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A Strategic Trade and Environmental Policy Argument for the Kyoto Protocol

By Z. Yu

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The Authors

Zhihao Yu is Lecturer in the School of Economics, University of Nottingham.

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Abstract

The paper identifies a unique aspect of the Kyoto Protocol from the view of strategic trade and environmental policy. While investigating the horizontal "profit-shifting", vertical "rent-extracting", and "collusion-facilitating" effects, it focuses on the strategic behaviour of the OPEC and the potential role of the Protocol on oil-rent extraction. Among other things, it is shown that those member countries that export oil can also benefit from the Protocol even in the absence of environmental considerations, and hence suggests a new argument for the Kyoto Protocol for participating countries.

Outline

Non-Technical Summary

One of the most important features of recent international environmental agreements (IEAs) is characterised by self-enforcing and voluntary participation [e.g., see Barrett [1], Saijo and Yamato [12]]. To explain them, we need to understand the incentives (i.e. the relevant costs and benefits) of their signatories to join such IEAs. Moreover, a better understanding of these benefits and costs is also very important for IEAs to be sustained in the long run. The 1998 Kyoto Protocol requires a rapid reduction of carbon emissions by industrial nations but leaving developing countries sitting on the sideline uncommitted. As Shogren [13] notices, this "[h]as left many experts unimpressed by the protocol, which seems to some as a quick political fix rather than a serious response driven by the natural sciences and economics". The Protocol, however, was open for signatures between 16 March 1998 and 15 March 1999 and by the closing date 39 nations have signed the accord. The break-down of the recent talk on implementing the protocol at the UN summit on global warming at Hauge reminds us again of the mounting obstacles ahead. The purpose of this paper is to suggest another argument for the Kyoto Protocol from the view of strategic trade and environmental policy.

There are two common arguments for IEAs and international coordination on environmental policy. The first argument is based on the fact that environmental issues are characterised by transboundary pollution and the associated free-riding problems. The second argument comes from the fear for the prison's dilemma: in a non-operative game each country might adopt lax environmental policy when it is concerned with the competitiveness of its firms in the world market. This paper, however, identifies a unique aspect of the Kyoto Protocol, which hopefully would not only help us to better understand the incentives of the signatories but also strengthen their future cooperation.

Specifically, notice that most signatories of the Kyoto Protocol are industrial nations and, unlike developing countries, a major part of their carbon emissions comes from consumption of oil. Most of them are also oil-importers (except a few countries, e.g., Norway and Britain) and they constitute the major demand in the world oil market. On the supply side of oil, the OPEC is the dominant player in the world market. Because of the collusive behaviour among the OPEC countries (through limiting output and hence raising oil price), they earn a huge amount of rents. This then suggests that the Kyoto Protocol could potentially play a role of "strategic rent-extraction" (see Brander and Spencer [4]).

As shown in the paper, however, the effect of such a rent-extracting initiative by one nation is limited due to the product competition in the world market and hence such an incentive is dominated by the concern for the competitiveness of its firms. But the Kyoto Protocol could potentially play the role of coordination for the rent-extracting effect to be achieved. Moreover, we show that having accounted for the strategic behaviour of the OPEC, the Kyoto Protocol could also benefit those member countries that actually export oil.

1. Introduction

One of the most important features of recent international environmental agreements (IEAs) is characterised by self-enforcing and voluntary participation [e.g., see Barrett [1], Saijo and Yamato [12]]. To explain them, we need to understand the incentives (i.e. the relevant costs and benefits) of their signatories to join such IEAs. Moreover, a better understanding of these benefits and costs is also very important for IEAs to be sustained in the long run. The 1998 Kyoto Protocol requires a rapid reduction of carbon emissions by industrial nations but leaving developing countries sitting on the sideline uncommitted. As Shogren [13] notices, this "[h]as left many experts unimpressed by the protocol, which seems to some as a quick political fix rather than a serious response driven by the natural sciences and economics". The Protocol, however, was open for signatures between 16 March 1998 and 15 March 1999 and by the closing date 39 nations have signed the accord. The break-down of the recent talk on implementing the protocol at the UN summit on global warming at Hauge reminds us again of the mounting obstacles ahead.[1] The purpose of this paper is to suggest another argument for the Kyoto Protocol from the view of strategic trade and environmental policy.

There are two common arguments for IEAs and international coordination on environmental policy. The first argument is based on the fact that environmental issues are characterised by transboundary pollution and the associated free-riding problems. The second argument comes from the fear for the prison's dilemma: in a non-operative game each country might adopt lax environmental policy when it is concerned with the competitiveness of its firms in the world market. This paper, however, identifies a unique aspect of the Kyoto Protocol, which hopefully would not only help us to better understand the incentives of the signatories but also strengthen their future cooperation.

Specifically, notice that most signatories of the Kyoto Protocol are industrial nations and, unlike developing countries, a major part of their carbon emissions comes from consumption of oil. Most of them are also oil-importers (except a few countries, e.g., Norway and Britain) and they constitute the major demand in the world oil market. On the supply side of oil, the OPEC is the dominant player in the world market. Because of the

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[1] The break-down at Hauge does not suggest that the Kyoto Protocol is 'dead', however. There are many opportunities down the road for the member countries to come together again to resolve their differences. For example, at an international climate conference in October, German Chancellor Gerhard Schroeder called on industrialized countries to ratify the Kyoto Protocol by 2002, the 10th anniversary of the Rio Earth Summit

collusive behaviour among the OPEC countries (through limiting output and hence raising oil price), they earn a huge amount of rents. This then suggests that the Kyoto Protocol could potentially play a role of "strategic rent-extraction" (see Brander and Spencer [4]).

As shown in the paper, however, the effect of such a rent-extracting initiative by one nation is limited due to the product competition in the world market and hence such an incentive is dominated by the concern for the competitiveness of its firms. But the Kyoto Protocol could potentially play the role of coordination for the rent-extracting effect to be achieved. Moreover, we show that having accounted for the strategic behaviour of the OPEC, the Kyoto Protocol could also benefit those member countries that actually export oil.

It is well-known that the entire burden of an excise tax falls on the supplier when a good is in fixed supply.[2] In general, if the elasticity of supply of a fuel is low, the produers will bear the most burden of any carbon tax. Most computational-general-equilibrium (CGE) models of economic effects of carbon reductions make little explicit provision for international trade effects (e.g., Manne and Richels [10]). The first exception is Whalley and Wigle [15], in which they employ an inelastic world supply curve for all carbon energy.[3] The study does not capture the strategic behaviour of the OPEC, however. With an inelastic supply, much of the impact of a reduction in demand falls on the price of the fuel, rather than on the level of its use. However, if a fuel is supplied by a major producer that has monopoly power, the supply response would be very different (monopoly does not have a supply curve). It would reduce its output to keep up the price of the fuel. This would reduce the negative impact (i.e., the reduction of price) on other exporters of the fuel. As it is shown in this paper, the Kyoto Protocol could actually benefit those member countries that actually export oil even in the absence of environmental consideration.

This idea of strategic rent-extracting is first illustrated by Brander and Spencer [4]. Our paper also benefits from a recent paper by Ishikawa and Spencer [7] in which these authors nicely analyze the issues of both horizontal profit-shifting and vertical rent-extracting under imperfect competition and the implications for strategic trade policy. The literature on strategic environmental policy has focused on the horizontal profit-shifting effect [e.g., see

[2] Bergerstrom [3] extends this insight to a multi-period framework, in which the total supply of a good is fixed, through imposing such a tax once and forever.

[3] They have estimated that oil-exporting countries would lose 18.7 percent of their GDP over the period 1990-2030 if national consumption taxes were applied to reduce global carbon emissions by 50 percent from the baseline they would otherwise follow (Cline [5]). For the typical set-up of the CGE models with international trade, see Perroni and Rutherford [11].

Barrett [2], Conrad [6], Kennedy [8], and Ulph [14] rather than the vertical rent-extracting effect as discussed in this paper.

The rest of the paper is organized as follows. Section 2 uses a model of Bertrand competition to highlight the conflict between the rent-extraction and competitiveness consideration. Section 3 uses a model of Cournot competition to analyze in detail the incentives associated with rent-extracting, profit-shifting, collusion-facilitating, and transboundary pollution. Section 4 concludes the paper.

2. Global Warming and the "Kyoto Protocol" – Bertrand Competition

To highlight the conflict between the rent-extraction and competitiveness considerations when governments impose carbon taxes, in this section we analyze the effects of the Kyoto protocal in the framework of Bertrand competition. The competitiveness of firms is illustrated most starkly under the Bertrand competition: the firm that is negatively affected by an environmental tax will be put out off the market due the intensive price competition.

Throughout the analysis in this paper, the structure of the game is as follows. In the first-stage a government (or governments) imposes a carbon tax.[4] In the second stage the oil monopolist decises the price of oil. In the third-stage firms comptete in the product market. Assuming that the equilibrium concept is the sub-game Perfect Nash Equilibrium, the game is solved from the backward.

2.1. Rent-extraction and Product Market Competition

In this section we first focus on the tension between the rent-extraction and competitiveness considerations alone, without introducing environmental issues. Assume that there are n identical countries - all have the same production technologies and labor endowments. In each country there are two industries that produce two homogenous goods, Y and X, respectively. Good Y is a numeraire good, which is produced under perfect competition by a CRS tenology using labor as the only factor of input. This also implies that trade ensures the wage rate to be the same in these countries, which rules out the difference in the cost of labor for producing good X. Good X is produced via a Leontif technology using both labor

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[4] We only discuss environmental taxes since the choice of policy instruments is not our focus.

and oil.[5] By choice of units, we assume that to produce one unit of good x requires one unit of labor and oil. That is , the production function is given by

(2.1) $$x = \min\{l, k\},$$

where l and k are inputs of labor and oil, respectively. Suppose labor is immobile between countries and oil is supplied by a monopolist in the word market (we will allow each country to have some oil endowment).

Following Brander and Spencer [4], we assume that in each country good X is produced by one firm and is sold at a “third market” that is outside their domestic markets – the ‘world market’. Suppose the demand of the world market for good X is given by the following inverse demand function,

(2.2) $$P = a - bX.$$

Assuming that the output of each firm is small relative to the total demand, we first solve for the symmetric equilibrium outcome.

Let w be the wage and r the price of oil. The price (p) and the unit cost (c) of good X are then given by

(2.3) $$p = c = w + r.$$

From (2.2) and (2.3) we obtain the output of good X for each country,

(2.4) $$x = \frac{a-(w+r)}{nb}$$

The profit of each firm is zero under Bertrand competition but this is not true for the monopolist that produces oil.

Using (2.4) we obtain the demand for oil as follows:

(2.5) $$K = nx = \frac{a-(w+r)}{b}.$$

For simplicity and without loss of generality, suppose the cost of producing and transporting oil is zero. The profit (or rent) for the monopolist becomes

(2.6) $$R = [\frac{a-(w+r)}{b}]r$$

[5] It will become clear that allowing substitution between l and k (e.g., Cobb-Douglas function) would strengthen our results.

Therefore, the price of oil that maximises the profit of the monopolist is

$$r^* = \arg\max_r \left[\frac{a-(w+r)}{b}\right]r = \frac{a-w}{2} \tag{2.7}$$

and the level of the profit is

$$R^* = \frac{(a-w)^2}{4b} \tag{2.8}$$

Now suppose that country i (independently) imposes a tax t_i on consumption of oil in order to extract some rent from the oil monopolist. Thus the unit cost of producing good X for firm i (the firm that produces good X in country i) becomes

$$c^i = w + r + t^i \tag{2.9}$$

which is higher than that of the other competitors in the world market. Under Bertrand competition, this means that firm i will be forced out of the world market and therefore the government in country i cannot extract any rent from the oil monopolist. Due to the pressure of competition at the world market, country i cannot gain anything by imposing a consumption tax on oil and therefore would have no incentives to act alone.

However, if these n countries could coordinate and together impose a consumption tax on oil, they can extract rents from the oil monopolist. Suppose they agree to impose a tax t on consumption of oil. As a result, the unit cost of producing good X for each firm (and hence the price of good X) becomes

$$p(t) = c(t) = w + r + t \tag{2.10}$$

The total demand for oil now becomes

$$K(t) = nk(t) = nx(t) = \frac{a-(w+r+t)}{b} \tag{2.11}$$

It is easy to show that the best response of the oil monopolist is to reduce the oil price by $t/2$ to

(2.12)
$$r^*(t) = \arg\max_r \left[\frac{a-(w+r+t)}{b}\right]r = \frac{a-w-t}{2}$$

As a result, its profit reduces to

(2.13)
$$R^*(t) = \frac{(a-w-t)^2}{4b}$$

It is straightforward to show that the "optimal tax" that maximizes the revenue for these n countires [$tk(t)$ or $ntk(t)$] is

(2.14)
$$t^* = \frac{a-w}{2}$$

Substituting (2.14) into (2.13), we find that the rent of the oil monopolist reduces to,

(2.15)
$$R^*(t^*) = \frac{(a-w-t^*)^2}{4b} = \frac{(a-w)^2}{16b},$$

which is only one-fourth of the previous level. The total rent that is captured by these n countries from the oil monopolist is

(2.16)
$$nT = \frac{(a-w)^2}{8b}$$

which is half of the amount of the original rent and twice as much as that of the current rent of the oil monopolist.

Since we use the simplest model to illustrate our point, the rest of our discussion will focus on each government's incentive to impose/raise taxes at the margin, instead of comparing with the levels of the equilibrium variables under different regimes.

2.2. Carbon Emission and Environmental Tax

To fully investigate the incentives and the effects of the Kyoto Protocol, our model has to capture the associated environmental issues (i.e., trans-boundary pollution) and the fact that the involved countries themselves have oil endowment and some may even export oil. Will a country have incentives to participate in the Kyoto Protocol if it actually exports oil?

Suppose that consumption of oil (by firms in producing good X) generates carbon emission, which is transboundary pollution that contributes to global warming. Since pollution abatement is not the focus of this paper, we assume that there is no pollution abatement and that one unit of consumption of oil generates one unit of pollution. Therefore, a reduction of carbon emission is possible only when the consumption of oil is reduced. Suppose governments use a consumption tax (on oil) to achieve this objective (this is equivalent to introducing an environmental tax on output of good *X* in our model).

Suppose that each country also has oil endowment, $\bar{k}^i (i = 1, n)$. The objective of each country therefore is to maximize the sum of the return of its oil endowment, the tax revenue on oil consumption, minus the damage due to global pollution. Specifically, the government in country i has the following objective function:[6]

(2.17) $$G^i = r\bar{k}^i + t^i k^i - D(K), \quad \mathrm{D}'(.) > 0, \ \ \mathrm{D}''(.) > 0,$$

where k^i is the consumption of oil in country i and $K = \sum k^i$ is the global consumption of oil, which also represents the total amount of global pollution in our model.

Assume that each country's oil endowment is small relative to the global demand and the the oil-producing monopolist acts as the price-leader in the oil market. The equilibruim price of oil, when no country imposes a tax, can be obtained as follows [using (2.5)]:

(2.18) $$\begin{aligned} r^* &= \arg\max_r \ [K - \sum_{i=1}^{n} \bar{k}^i] r \\ &= \frac{a-w}{2} - \frac{b}{2} \sum_{i=1}^{n} \bar{k}^i \end{aligned}$$

Therefore, we obtain that

(2.19) $$\begin{aligned} G^i &= r^* \bar{k}_i - D(K) \\ &= (\frac{a-w}{2} - \frac{b}{2} \sum_{i=1}^{n} \bar{k}_i)\bar{k}_i - D(\frac{a-w}{2b}) \end{aligned}$$

Can country i increase its welfare G_i by imposing an environmental tax on oil unilateraly? As discussed above, under Bertrand competition firm i will be priced out of the world market if its country impose a consumption tax on oil. However, the total output of good *X* and the world demand for oil do not change (the other *n-1* countries simply increase their shares). Thus the price of oil and the consumption of oil all stay the same.

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[6] The profit of its firm producing good *X* should also be included, which is zero under Bertrand competition, however.

Since pollution is fully transboundary, the demage of global pollution is also the same. Therefore, country i will not gain anything and hence has no incentives to impose a consumption tax on oil.[7]

Now suppose these n countries can sign an agreement to impose a carbon tax - an environmental tax t on oil - in order to reduce carbon emission. As discussed above, the oil monopolist will in turn reduce the price of oil by $t/2$. That is

(2.20) $$r^*(t) = \frac{a-w}{2} - \frac{b}{2}\sum_{i=1}^{n}\bar{k}^i - \frac{t}{2}$$

Welfare for each country now becomes ($i = 1, n$)

(2.21) $$G^i(t) = r^*(t)\bar{k}^i + tk^i - D(K(t))$$

Taking derivative with respect to t, we obtain that,

(2.22) $$\frac{dG^i(t)}{dt} = \bar{k}^i\frac{dr}{dt} + (k^i + t\frac{dk^i}{dt}) - D'(.)K'(t)$$

To evaluate each country’s incentive to join a treaty to impose/increase a carbon tax, we evaluate (2.22) at $t = 0$, which is [after substituting (2.21) into (2.23)]

(2.23) $$\left.\frac{dG^i(t)}{dt}\right|_{t=0} = -\frac{\bar{k}^i}{2} + k^i + \frac{D'(K)}{2b}$$

The first term is the “endowment effect”, which is negative. An environmental tax on oil reduces the price of oil and hence reduces the income from oil endowment. The second term is the “rent-extracting effect”, which is positive. By imposing an environmental tax on oil, these countries can shift some of the oil rents from the oil monopolist into their treasuries (tax revenues). The last term is the “environmental effect”, which is positive. As a result of the tax, the consumption of oil and the global pollution are reduced.

Equation (2.23) deserves further discusion. First, since global warming is transboundary pollution, the Kyoto Protocol is helpful for the participating countries to deal with the negative extranality of global warming. Second, althought the presence of oil endowment in

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[7] Notice that this is true for any country regardless whether it is an importer or exporter of oil (i.e., $k^i - \bar{k}^i > 0$ or < 0).

each country would reduce its incentive to join the Kyoto Protocol, the rent-extracting effect of the Kyoto Protocol might be high. In addition to the environmental consideration for cooperation (i.e., $D'(K)=0$), countries [even those that export oil (i.e., $\bar{k}^i > k^i$)] would benefit from the Kyoto agreement as long as their oil endowments are not very large relative to their demand (i.e., $\bar{k}^i < 2k^i$).

3. Cournot Competition

The effect of one country' unilateral environmental tax on oil on the competitiveness of its firm in the world market is illustrated starkly under the Bertrand competition in the previous section. A unilateral environmental tax on oil by a government would put its firm out of the world market. In this section we consider Cournot competition and investigate in more details the incentives associated with rent-extracting, profit-shifting, collusion-facilitating, and transboundary pollution.

3.1. Firm Profits Vs. the Rent of Oil

In this subsection we first illustrate, using the simplest set-up, how the monopoly power in the oil market could capture firms' profits from the goods market. Suppose that governments do not impose any tax on oil. Then each firm maximizes the following objective function:

(3.1) $$\max_{x^i} \ \pi^i = (a - b\sum_{i=1}^{n} x^i)x^i - (w+r)x^i, \ \text{i} = 1, \text{n}.$$

The associated first-order condition is

(3.2) $$\pi_i^i = (a - b\sum_{i=1}^{n} x^i) - bx^i - (w+r) = 0, \quad \text{i} = 1, \text{n}.$$

The second-order condition for maximization is $\pi_{ii}^i < 0 (i = 1, n)$. When the other regularity conditions for the equilibrium are satisfied, we obtain the symmetric equilibrium outcome for each firm's output and profit:

(3.3) $$x = x^i = \frac{a-w-r}{(n+1)b}, \quad \forall \text{i}$$

and

(3.4) $$\pi = \pi^i = \frac{(a-w-r)^2}{(n+1)^2 b}, \quad \forall \text{i}$$

Now assume that the marginal cost of producing oil is constant, c_o, for a moment. We first calculate the benchmark case in which the oil market is perfectly competitive. This implies that $r = c_o$. Therefore, the total profits of these oligopolies, when oil is supplied under perfect competition, are

$$\overline{\Pi} = n\pi = \frac{n(a-w-c_o)^2}{(n+1)^2 b} \tag{3.5}$$

To highlight how the monopoly power in the oil market could capture some of the profits from the product market, suppose that oil is supplied by a monopolist and other countries do not have any oil endowment. Therefore, the oil producer chooses r to maximise the following:

$$\max_r R = (r-c_o)\frac{n(a-w-r)}{(n+1)b}, \tag{3.6}$$

since the demand for oil is (recall K=X)

$$K = \frac{n(a-w-r)}{(n+1)b}. \tag{3.7}$$

Solving (3.6), we obtain

$$r^* = \frac{a-w+c_o}{2} \tag{3.8}$$

Therefore, the rent that the oil monopolist gains from controlling oil price/output is

$$R^* = \frac{n(a-w-c_o)^2}{4(n+1)b} \tag{3.9}$$

As a result, the total profits of these firms reduce to

$$\underline{\Pi} = \frac{n(a-w-c_o)^2}{4(n+1)^2 b} \tag{3.10}$$

Notice that $\underline{\Pi} = \overline{\Pi}/4$. They have lost 3 quarters of the total profits in the product market.

In the rest of this section, we show that an environmental tax on consumption of oil can extract some of the rent back from the oil monopolist and we will focus on the degrees of such incentives to impose a tax in the non-cooperative and cooperative environment, respectively. Since the insight of our analysis will still be preserved, we assume n=2 for the rest of our analysis to avoid the unnecessary mathematical complication. But we will discuss the implications of our results for the general n-country case.

3.2. Non-cooperative Environmental Tax

Suppose that two countries non-cooperatively impose an environmental tax, t^1 and t^2, on consumption of oil. Then, firm i's profit becomes:

$$\max_{x^i} \pi^i = (a - b\sum_{j=1}^{2} x^j)x^i - (w + r + t^i)x^i, \quad \text{i, j} = 1,2. \tag{3.11}$$

The first-order condition that maximizes the profit is

$$\pi_i^i = (a - b\sum_{j=1}^{2} x^j) - bx^i - (w + r + t^i) = 0, \quad \text{i, j} = 1,2. \tag{3.12}$$

The second-order condition for maximisation is $\pi_{ii}^i < 0$ ($i = 1,2$). It is easy to show that the regularity conditions for the equilibrium are satisfied for the linear demand function. The equilibrium outcomes can be summarised by

$$x^i(t^i, t^j); \;\; \pi^i(x^i(t^i, t^j), x^j(t^i, t^j), t^i). \quad \text{i, j} = 1,2.$$

It is easy to show that $dx^i / dt^i < 0, dx^i / dt^j > 0$.

Summing (3.12) over i and noticing that $X = \sum_{i=1}^{2} x^i$, we obtain that

$$2(a - bX) - bX - 2(w + r) + (t^1 + t^2) = 0 \tag{3.13}$$

The demand for oil therefore is (recall K=X and $k^i = x^i$),

$$K = \frac{2(a - w - r) - (t^1 + t^2)}{3b} \tag{3.14}$$

Similar to the previous section, assume that each country's endowment of oil ($\bar{k}^1$ and $\bar{k}^2$) is small relative to the total demand and the oil-producing "monopolist" acts as the price-leader in the oil market. The optimization problem for the oil monopolist becomes:

$$\max_r R = (r - c_o)[\frac{2(a - w - r) - (t^1 + t^2)}{3b} - \sum_{i=1}^{2} \bar{k}^i], \tag{3.15}$$

Solving (3.15), we obtain

$$r^*(\sum_{i=1}^{2} t^i) = \frac{2(a - w + c_o) - (t^1 + t^2)}{4} - \frac{3b}{4}\sum_{i=1}^{2} \bar{k}^i \tag{3.16}$$

Now suppose that pollution is not fully-transboundary. The emission that country i receives is[8]

(3.17)
$$E^i = k^i + \delta \sum_{j \neq i}^{2} k^i \text{ or}$$
$$= (1-\delta)k^i + \delta K, \quad 0 < \delta < 1, \quad i = 1,2.$$

Since under Cournot competition firms also earn profits from the product market, the objective function for governments becomes:

(3.18)
$$G^i = \pi^i + r^*(t)\bar{k}^i + t^i k^i - D(E^i), \ i = 1,2.$$

The first-order condition with respect to t_i is

(3.19)
$$G^i_i = [\frac{\partial \pi^i}{\partial t^i} + \frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt^i} + \frac{\partial \pi^i}{\partial r}\frac{dr}{dt^i}] + \bar{k}^i \frac{dr}{dt^i}$$
$$+(x^i + t^i \frac{dx^i}{dt^i}) - D'(E^i)\frac{dE^i}{dt^i} = 0, \quad i = 1,2.$$

Assume that the second-order and regularity conditions for maximizaiton are satisfied.

To evaluate a country's incentive to impose a non-cooperative environmental tax on oil, we set $t^i = 0$ in (3.19). Using (3.11) and the envelope theorem, we obtain,

(3.20)
$$G^i_i\Big|_{t^i=0} = \underbrace{\frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt^i}}_{(-)} \underbrace{-k^i \frac{dr}{dt^i}}_{(+)} + \underbrace{\bar{k}^i \frac{dr}{dt^i}}_{(-)} \underbrace{- D'(E^i)\frac{dE^i}{dt^i}}_{(+)}$$

The first term is the "profit-shifting effect", which is not present in the previous section since firms' profits are zero under Bertrand competition. This term is negative since $\frac{\partial \pi^i}{\partial x^j} < 0$ and $\frac{dx^j}{dt^i} > 0$. The intuition is straightforward. A tax on oil in country i will increase the marginal cost of production for firm i and hence reduce firm i's equilibrium output. Since x^i and x^j are strategic substitutes under Cournot competition, x^j goes up, which leads to a reduction of firm i's market share and profits. In contrast, a lower tax can shift profits from foreign to domestic firms. Therefore, the profit-shifting effect provides governments with a negative incentive to impose an environmental tax on oil. Notice that if we have an *n*-country case, as in the previous section, the (negative) profit-shifting effect becomes stronger because the first term in (3.20) would become

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[8] When pollution is fully-transboundary (i.e., $\delta = 1$), $E_i = K$.

$$\sum_{j\neq i}^{n} \frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt^i}, \quad \text{i, j} = 1, \text{n}.$$

The second term is the “rent-extracting effect”, which is positive. An environmental tax on oil reduces the demand for oil, which in turn forces the oil monopolist to reduce the price of oil.[9] Thus an environmental tax on oil would reduce rents for the monopolist and increase profits for product producers. Therefore, the rent-extracting effect gives governments a positive incentive to impose an environmental tax on oil. Notice that in an n-country case, the (positive) rent-extracting effect would be smaller since (3.16) becomes

(3.21)
$$r^*(\sum_{i=1}^{n} t^i) = \frac{n(a-w+c_o)-(\sum_{i=1}^{n} t^i)}{2n} - \frac{3b}{2n}\sum_{i=1}^{n}\bar{k}^i$$

and we have $dr/dt^i = 1/(2n)$. Therefore, the effect of a non-cooperative tax on the reduction of oil price becomes smaller when the number of countries becomes larger.

The third term is the “endowment effect”, which is negative. Similarly, this effect would be smaller in an n-country case since the effect of a non-cooperative tax on the reduction of the oil price becomes smaller.

The last term is the “environmental effect”, which is positive. Using (3.17) we obtain that

(3.22)
$$\frac{dE^i}{dt^i} = \frac{dx^i}{dt^i} + \delta\frac{dx^j}{dt^i}, i = 1,2.$$

When country i imposes/increases a tax t^i on oil, it will reduce the domestic consumption of oil and carbon emission. But unless $\delta = 0$ (i.e., pollution is purely local), this effect is mitigated by the fact that the firm in the foreign country increases its consumption of oil and carbon emission. This is due to the strategic interaction among firms that compete in the world market. Firm j increases its output in reaction to the reduction of x^i (i.e., $dx^j/dt^i > 0$). However, it can be shown that the total output still becomes lower (i.e., $dX/dt^i < 0$, where $X = x^i + x^j$), which means,

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[9] Since the direct effects of the tax on government tax revenue and the profit of the domestic firm cancel with each other, the rent-extracting effect in this section is the effect of a reduction of oil price (due to the tax) on the profit of the domestic firm. In the previous section, the rent-extracting effect is on the government tax revenue only.

$$\frac{dE^i}{dt^i} = \frac{dx^i}{dt^i} + \delta \frac{dx^j}{dt^i} = (1-\delta)\frac{dx^i}{dt^i} + \delta \frac{dX}{dt^i} < 0, \quad i, j = 1,2.$$

Therefore, the environmental effect is positive but is likely to be small. In an n-country case this effect would become smaller since (3.21) becomes

(3.23) $$\frac{dE^i}{dt^i} = \frac{dx^i}{dt^i} + \delta \sum_{j=1, j\neq i}^{n} \frac{dx^j}{dt^i}, \quad \mathrm{i} = 1, \mathrm{n}.$$

Therefore, in a non-cooperative environment, the profit-shifting effect might be strong relative to the others. This certainly becomes more likely when the number of countries becomes larger. If $G_i^i < 0$ at $t^i = 0$, country i has no incentives to impose a non-cooperative tax on oil.

If $G_i^i > 0$ at $t^i = 0$ $(i = 1,2)$, there will be a positive non-cooperative environmental tax on oil, t^{in}, and it is implicitly determined by the following set of equations:

t^{iu}: $$[\frac{\partial \pi^i}{\partial t^i} + \frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt^i} + \frac{\partial \pi^i}{\partial r}\frac{dr}{dt^i}] + (x^i + t^i \frac{dx^i}{dt^i}) - D'(E^i)\frac{dE^i}{dt^i} = 0, \ i = 1,2$$

Assuming a symmetric case, we have $t^n \equiv t^{1n} = t^{2n}$.

3.3. Cooperative Environmental Tax

In this section we examine the incentives to cooperatively impose an environmental tax on oil and compare them with those without cooperation discussed in Section 3.2. Now suppose that these two countries could sign a treaty to impose a common tax on consumption of oil, t, – an environmental tax to combat carbon emission. The first-order conditions corresponding to (3.12) become

(3.24) $$\pi_i^i = (a - b\sum_{j=1}^{2} x^j) - bx^i - (w + r + t) = 0, \quad \mathrm{i, j} = 1,2.$$

It is straightforward to obtain that [similar to (3.3)]

(3.25) $$x^i(t) = \frac{a - w - r - t}{3b}, \quad \forall \mathrm{i}$$

Notice that now $dx^i / dt < 0\,(i = 1,2)$ with a cooperative environmental tax. The equilibrium profits are $\pi^i(x^i(t,t), x^j(t,t), t)$ or simply, $\pi^i(x^i(t), x^j(t), t)$.

The demand for oil therefore is

(3.26) $$K(t) = \frac{2(a - w - r - t)}{3b}.$$

The price of oil set by the monopolist is given by

(3.27) $$r^*(t) = \frac{(a - w + c_o - t)}{2} - \frac{3b}{4}\sum_{i=1}^{2}\bar{k}^i.$$

Therefore the government objective function becomes,

(3.28) $$G^i = \pi^i + r^*(t)\bar{k}^i + t^i k^i - D(E^i),\ \mathrm{i} = 1,2.$$

The first-order condition with respect to t is

(3.29) $$\frac{dG^i}{dt} = [\frac{\partial \pi^i}{\partial t} + \frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt} + \frac{\partial \pi^i}{\partial r}\frac{dr}{dt}] + \bar{k}^i\frac{dr}{dt}$$
$$+(x^i + t\ \frac{dx^i}{dt}) - D'(E^i)\frac{dE^i}{dt} = 0, \quad \mathrm{i} = 1,2.$$

When $t = 0$, we have:

(3.30) $$\left.\frac{dG^i}{dt}\right|_{t=0} = \underbrace{\frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt}}_{(+)} \underbrace{-k^i\frac{dr}{dt}}_{(+)} + \underbrace{\bar{k}^i\ \frac{dr}{dt}}_{(-)} \underbrace{-\ D'(E^i)\frac{dE^i}{dt}}_{(+)}$$

The first term in (3.30) looks similar to that in (3.20) in the case of a non-cooperative environmental tax but it actually is positive rather than negative. Instead of the profit-shifting effect of a non-cooperative tax, a cooperative environmental tax on consumption of oil has a "collusion-facilitating effect". This is very important. When governments impose a common environmental tax on oil, they eliminate the strategic effect on the product market. Instead of $dx^j / dt^i > 0\ \forall i$ as in the previous case, now we have $dx^j / dt < 0$. Since firms already produce too much in the product market, a common environmental tax on oil effectively facilitates collusion through reducing output of all firms.

The second term is still the "rent-shifting effect" but it is as twice large as that in the case with non-cooperative taxes. Using (3.16), we can show that $dr / dt = -(1/2)$ in (3.30) but $dr / dt^i = -(1/4)$ in (3.20). In an n-country case the difference would be even greater since $dr / dt^i = -[1/(2n)]$. The effect of a cooperative tax on the reduction of oil price is much greater than that of a non-cooperative tax. Similar to the rent-extracting effect, the negative "endowment effect" (the third term) also becomes larger with a cooperative environmental tax.

The last term is the "environmental effect" but it is also much greater than that in the case with non-cooperative environmental taxes. Since a common environmental tax eliminates the strategic effect in output and reduces the output of all firms, the pollution reduction is more effective. Notice that this effect would be much stronger in an n-country case since

$$\frac{dE^i}{dt} = \frac{dx^i}{dt} + \delta \sum_{j=1, j\neq i}^{n} \frac{dx^j}{dt}, \quad \text{i} = 1, \text{n}. \tag{3.31}$$

Compared with (3.23) in the previous section, the second term is negative instead of positive.

The collusion-facilitating effect, the rent-shifting effect and the environmental effect (except the endowment effect) all provide governments with positive incentives to cooperatively impose environmental taxes on consumption of oil. Therefore, <u>as long as a country does not have a very large endowment of oil (though it can also be an exporter of oil), it would benefit from the Kyoto agreement.</u>

To compare with the previous section, we can also show that

$$\left.\frac{dG^i}{dt}\right|_{t=0} > \left.\frac{dG^i}{dt^i}\right|_{t^i=0}.$$

<u>That is, the incentives to impose a cooperative environmental tax are much greater than a non –cooperative tax and this is true even when the impact of carbon emission on the global environment is not taken into account.</u>

The cooperative environmental tax on oil in a symmetric equilibrium, $t^c(t^c \equiv t^{1c} = t^{2c})$, is implicitly given by the following equations:

$$t^c: \quad [\frac{\partial \pi^i}{\partial t} + \frac{\partial \pi^i}{\partial x^j}\frac{dx^j}{dt} + \frac{\partial \pi^i}{\partial r}\frac{dr}{dt}] + (x^i + t\frac{dx^i}{dt}) - D'(E^i)\frac{dE^i}{dt} = 0, \; i = 1,2$$

It is not difficulty to show that $t^c > t^u$, *ceteris paribus*.

4. Concluding Remarks

This paper has identified a potential effect of the Kyoto Protocol on the oil market characterised by the strategic behaviour of the OPEC and show that, among other things, even those member countries that export oil could benefit from the accord. The paper deliberately uses the simplest model that we could image to illustrate our points thus might miss other important factors. For example, we did not consider the substitution effect between different energies (e.g. coal) on the demand for oil. Restrictions on carbon emission may cause a substitution of oil for coal. This would increase the demand for oil and could become important in the long run. Also, we did not address the free-riding problem, which still exists for member countries in our model. However, it seems from recent experience that the theoretical expectation on free-riding did not prevent many countries from participating international environmental agreements. A possible reason for this might be that a small member-country cannot gain much by free-riding and a large member-country realises that if it does not participate, neither will other members.

Although the paper is a theoretical exercise, it is our hope that it would convince other researchers to incorporate the aspect of the strategic behaviour of the OPEC into the formal CGE modelling on the economic effects of carbon reductions.

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