overline{P}^Y$$

$$\rightarrow e_1^Y.\left(\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right)\right) + e_2^Y.\left(\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right)\right) = \overline{P}^Y$$

$$\rightarrow$$

$$e_1^{Y,H} z_1^H.L^H\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^{Y,H} z_2^H.L^H\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + e_1^{Y,F} z_1^F.L^F\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^{Y,F} z_2^F.L^F\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = \overline{P}^Y \tag{23}$$

Under autarky, both countries (home and foreign) produce both goods. The total amount of production pollution function without constraint has a positive and linear relationship with the emission intensity, productivity, and utility of goods produced in the home and foreign countries. The production pollution function under autarky can be divided into two main categories: In the first one, the labour endowment will be similar for two countries but in the second one, the labour endowment will be different for both countries.

$$\textit{if } L^H = L^F = L \rightarrow$$

$$L^{*H} = L^{*F} = \frac{\beta P^Y}{e_1^{Y,H} z_1^H \theta_1 + e_2^{Y,H} z_2^H \theta_2 + e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2} > 0 \tag{24}$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{\partial L^{*F}}{\partial \beta} = \frac{P^Y}{e_1^{Y,H} z_1^H \theta_1 + e_2^{Y,H} z_2^H \theta_2 + e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2} > 0 \tag{25}$$

When the number of workforces is equal in both countries, and the world emission target gets tighter (we have a target to restrain pollution), some proportion of labour should leave their jobs. This will lead to the unemployment of both countries' labour forces of similar size. Moreover, by increasing the intensity of pollution, and preferences towards producing each good in both countries, the unemployment level will also be increased subsequently. The production pollution level without constraint can increase the employment level of each country.

If $\beta > 1$, it will be a horizontal line, and we have no response because the actual production level is the critical factor. Hence, this is a non-binding situation, and the tightness of the target would not have any impact on the behaviour of production but when $0 < \beta < 1$, then we can see a positive relationship here. Hence, by reducing $\beta$, $L^{*H}, L^{*F}$ will get smaller. Hence, if the global emission constraint is more binding, countries should scale back their production size.

We can assume a situation in which $L^F$ and $L^H$ are different.

$$if\ L^F = \alpha L^H\ (\alpha > 0) \rightarrow$$

$$L^{*H} = \frac{\beta P^Y}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2} \rightarrow$$
$$L^{*F} = \frac{\alpha\beta P^Y}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2} > 0 \quad (26)$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{P^Y}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2} > 0$$
$$\frac{\partial L^{*F}}{\partial \beta} = \frac{\alpha P^Y}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2} > 0 \quad (27)$$

Also, by derivation of above formulae to $\alpha$, we have:

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha} = 0$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha} = \frac{P^Y}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2} > 0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\alpha$.

$$\frac{\partial L^{*H}}{\partial \alpha} = 0$$

$$\frac{\partial L^{*F}}{\partial \alpha} = \frac{\frac{1}{\alpha^2}\left(e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2\right)}{\left(\frac{1}{\alpha} e_1^{Y,H} z_1^H.\theta_1 + \frac{1}{\alpha} e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2\right)^2} > 0 \quad (28)$$

In this situation where the relative size of the labour force is different for two countries, we can conclude that countries with different labour force sizes will behave differently in the face of global emission control targets. Therefore, the larger country will face more unemployment than the smaller one. Here, by an increase in the production pollution function and binding of pollution, and of course, the reduction in productivity, emission intensity, and preferences toward producing each good, the number of employments in each country will increase.

When the number of workforces is different in both countries, and the world emission target gets tighter (we have a target to restrain pollution), some labour should leave their jobs. This will lead to unemployment in the country with a higher labour force. Moreover, by increasing the intensity of pollution, and preferences towards producing each good in both countries, which leads to much pollution, the unemployment level will also increase.

In this situation if $\beta > 1$, it will be a horizontal line, and we have no response because the actual production level is critical factor. Hence, in this non-binding situation, and the tightness of the target would not have any impact on the behaviour of production but when $0 < \beta < 1$, then we can see a positive relationship here. Hence, by reducing $\beta$, then $L^{*H}, L^{*F}$ will be smaller. Hence, countries should scale back their production size if the global emission constraint is more binding.

The number of employed individuals in both countries will be reduced if we want to bind our production pollution level. Moreover, the labour endowment of both countries will reduce, if we can increase the productivity, the preference towards each good, and the emission intensity of both goods. The critical point here is that by an increasing one unit of binding in pollution, the labour endowment in both countries is more significant than zero.

## 3.2 Autarky-Consumption Pollution Function

$$E_1^{C,H} + E_2^{C,H} + E_1^{C,F} + E_2^{C,F} = \overline{P}^{C,H} + \overline{P}^{C,F} = \overline{P}^{C}$$

$$\rightarrow$$

$$e_1^{C,H} z_1^H . L^H \left( \frac{\theta_1}{\theta_1 + \theta_2} \right) + e_2^{C,H} z_2^H . L^H \left( \frac{\theta_2}{\theta_1 + \theta_2} \right) + e_1^{C,F} z_1^F . L^F \left( \frac{\theta_1}{\theta_1 + \theta_2} \right) + e_2^{C,F} z_2^F . L^F \left( \frac{\theta_2}{\theta_1 + \theta_2} \right) = \overline{P}^{C} \tag{29}$$

Under autarky, the total amount of production is equal to that of consumption, we can have a similar interpretation for both situations (whether the relative size of labor force of countries is equal or not equal). In this situation, all the produced productions will be consumed.

$$if\ L^H = L^F = L \rightarrow$$

$$L^{*H} = L^{*F} = \frac{\beta P^C}{e_1^{C,H} z_1^H \theta_1 + e_2^{C,H} z_2^H \theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2} \tag{30}$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{\partial L^{*F}}{\partial \beta} = \frac{P^C}{e_1^{C,H} z_1^H \theta_1 + e_2^{C,H} z_2^H \theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2} \tag{31}$$

When the number of workforces is equal in both countries, and the world emission target gets tighter (we have a target to restrain pollution), some labour should leave their jobs. This will lead to the unemployment of both countries' labour forces of similar size. Moreover, with an increase in the intensity of pollution, and preferences towards consuming each good in both countries, the unemployment level will also be increased subsequently. The consumption pollution level without constraint can increase the employment level of each country.

If $\beta > 1$, it will be a horizontal line, we will have no response because the actual consumption level is the key factor. Hence, this is a non-binding situation, and the tightness of the target would not have any impact on the behaviour of consumption but when $0 < \beta < 1$, then we can see a positive relationship here. Hence, by reducing $\beta$, $L^{*H}, L^{*F}$ will get smaller. Hence, if the global emission constraint is more binding, countries should scale back their consumption level.

We can assume a situation in which $L^F$ and $L^H$ are different.

In this situation the relative size of labour force is different for two countries.

$$if\ L^F = \alpha L^H\ (\alpha > 0) \rightarrow$$

$$L^{*H} = \frac{\beta P^C}{e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2} > 0,$$

$$L^{*F} = \alpha.\frac{\beta P^C}{e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2} > 0 \tag{32}$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{C}{e_1^{C,H} z_1^H \theta_1 + e_2^{C,H} z_2^H \theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2} > 0$$

$$\frac{\partial L^{*F}}{\partial \beta} = \frac{\alpha P^C}{e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha\theta_1 + e_2^{C,F} z_2^F.\alpha\theta_2} > 0 \tag{33}$$

Also, by derivation of above formulae to $\alpha$, we have:

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha} = 0$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha} = \frac{\alpha P^{C}}{e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha\theta_1 + e_2^{C,F} z_2^F.\alpha\theta_2} > 0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\alpha$:

$$\frac{\partial L^{*H}}{\partial \alpha} = 0$$

$$\frac{\partial L^{*F}}{\partial \alpha} = \frac{\frac{1}{\alpha^2}\left(e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2\right)}{\left(\frac{1}{\alpha} e_1^{C,H} z_1^H.\theta_1 + \frac{1}{\alpha} e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2\right)^2} > 0 \tag{34}$$

In this situation in which the relative size of labour force is different for two countries, we can conclude that countries with different labour force sizes will behave differently in face of global emission control target. Therefore, the larger country will face more unemployment than the smaller one. Here, by increase in the consumption pollution function and binding of pollution, and of course, the reduction in productivity, and emission intensity, and preferences toward consuming each good, the number of employments in each country will increase.

When the number of workforces is equal in both countries, and the world emission target gets tighter (we have a target to restrain pollution), some labour should leave their jobs. This will lead to the unemployment of both countries' labour forces of similar size. Moreover, with an increase in the intensity of pollution, and preferences towards consuming each good in both countries, the unemployment level will also increase. The consumption pollution level without constraint can increase the employment level of each country.

In this situation if $\beta > 1$, it is a horizontal line, we will have no response because the actual consumption level is the key factor. Hence, in this non-binding situation, and the tightness of the target would not have any impact on the behaviour on consumption but when $0 < \beta < 1$, then we can see a positive relationship here. Hence, by reducing $\beta$, then $L^{*H}, L^{*F}$ will be smaller. Hence, countries should scale back their consumption level if the global emission constraint is more binding.

The number of employed individuals in both countries will be reduced if we want to bind our consumption pollution level. Moreover, the labour endowment of both countries will reduce, if we can increase the productivity, the preference towards each good, and the emission intensity of both goods. The key point here is that by an increase of one unit of binding in pollution, the labour endowment in both countries is larger than zero.

### 3.3 Autarky-Total Pollution Function

In Autarky the total pollution function can be generated by adding the production pollution function and consumption pollution function, and we can achieve similar results, as follows:

$$E_1^{Y+C,H} + E_2^{Y+C,H} + E_1^{Y+C,F} + E_2^{Y+C,F} = \overline{P}^{Y+C}$$

$$e_1^{Y,H} z_1^H.L^H\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^{Y,H} z_2^H.L^H\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + e_1^{Y,F} z_1^F.L^F\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^{Y,F} z_2^F.L^F\left(\frac{\theta_2}{\theta_1+\theta_2}\right) +$$

$$e_1^{C,H} z_1^H.L^H\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + e_2^{C,H} z_2^H.L^H\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + e_1^{C,F} z_1^F.L^F\left(\frac{\theta_1}{\theta_1+\theta_2}\right) +$$

$$e_2^{C,F} z_2^F.L^F\left(\frac{\theta_2}{\theta_1+\theta_2}\right) = \overline{P}^{Y+C}$$

$$if\ \theta_1+\theta_2 = 1 \rightarrow e_1^{C,H} z_1^H.L^H\theta_1 + e_2^{C,H} z_2^H.L^H\theta_2 + e_1^{C,F} z_1^F.L^F\theta_1 + e_2^{C,F} z_2^F.L^F\theta_2 = \overline{P}^{Y+C} \tag{35}$$

$$if\ L^H = L^F = L \rightarrow$$

$$L^{*H} = L^{*F} = \frac{\beta P^Y + \beta P^C}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2 + e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2} > 0 \tag{36}$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{\partial L^{*F}}{\partial \beta} = \frac{P^Y + P^C}{e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\theta_1 + e_2^{Y,F} z_2^F.\theta_2 + e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2} > 0$$

The labour force adjustment can be increased equally in both countries by the rise of emission intensity, preference towards consumption/production, and productivity of each good. Since the gap between the total labour force and labour force adjustment shows total unemployment, by an increase in the level of labour force adjustment, total unemployment will be reduced. In this situation the relative size of the labour force is different for the two countries.

$$if\ L^F = \alpha L^H\ (\alpha > 0)$$

$$\rightarrow L^{*H} = \frac{\beta P^Y + \beta P^C}{\begin{gathered} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2 \end{gathered}} > 0 \tag{37}$$

$$L^{*F} = \frac{\alpha\left(\beta P^Y + \beta P^C\right)}{\begin{gathered} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2 \end{gathered}} > 0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{P^Y + P^C}{\begin{array}{c} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2 \end{array}} > 0$$

$$\frac{\partial L^{*F}}{\partial \beta} = \frac{\alpha\left(P^Y + P^C\right)}{\begin{array}{c} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2 \end{array}} > 0$$

Also, by derivation of above formulae to $\alpha$, we have:en

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha} = 0$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha} = \frac{\left(P^Y + P^C\right)}{\begin{array}{c} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 + e_1^{C,F} z_1^F.\alpha.\theta_1 + e_2^{C,F} z_2^F.\alpha.\theta_2 \end{array}} > 0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\alpha$:

$$\frac{\partial L^{*H}}{\partial \alpha} = 0$$

$$\frac{\partial L^{*F}}{\partial \alpha} = \frac{\frac{1}{\alpha^2}\left(\beta P^Y + \beta P^C\right)\left(\begin{array}{c} e_1^{Y,H} z_1^H.\theta_1 + e_2^{Y,H} z_2^H.\theta_2 + e_1^{Y,F} z_1^F.\alpha.\theta_1 + e_2^{Y,F} z_2^F.\alpha.\theta_2 + \\ e_1^{C,H} z_1^H.\theta_1 + e_2^{C,H} z_2^H.\theta_2 \end{array}\right)}{\left(\begin{array}{c} e_1^{Y,H} z_1^H.\theta_1 \frac{1}{\alpha} + e_2^{Y,H} z_2^H.\theta_2 \frac{1}{\alpha} + e_1^{Y,F} z_1^F.\alpha.\theta_1 \frac{1}{\alpha} + e_2^{Y,F} z_2^F.\alpha.\theta_2 \frac{1}{\alpha} + \\ e_1^{C,H} z_1^H.\theta_1 \frac{1}{\alpha} + e_2^{C,H} z_2^H.\theta_2 \frac{1}{\alpha} + e_1^{C,F} z_1^F.\theta_1 + e_2^{C,F} z_2^F.\theta_2 \end{array}\right)^2}$$

Trade is a situation in which both countries enter specialization. Unlike Autarky in which both the foreign and home countries produce and consume both goods, in trade, the home country produces only good one. Hence, the amount of production for good two in the home country is equal to zero. Similarly, foreign country merely produces good two. Therefore, the amount of production for good one in a foreign country equals zero. It is evident that when two countries enter the trade, the country with more workforces will produce and consume much emissions. This will force the smaller country to participate less in economic activities.

## 3.4 Trade-Production Pollution Function

The total amount of production pollution function without constraint has a positive and linear relationship with the emission intensity, productivity, and the utility (preference) of goods produced in the home and foreign countries.

$$E^{Y,H} + E^{Y,F} = E_1^{Y,H} + E_2^{Y,H} + E_1^{Y,F} + E_2^{Y,F} = \overline{P}^Y$$

$$e_1^Y.Y_1^H + e_2^Y.Y_2^H + e_1^Y.Y_1^F + e_2^Y.Y_2^F =$$

$$e_1^Y.\left(\frac{w^H L^H}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_1}\left(\frac{\theta_1}{\theta_1+\theta_2}\right)\right) + e_2^Y.\left(\frac{w^H L^H}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right) + \frac{w^F L^F}{p_2}\left(\frac{\theta_2}{\theta_1+\theta_2}\right)\right)$$

$$= e_1^Y L^H z_1^H + e_2^Y L^F z_2^F = \overline{P}^Y \quad (38)$$

The production pollution function under trade can be divided into two main categories: In the first one, the number of employed individuals is equal for the two countries, but in the second one, the labour endowment will be different for both countries.

$$L^H = L^F = L \rightarrow$$

$$L^{*H} = L^{*F} = \frac{\beta P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{w^F}{p_2}\theta_2\right)} \quad (39)$$

$$= \frac{\beta P^Y}{e_1^Y\left(z_1^H\right) + e_2^Y\left(z_2^H\right) + e_1^Y\left(z_1^F\right) + e_2^Y\left(z_2^F\right)} > 0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{\partial L^{*F}}{\partial \beta} = \frac{P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{w^F}{p_2}\theta_2\right)} > 0 \quad (40)$$

In this situation, where the labour force is equal for both countries, intuitively when they are facing a constraint, they must reduce their labour force. By producing less, we have less amount of pollution. In this situation, some people will be redundant in the labour force to reduce pollution ($L^* < L$). Hence, controlling temperature comes as a price of unemployment. In the extreme case ($\overline{P}^Y = 0$), if we do not have to emit any emission, two countries should stop working, we have: $L^{*H} = L^{*F} = 0$. There are some factors, which influence the size of unemployment. By increase in the intensity of pollution, and preferences towards producing each good in both countries, the unemployment level will also increase subsequently. Clearly, the production pollution level without constraint can increase the employment level of each country.

If $\beta > 1$, it will be a horizontal line, we will have no response because the actual production level is the key factor. Hence, this is a non-binding situation, and the tightness of the target would not have any impact on the behaviour of production but when $0 < \beta < 1$, by reducing $\beta$, $L^{*H}, L^{*F}$ will get smaller. Hence, if the global emission constraint is more binding, countries should scale back their production size.

In this situation in which the relative size of the labour force is different for two countries, we can conclude that countries with different labour force sizes will behave differently in the face of global emission control targets. Therefore, the larger country will face more unemployment than the smaller one. Here, by the increase in the production pollution function and binding of pollution, and of course, the reduction in productivity, emission intensity, and preferences toward producing each good, the number of employments in each country will increase.

We can assume a situation in which $L^F$ and $L^H$ are different. In this situation, the relative size of the labour force is different for the two countries.

$$if\ L^F = \alpha L^H\ (\alpha > 0) \rightarrow$$

$$L^{*H} = \frac{\beta P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{\alpha w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{\alpha w^F}{p_2}\theta_2\right)} > 0,$$
$$L^{*F} = \alpha.L^{*H} \rightarrow L^{*F} = \frac{\alpha.\beta P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{\alpha w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{\alpha w^F}{p_2}\theta_2\right)} > 0 \tag{41}$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{\alpha w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{\alpha w^F}{p_2}\theta_2\right)} > 0$$
$$\frac{\partial L^{*F}}{\partial \beta} = \frac{\alpha.P^Y}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1 + \frac{\alpha w^F}{p_1}\theta_1\right) + e_2^Y.\left(\frac{w^H}{p_2}\theta_2 + \frac{\alpha w^F}{p_2}\theta_2\right)} > 0 \tag{42}$$

Also, by derivation of above formulae to $\alpha$, we have:

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha} = 0$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial\beta}\right)}{\partial\alpha}=\frac{P^{Y}}{e_1^{Y}.\left(\frac{w^H}{p_1}\theta_1+\frac{\alpha w^F}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^H}{p_2}\theta_2+\frac{\alpha w^F}{p_2}\theta_2\right)}>0$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\alpha$:

$$\frac{\partial L^{*H}}{\partial\alpha}=0$$

$$\frac{\partial L^{*H}}{\partial\alpha}=\frac{\beta P^{Y}\left[e_1^{Y}.\left(\frac{w^H}{p_1}\theta_1+\frac{\alpha w^F}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^H}{p_2}\theta_2+\frac{\alpha w^F}{p_2}\theta_2\right)\right]-\left[\alpha.\beta P^{Y}.\left(e_1^{Y}\left(\frac{w^F}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^F}{p_2}\theta_2\right)\right)\right]}{\left(e_1^{Y}.\left(\frac{w^H}{p_1}\theta_1+\frac{\alpha w^F}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^H}{p_2}\theta_2+\frac{\alpha w^F}{p_2}\theta_2\right)\right)^2}>0 \tag{43}$$

In trade, when the number of workforces is different in both countries, and the world emission target gets tighter (we have a target to restrain pollution), some proportion of labour should leave their jobs during the trade. This will lead to unemployment in the country with a higher amount of labour force. Moreover, by increasing the intensity of pollution, and preferences towards producing each good in both countries, the unemployment level will also be increased subsequently. The intensity of pollution in each industry can increase the level of unemployment in both countries. At the same time, when two countries become more productive in their own work, they produce more but this can be at the price of unemployment of their own employees because more productive industries can increase the pollution level.

## 3.5 Trade-Consumption Pollution Function

In trade, unlike the production pollution function, in which each country is specialized in producing one good; both countries consume both goods. The total amount of consumption pollution function without constraint has a positive and linear relationship with the emission intensity, productivity, and utility of goods consumed in the home and foreign countries.

$$\begin{aligned}\overline{P}^{C}&=E^{C,H}+E^{C,F}=E_1^{C,H}+E_2^{C,H}+E_1^{C,F}+E_2^{C,F}=\\ &e_1^{C}.\frac{w^HL^H}{p_1}\theta_1+e_2^{C}.\frac{w^HL^H}{p_2}\theta_2+e_1^{C}.\frac{w^FL^F}{p_1}\theta_1+e_2^{C}.\frac{w^FL^F}{p_2}\theta_2\\ &=w^HL^H\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)+w^FL^F\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{aligned} \tag{44}$$

The consumption pollution function under trade can be divided into two main categories: In the first one, the number of employed individuals is equal for the two countries, but in the second one, the labour endowment will be different for both countries.

$$L^H = L^F = L \rightarrow L^{*H} = L^{*F} = \frac{\beta P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} > 0 \tag{45}$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{\partial L^{*F}}{\partial \beta} = \frac{P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} > 0 \tag{46}$$

In this situation, where the labour force is equal for both countries, intuitively when they are facing a constraint, they must reduce their labour force. By consuming less, we have less amount of pollution. In this situation, some people will be redundant in the labour force to reduce pollution ($L^* < L$). Hence, controlling temperature comes as a price of unemployment. In the extreme case ($\overline{P}^C = 0$), if we do not have to emit any emission, two countries should stop consumption, we have: $L^{*H} = L^{*F} = 0$. There are some factors, which influence the size of unemployment. By increase in the intensity of pollution, and preferences towards producing each good in both countries, the unemployment level will also increase subsequently. Clearly, the consumption pollution level without constraint can increase the employment level of each country.

If $\beta > 1$, it will be a horizontal line, we will have no response because the actual consumption level is the critical factor. Hence, this is a non-binding situation, and the tightness of the target would not have any impact on the consumption behaviour but when $0 < \beta < 1$, then we can see a positive relationship here. Hence, by reducing $\beta$, $L^{*H}, L^{*F}$ will get smaller. Hence, if the global emission constraint is more binding, countries should scale back their consumption level.

In this situation where the relative size of the labour force is different for two countries, we can conclude that countries with different labour force sizes will behave differently in the face of global emission control targets. Therefore, the larger country will face more unemployment than the smaller one. Here, the number of employments in each country will increase by an increase in the consumption pollution function and binding of consumption, and of course, the reduction in productivity, emission intensity, and preferences toward consuming each good.

$$L^F = \alpha L^H \ (\alpha > 0) \rightarrow$$

In this situation, the relative size of the labour force is different for the two countries. By consuming less, we have less amount of pollution. In this situation, some people will be redundant in the labour force to reduce pollution ($L^* < L$). Hence, controlling temperature comes as a price of unemployment. In the extreme case ($\overline{P}^C = 0$), if we do not have to emit any emission, two countries should stop consuming, we have: $L^{*H} = L^{*F} = 0$. There are some factors, which influence the size of unemployment. By increase in the intensity of pollution, and preferences towards consuming each good in both countries, the unemployment level will also be increased subsequently. Clearly, the consumption pollution level without constraint can increase the employment level of each country. Besides, if we bind our consumption, it leads to unemployment in the labour force.

$$L^{*H} = \frac{\beta P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + \alpha w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)},$$
$$L^{*F} = \frac{\alpha \beta P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + \alpha w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} \tag{47}$$

By derivations, we can see how $L^{*H}$, $L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta} = \frac{P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + \alpha w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} > 0$$
$$\frac{\partial L^{*F}}{\partial \beta} = \frac{\alpha P^C}{w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + \alpha w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} \tag{48}$$
$$= \frac{P^C}{\frac{1}{\alpha} w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)} > 0$$

Also, by derivation of above formulae to $\alpha$, we have:

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha} = \frac{-P^C w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)}{\left(w^H\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right) + \alpha w^F\left(\frac{e_1^C.\theta_1}{p_1} + \frac{e_2^C.\theta_2}{p_2}\right)\right)^2} < 0$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha}=\frac{P^{C}\frac{1}{\alpha}w^{H}\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}{\left(w^{H}\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^{F}\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)\right)^2}>0$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\alpha$:

$$\frac{\partial L^{*H}}{\partial \alpha}=0$$

$$\frac{\partial L^{*F}}{\partial \alpha}=\frac{\beta P^{C}w^{H}.\frac{1}{\alpha^2}.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}{w^{H}.\frac{1}{\alpha}.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^{F}\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)^2}>0 \tag{49}$$

## 3.6 Trade-Total Pollution Function for Trade

Under trade, the total amount of pollution function is equal to the summation of the production pollution function and consumption pollution function. Hence, we can have similar interpretations for the unemployment, emission intensity of each industry, and share of the labour force to produce both goods in both countries.

$$\begin{aligned}\overline{P}^{Y+C}&=E_1^{Y,H}+E_2^{Y,H}+E_1^{Y,F}+E_2^{Y,F}+E_1^{C,H}+E_2^{C,H}+E_1^{C,F}+E_2^{C,F}=\\ &e_1^Y.\left(\frac{w^HL^H}{p_1}\theta_1+\frac{w^FL^F}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^HL^H}{p_2}\theta_2+\frac{w^FL^F}{p_2}\theta_2\right)\\ &+w^HL^H\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^FL^F\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)\end{aligned} \tag{50}$$

$$L^H=L^F=L\rightarrow$$

$$L^{*H}=L^{*F}=\frac{\beta\left(P^C+P^Y\right)}{\begin{aligned}&e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F}{p_2}\theta_2\right)+\\ &w^H.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)\end{aligned}}>0 \tag{51}$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta}=\frac{\partial L^{*F}}{\partial \beta}=\frac{\left(P^C+P^Y\right)}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F}{p_2}\theta_2\right)+w^H.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}>0$$

The labour force adjustment can be increased equally in both countries by the rise of emission intensity, preference towards consumption/production, and productivity of each good and reduction in wages. Since the gap between the total labour force and labour force adjustment shows total unemployment, by an increase in the level of labour force adjustment, total unemployment will be reduced.

$$L^F=\alpha L^H\ (\alpha>0)\rightarrow$$

In this situation, the relative size of the labour force is different for the two countries. Hence, the labour force adjustment level for both countries is different.

$$L^{*H}=\frac{\beta\overline{P}^{Y+C}}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F\alpha}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F\alpha}{p_2}\theta_2\right)+.w^H.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F\alpha\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}>0$$

$$L^{*F}=\frac{\alpha\beta\left(P^C+P^Y\right)}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F\alpha}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F\alpha}{p_2}\theta_2\right)+w^H\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F\alpha\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}>0 \tag{52}$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\beta$:

$$\frac{\partial L^{*H}}{\partial \beta}=\frac{\left(P^C+P^Y\right)}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F\alpha}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F\alpha}{p_2}\theta_2\right)+w^H.\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F\alpha\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}$$

$$\frac{\partial L^{*F}}{\partial \beta}=\frac{\alpha\left(P^C+P^Y\right)}{e_1^Y.\left(\frac{w^H}{p_1}\theta_1+\frac{w^F\alpha}{p_1}\theta_1\right)+e_2^Y.\left(\frac{w^H}{p_2}\theta_2+\frac{w^F\alpha}{p_2}\theta_2\right)+w^H\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)+w^F\alpha\left(\frac{e_1^C.\theta_1}{p_1}+\frac{e_2^C.\theta_2}{p_2}\right)}>0$$

Also, by derivation of above formulae to $\alpha$, we have:

$$\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha}=\frac{-\left(P^{C}+P^{Y}\right)\begin{pmatrix} e_1^{Y}.\left(\frac{w^{F}}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{F}}{p_2}\theta_2\right)+ \\ +w^{F}\alpha\left(\frac{e_1^{C}.\theta_1}{p_1}\right)\end{pmatrix}}{\begin{pmatrix} e_1^{Y}.\left(\frac{w^{H}}{p_1}\theta_1+\frac{w^{F}\alpha}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{H}}{p_2}\theta_2+\frac{w^{F}\alpha}{p_2}\theta_2\right)+ \\ w^{H}.\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)+w^{F}\alpha\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{pmatrix}^{2}}<0$$

$$\left(P^{C}+P^{Y}\right)\begin{pmatrix} e_1^{Y}.\left(\frac{w^{H}}{p_1}\theta_1+\frac{w^{F}\alpha}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{H}}{p_2}\theta_2+\frac{w^{F}\alpha}{p_2}\theta_2\right)+ \\ w^{H}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)+w^{F}\alpha\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{pmatrix}$$

$$\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha}=\frac{-\alpha\left(P^{C}+P^{Y}\right)\left(e_1^{Y}.\left(\frac{w^{F}}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{F}}{p_2}\theta_2\right)+w^{F}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\right)}{\begin{pmatrix} e_1^{Y}.\left(\frac{w^{H}}{p_1}\theta_1+\frac{w^{F}\alpha}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{H}}{p_2}\theta_2+\frac{w^{F}\alpha}{p_2}\theta_2\right)+ \\ w^{H}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)+w^{F}\alpha\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{pmatrix}^{2}}$$

By derivations, we can see how $L^{*H}, L^{*F}$ can be changed to the response of $\alpha$:

$$\frac{\partial L^{*H}}{\partial \alpha}=0$$

$$\frac{\partial L^{*F}}{\partial \alpha}=\frac{\beta\left(P^{C}+P^{Y}\right)\begin{bmatrix} e_1^{Y}.\left(\frac{w^{H}}{p_1}\theta_1\frac{1}{\alpha^{2}}\right)+e_2^{Y}.\left(\frac{w^{H}}{p_2}\theta_2\frac{1}{\alpha^{2}}\right)+ \\ w^{H}\frac{1}{\alpha^{2}}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{bmatrix}}{\begin{bmatrix} e_1^{Y}.\left(\frac{w^{H}}{p_1}\theta_1\frac{1}{\alpha}+\frac{w^{F}}{p_1}\theta_1\right)+e_2^{Y}.\left(\frac{w^{H}}{p_2}\theta_2\frac{1}{\alpha}+\frac{w^{F}}{p_2}\theta_2\right)+ \\ w^{H}\frac{1}{\alpha}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)+w^{F}\left(\frac{e_1^{C}.\theta_1}{p_1}+\frac{e_2^{C}.\theta_2}{p_2}\right)\end{bmatrix}^{2}}$$

# 4 Discussion

We can have the following scenarios for the impact of labour adjustment on pollution tightness on the relative labour force. Hence, when a country shifts itself from Autarky to trade, the consumption pollution function for the home country impact will be changed from no impact to the negative one. The impact of labour adjustment on pollution tightness on the relative labour force will not change under the production pollution function.

This tells us how the sensitivity of labour adjustment in foreign and home countries with respect to pollution tightness changes as we change the relative size of labour. According to table 1, in Autarky, the sensitivity of change for labour adjustment in the home country regarding pollution tightness with respect to relative labour size is zero while the same value is negative for trade. The difference between Autarky and trade is understandable in the consumption pollution function for the home country. In Autarky, the sensitivity of change for labour adjustment in the home country regarding pollution tightness with respect to relative labour size is zero while the same value is negative for trade.

**Table 1:** Pollution function derivations in Autarky and trade.

| Function | Derivations | Autarky | Trade |
|---|---|---|---|
| Production pollution function | $\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha}$ | 0 | 0 |
| | $\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha}$ | + | + |
| Consumption pollution function | $\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha}$ | 0 | – |
| | $\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha}$ | + | + |
| Total pollution function | $\frac{\partial\left(\frac{\partial L^{*H}}{\partial \beta}\right)}{\partial \alpha}$ | 0 | – |
| | $\frac{\partial\left(\frac{\partial L^{*F}}{\partial \beta}\right)}{\partial \alpha}$ | + | + |

# 5 Conclusion

In this paper, we separately discussed six scenarios for Autarky and trade. For each one, the production pollution function, consumption pollution function, and their summation are discussed. These were investigated under the assumption of whether the number of the labour force (economic size scale) is different or not. Moreover, we considered bindingness, which means how much the targeted emission level is lower than the actual equilibrium emission. If this is not binding, then there is no need to make any production or consumption changes. However, if it is binding, that implies the world is producing or consuming much, and that production or consumption requires scaling back to reduce the emission to the level of emission constraint. This will lead to the unemployment of some individuals in the labour force. We also analysed the main factors on how two countries should adjust their production or consumption patterns to meet the emission control target. We showed that cleaner countries and industries should have less adjustment and sacrifice of their labour force.

According to the facts, the overall environmental impact of international trade is relatively insignificant. When it comes to aggregate metrics, however, they obscure regional and industry-specific variances. As a result, if the right regulations are not put in place to balance trade and environmental results, it may have significant negative consequences on the region's production and renewable resources. There is a great deal of research to be done in the future to better understand how trade affects the environment in various countries.

Trade and environmental studies are starting to be influenced by recent work that focuses on firm-level reactions to free trade. Emission intensity reductions in manufacturing in high-income nations have been the primary source of pollution reductions, not a move toward cleaner sectors. It's still unclear how commerce impacts emissions intensity, particularly regarding offshore polluting duties from a company. In developing nations, trade-induced changes in the mix of production may contribute to pollution that needs more investigation.

According to the targeting principle, environmental policy should focus on environmental issues, with no need to alter trade policies to address them. But when the costs of environmental policy implementation are fixed and when the economy is distorted, trade and environmental policy are inextricably connected. Climate change policy has unique difficulties in tackling global collective action concerns, which means that problems like carbon leakage will play a prominent role.

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