Technology Transfer, Emissions Trading, and International Trade

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Global Warming

- Global warming is one of the greatest concerns of the world. The global average temperature increased by 0.85°C between 1880 and 2012.
- Rising global temperatures have been accompanied by climate changes, causing extensive damage.
- For example, in recent times, unusual weather conditions have been causing a high number of floods and droughts and severe heat waves across the world.
- In the COP 21 Paris sessions, 197 Parties including both developed and developing countries submitted their specific GHG emission reduction targets, but these targets were heterogeneous because the Parties set their emission targets non-cooperatively.
- For example, the EU's target is a 40% GHG reduction by 2030 from their 1990 level, while China's target is a 60-65% reduction in CO2 emissions per unit of GDP by 2030 from their 2005 level.
- Since China's reduction target is in terms of per unit of GDP, their emissions are expected to keep increasing and reach the maximum in 2030.

Emissions Trading and Technology Differences

- Emissions trading
  - Emissions trading would be inevitable for many countries to meet their targets.
  - According to the World Bank, there are 28 implemented and 3 scheduled ETSs.
  - International emissions trading is yet to fully developed. On January 1, 2020, the Swiss and EU ETSs were linked. The United Kingdom is considering to construct its own ETS and link it to the EU ETS.
- Emissions intensities
  - Emissions intensities significantly differ between developed and developing countries.
  - In 2019, China has 0.45 in its CO_2 emissions intensity (kg of CO_2 per PPP USD of GDP), while those of EU, Japan, and the US are 0.13, 0.20, and 0.22, respectively (World Development Indicators).
- Technology differences
  - Douglas and Nishioka (2012, JDE) find a negative relation between emission intensity and TFP, concluding that technology differences play an important role in explaining differences in emission intensities across countries.
  - Douglas and Nishioka (2012, JDE) point out that current implicit emissions prices differ because of international differences in production techniques and technology transfers could reduce global emissions.

Purpose and Related Literature

- In this study, we explore the following question:
  - Would international technology transfers (henceforth ITT) lead to economic and environmental benefits under international trade in emissions as well as in goods?
- The literature on technology transfer and permit trading:
  - Greaker and Hagem (2014, Environ Resource Econ):
  - Industrial countries benefit from investing in reducing abatement costs in developing countries because such investments will reduce the future permit price.
  - Helm and Pichler (2015, Environ Resource Econ):
  - For the North, the motive for subsidizing ITT is to reduce the permit since the North is a permit buyer.
- In the current study:
  - We use a general equilibrium model based on Ishikawa and Kiyono (2006, IER) and complement Ishikawa, Kiyono, and Yomogida (2012, JER) in that we examine the effects of ITT.
  - Unlike the previous studies, we use a general equilibrium model that considers trade in goods and emissions and show that ITT can increase the permit price.

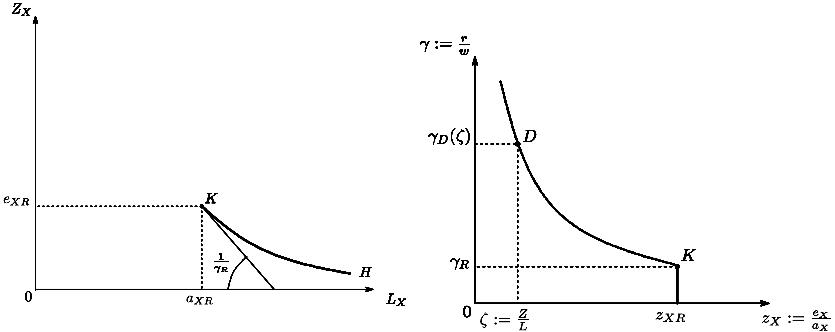
Model

- We build a model based on Ishikawa and Kiyono (2008).
- There are two goods, X and Y, and two factors, labor and environmental resources.
- Following the idea of Meade (1952), we treat GHG emissions as the input of an environmental resource for the production of good X.
- This environmental resource is an unpaid, unregulated, and socially overused production factor.
- The production of one unit of good Y requires a_Y units of labor.
- The production of good X requires labor input, L_X, and the amount of GHG emissions during production, Z_X:

$$X = F(L_X, Z_X),$$

where F is concave, continuously differentiable, and linearly homogeneous.

A Unit Isoquant for Good X and Input Substitution



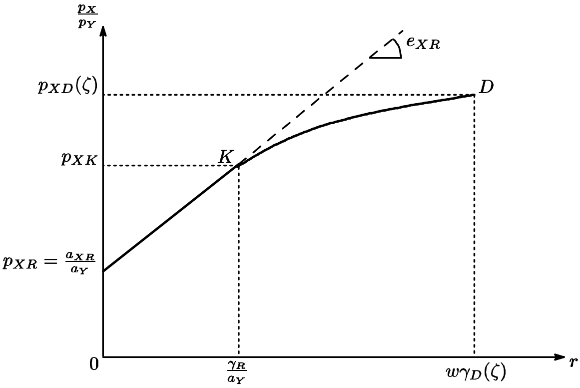
- Labor includes the inputs for emission abatement.
- A firm can substitute GHG emissions (an environmental resource) for labor inputs, but this has a limit, given by (a_{XR}, e_{XR}), where a_{XR} is the minimum labor input and e_{XR} is the maximum GHG emissions for the production of one unit of good X.
- The government imposes the per-capita emission quota $\zeta := \frac{Z}{L} < z_{XR}$.

Unit Cost Curve

- Given the prices of goods X and Y, p_X and p_Y, respectively, the competitive conditions for the goods are represented by

$$c_X(w, r) \geq p_X,$$
$$wa_Y \geq p_Y = 1,$$

where we assume the good Y is a numeraire.

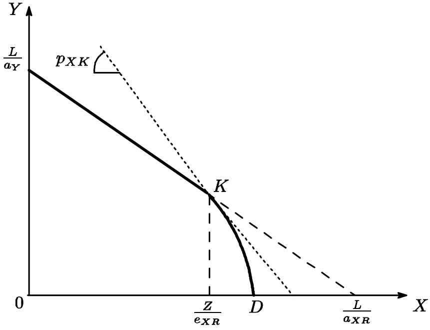


Production Possibility Frontier

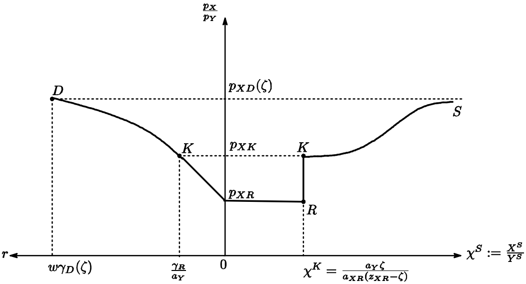
- Factor constraints are represented by

$$a_X(r/w)X + a_Y Y \leq L,$$
$$e_X(r/w)X \leq Z.$$

Prior to the introduction of emission quotas, producers of good X did not incur GHG emitting costs. Thus, the production possibility frontier is illustrated as a downward straight line as in the Ricardian model.



Relative Supply Curve



- For $p \in (p_{XR}, p_{XK})$, production takes place at the kinky point K on the production possibility frontier.

$$\chi^K = \frac{a_Y \zeta}{a_{XR}(z_{XR} - \zeta)}.$$

- For $p_X \in (p_{XK}, p_{XD})$, the relative supply of good X is strictly increasing in the relative price p_X because $r_D'(p_X) > 0$,

$$\chi^S(p_X, \zeta) = \frac{X^s}{Y^s} := \frac{a_Y \zeta}{a_X(r_D(p_X)a_Y)\left[z_X(r_D(p_X)a_Y) - \zeta\right]}.$$

National Welfare

- The national welfare of the country is measured by the utility of the representative household with the following utility function,

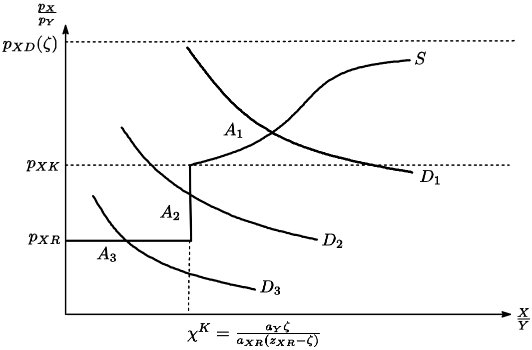
$$U = U\left(u(X^c, Y^c), Z^W\right),$$

where X^c is the consumption of good X, Y^c is the consumption of good Y, $u(\cdot)$ is a sub-utility function, and Z^W is the total GHG emissions in the world.

- The household's utility function satisfies the following properties.

1. $U(u, Z^W)$ is (i) strictly increasing in the sub-utility u (ii) strictly decreasing in Z^W, and (iii) twice continuously differentiable.
2. $u(X^c, Y^c)$ is (i) strictly increasing in the consumption of each good, (ii) twice-continuously differentiable, (iii) strictly concave, and (iv) homothetic. It also satisfies (v) $\lim_{\chi^C \to +0} \frac{\partial u(\chi^C,1)/\partial X^c}{\partial u(\chi^C,1)/\partial Y^c} = +\infty$ and $\lim_{\chi^C \to +\infty} \frac{\partial u(\chi^C,1)/\partial X^c}{\partial u(\chi^C,1)/\partial Y^c} = 0$ where $\chi^C := X^c/Y^c$.

Autarky Equilibrium



- The autarky equilibrium is governed by

$$\chi^S(p_X, \zeta) = \chi^D(p_X).$$

- There are possible equilibria, that is, $A_i (i = 1, 2, 3)$ for each relative demand curve D_i. The emission quota is strictly binding at A_1, and is strictly unbinding at A_3. It is just binding at A_2.

Two Country Model

- We consider the international trade in goods and emissions between the two countries that have already implemented domestic emission quotas.
- There are two potential causes for international trade, per-capita emissions quotas and production technologies.
- The per-capita emission quota of the home country is less than that of the foreign country,
$$\frac{Z}{L} < \frac{Z^*}{L^*}.$$
- The production technology for good X in the foreign country is given by the function
$$X^* = \frac{1}{\lambda_X} F(L_X^*, Z_X^*),\ \lambda_X > 1.$$
- For a unit output of good X, the abetment constraint is given by $(\lambda_X a_{XR}, \lambda_X e_{XR})$, where the minimum emission intensity, z_{XR}, is the same as that for the home country.

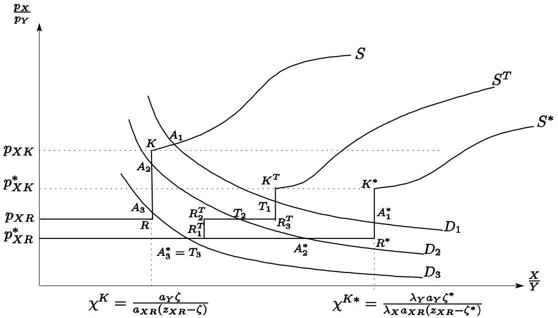
Two Country Model (continued)

- The production technology for good Y in the foreign country is given by

$$Y^* = \frac{L_Y^*}{\lambda_Y a_Y}, \ \lambda_Y > 1.$$

- When $\lambda_X = \lambda_Y$ holds, the technology gaps are the same between the sectors, and technological differences do not lead to a comparative advantage.
- Thus, under the assumption that $\lambda_X = \lambda_Y$, trade could arise from the comparative advantage based on the difference in per-capita emission quotas between the countries.
- We assume that the technology gap is smaller in good X than in good Y, i.e., $\lambda_X < \lambda_Y$
- Then, the technological difference reinforces a comparative advantage based on the difference in per-capita emission quotas between the countries.

Free commodity-trade equilibrium under technology gaps

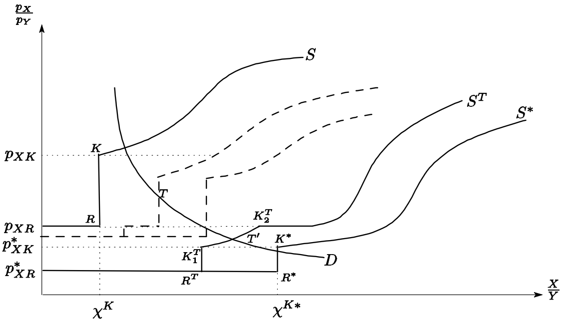


- The technology gap is smaller in good X than that in good Y, i.e., $\lambda_X < \lambda_Y$
- Under the countries' emission quotas being unbinding, $p^*_{XR} = \lambda_X a_{XR} / \lambda_Y a_Y < a_{XR}/a_Y = p_{XR}$.
- Under the countries' emission quotas being just biding, $p^*_{XK} = p^*_{XR} + \frac{\lambda_X e_{XR}}{\lambda_Y a_Y} \gamma^*_R < p_{XR} + \frac{e_{XR}}{a_Y} \gamma_R = p_{XK}$.

The Effects of Commodity Trade Liberalization

1. If the technology gap is smaller in good X than good Y, commodity trade would arise from comparative advantage based on the differences in both per-capita emission quotas and production technologies between the countries.
2. The home country would export good Y and the foreign country would export good X.
3. The trade liberalization in goods may not successfully mitigate global warming.

Technology Transfer in Import-Competing Sector



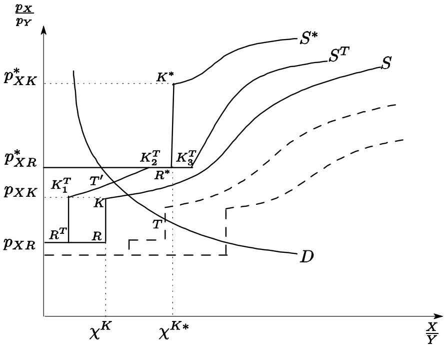
- We examine the effects of technology transfers at a trading equilibrium in which emissions quotas are binding for both countries before the technology transfers arise.

The Effects of Technology Transfer in Import-Competing Sector

Suppose that the home country transfers its superior technology in import-competing sector X to the foreign country.

1. The home country is specialized in producing good Y and its emissions of GHG decrease.
2. The foreign country expands its production of good X but its emissions remain the same due to its binding emission quota.
3. The home country gains from the technology transfer due to both the improvement in its terms of trade and the reduction of global GHG emissions.
4. It is ambiguous whether the technology transfer benefits the foreign country since the loss from the worsening in its terms of trade may exceed the gains from the global GHG reduction.

Technology Transfer in Export Sector



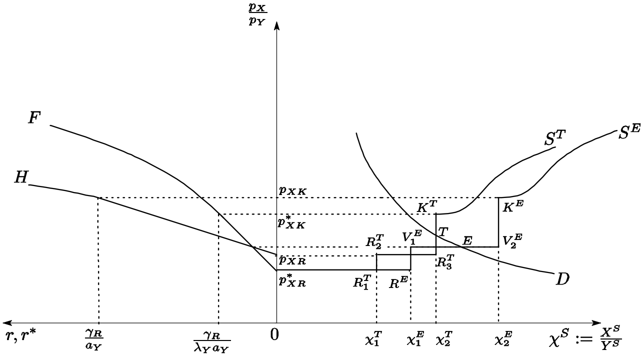
- If the home country transfers its superior technology in export sector Y to the foreign country, then the parameter for the technology gap in good Y, λ_Y, decreases.
- As a result, the technology gap in sector Y becomes smaller than that in sector X, $\lambda_Y < \lambda_X$.

The Effects of Technology Transfer in Export Sector

Suppose that the home country transfers its superior technology in export sector Y to the foreign country and the trade pattern is reversed.

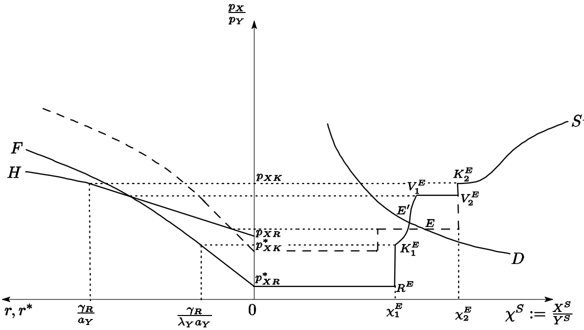
1. The home country is incompletely specialized in good X and its emissions remain the same due to its quota being binding before and after the technology transfer.
2. The foreign country is completely specialized in good Y and its emissions decrease to zero.
3. The welfare effects of the technology transfer are ambiguous for the countries.
4. Their benefits from the reduction in global emissions are greater under the technology transfer in sector Y than that in sector X.

International Emissions Trading Equilibrium



- At the initial equilibrium with free trade in goods only, emissions quotas are binding for both countries.
- At the free trade equilibrium, T, the emissions permit price in the home country, r, is higher than that in the foreign country, r^*.
- At the equilibrium with free trade in permits as well as goods, E, the home country imports permits from the foreign country.

Technology Transfer in Sector X under Emissions Trading



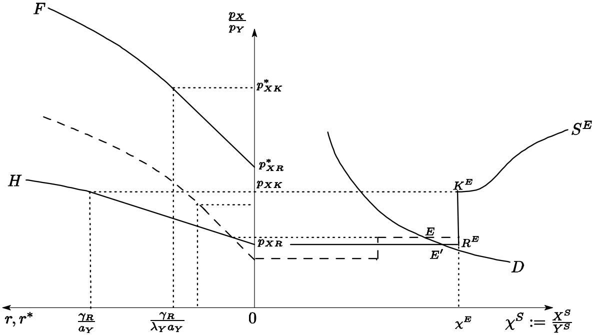
- If the home country transfers its superior technology in sector X to the foreign country, then the unit cost curve of the foreign country would move down to $p^*_{XR}F$ from the dotted curve.
- At the initial equilibrium, E, the technology transfer allows the foreign country to offer a higher return to emissions permits than the home country.
- The home country exports permits to the foreign country.

The Effects of Technology Transfer in Sector X under Emissions Trading

Suppose that the home country transfers its superior technology in import-competing sector X to the foreign country under free trade in emissions permits as well as goods.

1. The permit price increases.
2. The home country is specialized in producing good Y by exporting permits and the foreign country is incompletely specialized in good X by importing permits.
3. The technology transfer can hurt the home country but benefit the foreign country.
4. There is no change in the global emissions of GHG due to the technology transfer.

Technology Transfer in Sector Y under Emissions Trading



- The technology transfer in sector Y moves the relative cost curve of the foreign country upward to $p^*_{XR}F$ from the dotted curve.
- In the foreign country, the improvement of labor productivity in sector Y results in a higher wage rate, leading to a decrease in the permit price in the foreign country.
- The home country having a higher permit price expands the production of good X by importing permits from the foreign country.

The Effects of Technology Transfer in Sector Y under Emissions Trading

Suppose that the home country transfers its superior technology in sector Y to the foreign country under free trade in emissions permits as well as goods.

1. The permit price decreases.
2. The home country is incompletely specialized in producing good X by importing permits and the foreign country is completely specialized in good Y by exporting permits.
3. If the home country exports good Y and the foreign country exports good X initially, it is ambiguous whether the technology transfer can benefit or hurt each country.
4. Due to the technology transfer, the global emissions of GHG can decrease.

Concluding Remarks

We explore the effects of international technology transfers on global warming and welfare in a two-country, two-good, general equilibrium model, having both Ricardian and Heckscher-Ohlin features.

- The following results are obtained if the countries engage in trade in goods.
- The home country benefits from the technology transfer in its import-competing and more emissions-intensive sector due to its terms of trade improvement and an reduction in global emissions.
- The technology transfer in home country's export and less emissions-intensive sector leads to ambiguous welfare effects due to the trade pattern reversal.
- A reduction in global emissions is larger due to the technology transfer in the export sector of the home country compared to that due to the technology transfer in the import-competing sector.

Concluding Remarks (continued)

- The following results are obtained if the countries engage in trade in emissions and goods.
- Technology transfers do not necessarily reduce the permit price.
- The technology transfer in the import and more emissions-intensive sector of the home country can increase the permit price and hurt the home country due to a deterioration in its terms of trade.
- The technology transfer in the export and less emissions-intensive sector of the home country reduces the permit price, leading to a reduction in global emissions and ambiguous welfare effects due to the trade pattern reversal.