L Karp
International Trade
December 7, 2005

5 Environmental policy and comparative advantage

Stricter environmental policies (e.g. an increase in emissions taxes or a decrease in allowable emissions) increase the costs of production in sectors that use environmental services. Most (if not all) economic models imply that stricter environmental policies decrease output in environmental-intensive sectors. It might seem from this statement that stricter environmental policies reduce a country's comparative advantage in environmental-intensive goods, because stricter polices reduce the supply of the dirty good. This chapter explains why that conclusion might be either true or false.

The pollution haven hypothesis is based on the idea that weak environmental protection promotes a comparative advantage in environmentally intensive industries. The corollary to this idea is that increased domestic environmental protection risks causing industries that use environmental services intensively to relocate to other countries.

The view that stricter environmental standards decrease the comparative advantage of the environment-intensive sector may appear to be obviously true. It is probably based on intuition from a partial equilibrium setting, where factor prices are taken as given. The logic behind the belief is clear in a model with two commodities, where the "dirty sector" creates pollution and the "clean sector" does not, and both sectors have constant returns to scale. In a competitive equilibrium profits in both sectors are zero. In a partial equilibrium model, where factor prices are fixed, a higher pollution tax has no effect on costs in the clean sector, but it raises (tax-inclusive) costs in the dirty sector. Since profits in the dirty sector are initially zero, continued operation of the sector (after the tax increase) requires an offsetting increase in the price of the commodity produced by the dirty sector. Since the price of the dirty good has increased and the price of the clean good has not changed, the relative price of the dirty good has increased. That is, the higher tax reduces the country's comparative advantage in the dirty good.

Although this conclusion may be correct, the reasoning behind it is not valid in a general equilibrium setting, where factor prices adjust. The next section presents elements of the general-equilibrium model in chapter 2 of Copeland and Taylor's Trade and the Environment.

There, a stricter environmental policy does reduce a country's comparative advantage in the environmentally intensive sector. The following section discusses Chau's general equilibrium model (Oxford Economic Papers, 55 (2003) pages 25 - 35 "Does tighter environmental policy lead to a comparative advantage in less polluting goods?"). In this setting, the relation between environmental policies and comparative advantage can be ambiguous.

The two general equilibrium models have different implications because they make different assumptions about the abatement technology. In Copeland and Taylor's model, the abatement technology is identical to the production technology in a sector: a unit of abatement and a unit of production within a sector always use factors in the same ratio. With this abatement technology, it is as if a firm uses a fraction of its output to clean up emissions. Chau's model allows the production and abatement activities within a sector to use inputs in different ratios. For example, production of a good may use a lot of labor and a small amount of capital, but reducing emissions may require substantial additional capital and little additional labor.

5.1 A special abatement technology

There are two sectors, a clean and a dirty sector. The clean sector produces the numeraire good, so the relative price of the good produced by the dirty sector is p. In the absence of abatement, one unit of output from the dirty sector creates one unit of emissions; this assumption amounts to a choice of units. Denoting x as output and z as emissions, the joint production function in the sector is

$$x = (1-\theta)\,F(K,L)$$

$$z = \varphi(\theta)\,F(K,L), \tag{87}$$

where F is a constant returns to scale technology and $0 \leq \theta < 1$. The function F determines "potential output", the amount of output that would be available if no factors were used to abate emissions, and θ is the fraction of potential output that is used to abate emissions. Copeland and Taylor assume that

$$\varphi(\theta) = (1-\theta)^{1/\alpha}. \tag{88}$$

This functional form implies that, if abatement is positive, i.e. if $\theta > 0$ (as we hereafter assume) then it is possible to invert the joint production function to write output as

$$x = z^{\alpha}\left[F(K,L)\right]^{1-\alpha}. \tag{89}$$

The output of x is a Cobb-Douglas function of potential output F and emissions z (for $\theta > 0$). This function has constant returns to scale in z, K, L.

The firm faces factor costs w and r, output price p, and a unit tax of τ. The firm pays τ for each unit of pollution, so its total tax payments are τz. Because of constant returns to scale, profits are 0, so costs are px in equilibrium. The Cobb-Douglas structure implies that the firm always spends the fraction α "buying" emissions rights, i.e., paying emissions taxes:

$$\frac{z\tau}{px} = \alpha \Longrightarrow z = \alpha \frac{p}{\tau} x. \tag{90}$$

This relation implies that the emissions per unit of out put is

$$e \equiv \frac{z}{x} = \alpha \frac{p}{\tau}. \tag{91}$$

Using equations (87) and (90) and the functional form shown in equation (88), we can obtain the equilibrium value of θ as a function of the ratio of the price to the tax, $\theta = \theta^* \left(\frac{p}{\tau}\right)$.[13] It can be shown that

$$\frac{\partial \theta^*}{\partial \tau} > 0. \tag{92}$$

As the tax rises, the firm uses a greater fraction of potential output to abate emission.

The firm's profits are

$$\begin{aligned} px - wL - rK - \tau z &= p(1-\alpha)x - wL - rK \\ &= p(1-\alpha)(1-\theta)F(K,L) - wL - rK. \end{aligned} \tag{93}$$

Define $q^F = p(1-\alpha)(1-\theta)$; this is the amount that the firm receives for each unit of *potential output* $(F(K,L))$; q^F can be thought of as the "effective price" per unit of potential output. The fraction θ of potential revenue ($p \cdot F(K,L)$) is paid to abate emissions, and the fraction α is used to pay taxes, leaving the firm with the fraction $(1-\alpha)(1-\theta)$ to sell at the market price p. The actual (as distinct from potential) amount of the dirty good that the firm sells is $x = (1-\theta)F(K,L)$. The after-tax revenue per unit of actual output is $q = (1-\alpha)p$.

[13] Equations (87) and (90) imply

$$\begin{aligned} z &= \varphi(\theta)F = \alpha\frac{p}{\tau}(1-\theta)F \Longrightarrow \\ \varphi(\theta) &= \alpha\frac{p}{\tau}(1-\theta). \end{aligned}$$

Using equation (88) we can solve this implicit equation to obtain the function θ^*.

The difference between q^F and q reflects the difference between an output tax and an emissions tax. With an ad valorem output tax of α the firm has an incentive to reduce output, because it receives the after-tax unit revenue of $(1-\alpha)\,p$, but it has no incentive to reduce emissions per unit of output. With the ad valorem tax, $\theta = 0$. A sufficiently large emissions tax creates an incentive to reduce both emissions per unit of output and to reduce output. The emissions tax affects both scale and "technique", whereas the output tax affects only scale.

5.1.1 The result

In view of equation (92), we have

$$\frac{\partial q^F}{\partial \tau} < 0. \tag{94}$$

Inequality (94) states that an increase in the tax reduces the "effective price". The same result holds in a partial equilibrium setting, where factor prices are constant and therefore the cost of producing potential output is constant. In this general equilibrium setting, factor prices adjust to a change in the tax (or the price p), but it is not been necessary to consider those adjustments to obtain inequality (94).

This inequality is almost enough to conclude that a higher emissions tax (i.e. a stricter environmental policy) erodes a country's comparative advantage in the dirty good. As the tax increases, the effective relative price of the dirty good falls, making production in that sector relatively less attractive. Figure 1 graphs the relative demand for the dirty good x and the clean good Y as a function of the relative price, under the assumption of homothetic preferences (so that relative demands depend only on price, not on income). The assumption of CRTS implies that the relative supply of x to Y also depends on the relative commodity price – see equation (83) in Chapter 4.5.2. Of course, the relative supply also depends on parameters that are held constant (e.g.the emissions tax).

Since higher taxes reduce the effective price received by producers of the dirty good, it seems natural that a higher tax shifts in the relative supply of the dirty good. Figure 1 illustrates this possibility. At the original tax, the relative supply function is S and the equilibrium autarkic price is p_1. When the supply curve shifts in, the autarkic price rises to p_2. In this case, the higher tax increases the autarkic price of the dirty good, reducing a country's comparative advantage in the dirty good. However, as the tax changes, the firm changes the level of abatement, thus changing the quantities of capital and labor that is uses for abatement. There is a corresponding change in factor prices, which alters the supply of the clean good Y. We need to take this change into account, in finding the relation between the tax and relative supplies of the two goods.

We need to show that the higher tax does indeed shift in the relative supply curve, as assumed in figure 1. Figure 2 shows three PPFs. The outer curve is the PPF when there is no abatement, $\theta = 0$, and the inner two curves show the PPF corresponding to successively higher levels of abatement, $\theta'' > \theta' > 0$. For a fixed output of Y, given by the level $\hat{Y}$ in figure 2, the maximum technically feasible supply of x is given by the x coordinate of the points a, b, and c. These are points on the PPFs corresponding to values of θ equal to 0, θ' and θ''.

We want to show that at a fixed (arbitrary) price p, the equilibrium relative supply of x (i.e., relative to the supply of good Y) is smaller at higher taxes. Therefore, we hold p constant for this exercise and vary τ. We noted above that the equilibrium θ is an increasing function of τ (for fixed price p). We can view θ' and θ'' as the optimal value θ, for a fixed price p and for two values of τ, τ' and τ''. Given the optimal choice of θ, the producer chooses levels of capital and labor to maximize profits, given by the second line in equation (93). For each unit of output, x, the producer receives the net-of-tax payments price $1 - \alpha$. Thus, the net-of-tax price is $q = (1 - \alpha)\,p$; recall that this is a relative price, since we took the price of the clean good as the numeraire. Using the usual tangency condition, the equilibrium production point is at d in figure 2 when the price is p and the tax is τ' (so that $\theta = \theta'$) and the production point is at c when price is p and the tax is τ'' (so that $\theta = \theta''$).

From this figure it is clear that a higher tax (which corresponds to a larger value of θ) must decrease the relative supply of the dirty good at relative price p. Therefore, a higher tax causes the relative supply curve to shift in, as shown in figure 1. A higher tax increases the autarkic relative price of the dirty good, and therefore erodes the country's comparative advantage in the dirty good.

This model produces a plausible result, but it relies on a particular abatement technology. The firm uses some of its potential output in order to reduce abatement. The abatement technology is identical to the production technology for the dirty good, in the sense that the capital/labor ratio is identical for production and for abatement. This assumption makes it possible to model the economy as consisting of two sectors. In this setting, all of the basic theorems of the HOS model, discussed in Chapter 4, continue to hold.

5.2 A more general abatement technology

In view of the special nature of the technology assumed in the previous section, it is worth investigating whether the relation between environmental policies and comparative advantage survives in a more general setting. Chau's model allows the sector that produces abatement services to use capital/labor ratios that might differ from the ratios used in either the dirty or the clean sector. This change means that there really are three sectors in the economy. We can think of the dirty and the clean sector as producing tradeable goods, and the abatement sector as producing a non-tradeable service.

We retain the assumption of constant returns to scale in each sector, and the assumption that there are only two factors of production, capital and labor. Recall that the assumption of constant returns to scale means that capital/labor ratios depend on relative factor prices but not on the scale of output. In contrast to the version of the HOS model that we previously considered, we now have three sectors and two factors of production.

This "imbalance" is reminiscent of the Ricardian model in Chapter 1, where there are two sectors and one factor. There we saw that the assumption of incomplete specialization determined the equilibrium relative commodity price. Here we obtain a similar result: the assumption of incomplete specialization, together with an exogenously chosen emissions tax, determines the equilibrium relative commodity price between the two tradeable goods. In the Ricardian model, the autarkic price – and thus, comparative advantage – depends only on relative productivity in the two sectors. In particular, it does not depend on tastes, as occurs in the HOS model. In the Ricardian model, if two countries have the same relative productivity, their autarkic relative prices are equal, and there are no gains from trade.

In the model discussed here, there is an extra degree of freedom. Two countries might have the same technology but different environmental policies – specifically, different emissions taxes. In that case, they have different autarkic relative prices for the two tradeable goods. In this case, comparative advantage depends only on the relative emissions taxes in the two countries. Our objective is to determine whether higher emissions taxes lead to a higher autarkic relative price for the dirty good. In other words, does a higher emissions tax erode comparative advantage in the dirty good sector?

In contrast to the model in the previous section, here the answer is ambiguous. Consider the effect of moving from a 0 emissions tax to a positive tax. At constant factor prices, the imposition of a sufficiently large tax causes the firm in the dirty sector to incur abatement costs.

To the extent that the firm continues to emit pollution, it also has to pay taxes. Both of these effects decrease net revenue (i.e., revenue net of abatement costs and tax payments), thereby decreasing the effective price that the dirty sector firm faces. If factor costs were to remain constant (as in a partial equilibrium setting) the relative price of the dirty good has to rise in order to maintain 0 profits in the dirty good sector. I refer to this as the "partial equilibrium effect". The partial equilibrium effect causes pressure for an increase in the relative price of the dirty good under stricter environmental policies.

In the general equilibrium setting, the tax does change factor prices. In the general equilibrium model in the previous section, the change in costs in both the abatement sector and the dirty sector are proportional, since (as explained above) those two sectors are essentially the same. In a more general setting, however, the two sectors are distinct (since they use different capital-labor ratios).

For concreteness, suppose that the dirty sector is the most labor intensive of the three sectors, and the abatement sector is the most capital intensive of the three. The imposition of the tax creates the demand for abatement, which requires relatively large amounts of capital. This increased demand for capital tends to increase the price of capital relative the price of labor. Since (by assumption) the clean sector is capital intensive relative to the dirty sector, this change in factor prices raises costs in the clean sector by more than in the dirty sector. In order to maintain 0 profits in all sectors, this change in costs causes pressure for the price of the clean good to rise relative to the price of the dirty good. I refer to this as the "general equilibrium effect" as it involves a change in factor prices. The general equilibrium effect might either counter or reinforce the partial equilibrium effect, depending on the relative capital intensity of the sectors. In some cases, the general equilibrium effect can overwhelm the partial equilibrium effect. In that case, the emissions tax promotes the country's comparative advantage in the dirty good.

5.2.1 The model and result

The clean sector, which produces the numeraire good, creates no emissions. In the absence of abatement, the dirty sector produces one unit of emissions per unit of output. The price of the dirty good is p. The firm in the dirty sector can remove a unit of emissions by buying a unit of "abatement services" at price p^A, and the firm faces a unit emissions tax of τ. The prices p, p^A and τ are all relative prices; they are the price relative to the price of the numeraire, the clean good. Profits in the dirty sector equal revenues minus tax payments minus payments to labor and capital minus the cost of abatement services. If the firm buys A units of abatement services, its profits are

$$\begin{aligned} \pi_2 &= py_2 - \tau\left(y_2 - A\right) - wL_2 - rK_2 - p^A A \\ &= y_2\left(p - \tau\right) - wL_2 - rK_2 + \left(\tau - p^A\right) A. \end{aligned} \tag{95}$$

Suppose that in equilibrium the firm abates at a positive level but does not eliminate emissions: $0 < A < y_2$. This assumption, together with profit maximization, requires that in equilibrium

$$\tau = p^A. \tag{96}$$

If this equality did not hold, the firm would either choose not to abate, or would abate all emissions.

As in Chapter 4, define $c_i(w, r)$ as the unit cost of producing one unit of output in sector i, for $i = 1$ (the clean sector) $i = 2$ (the dirty sector) and $i = A$ (the abatement sector. The assumption that all sectors operate, means that there must be 0 profits in each sector and the equilibrium condition (96) must hold:

$$\begin{aligned} \tau &= c_A(w, r) \\ 1 &= c_1(w, r) \\ p - \tau &= c_2(w, r). \end{aligned} \tag{97}$$

This system contains three equations in three unknowns, w, r and p; it has a unique solution. The assumption of incomplete specialization determines the relative price of tradeables, as in the Ricardian model.

Figure 3 shows the isocost curves for the numeraire good and for abatement services, for a fixed τ. The equilibrium factor price is at point A. The figure assumes that the abatement sector is capital intensive relative to the clean sector, in line with the example above. (The tangent to the isocost c_A is steeper than the tangent to the isocost c_1 at point A.) An increase in the abatement tax to $\tau' > \tau$ causes equilibrium factor prices to move to point B; the price of capital rises and the price of labor falls, to maintain 0 profits in each sector. (Recall Property 2 in Chapter 4.3.2.)

Figure 4 reproduces figure 3, adding the isocost curve for the dirty good sector (the dashed curve), and showing the price that is consistent with incomplete specialization. This equilibrium price is the price at which the three curves intersect at point A. At any other value of p the three curves do not intersect at the same point. In that case, there is no solution to the system (97): for such a price, there is not an equilibrium in which all three sectors operate.

An increase in τ causes the equilibrium factor prices to move to point B as explained above. In general, p must also change in order that the three curves intersect at B (i.e., in order to maintain incomplete specialization). The direction of change of p following an increase in τ is not obvious from the figure. (It is clear that $p-\tau$ must fall in order for the dashed curve to pass through point B, but that fact does not tell us whether p increases or decreases following an increase in τ.)

In order to determine the comparative statics we need to totally differentiate the system (97). As in Chapter 4, we use the envelope condition

$$\frac{\partial c_i\left(w,r\right)}{\partial w}=a_{iL} \qquad \frac{\partial c_i\left(w,r\right)}{\partial r}=a_{iK}, \quad i=1,2,A, \tag{98}$$

to write the differential of system (97) as

$$d\tau = a_{AL}dw + a_{AK}dr$$

$$0 = a_{1L}dw + a_{1K}dr$$

$$dp - d\tau = a_{2L}dw + a_{2k}dr.$$

It is straightforward but tedious to solve this system to find the expression for $\frac{dp}{d\tau}$:

$$\frac{dp}{d\tau}=1-\frac{a_{1K}a_{2L}-a_{2k}a_{1L}}{a_{1L}a_{AK}-a_{1K}a_{AL}}=1-\left(\frac{a_{2L}}{a_{AL}}\right)\frac{k_1-k_2}{k_A-k_1}. \tag{99}$$

At constant factor prices, a unit increase in the tax requires a unit increase in the commodity price in order to maintain 0 profits in the dirty sector. The first term (1) of the comparative statics expression measures this partial equilibrium effect. The second term can be positive or negative, depending on the sign of $\frac{k_1-k_2}{k_A-k_1}$. If this expression is negative, the general equilibrium effect (operating through the change in factor prices) reinforces the direct (partial equilibrium) effect. However, if this expression is positive, the general equilibrium effect tends to offset the partial equilibrium effect.

Equation (99) shows that a *necessary* condition for $\frac{dp}{d\tau} < 0$ (the counter-intuitive case) is

$$\text{sign } (k_1 - k_2) = \text{sign } (k_A - k_1) .$$

That is, the necessary condition for an increase in the tax to increase the country's comparative advantage in the dirty sector is that either of the following pair of inequalities hold: $k_A > k_1 > k_2$ or $k_A < k_1 < k_2$. In either of these cases, an increase in abatement services (following an increase in the tax) uses primarily the factor that is used intensively in the clean sector (relative to the dirty sector). In these cases, an increase in the tax decreases the cost of producing the dirty good. Chau uses Cobb-Douglas functional forms to confirm that the sufficient condition for $\frac{dp}{d\tau} < 0$ can hold for some parameter values.