ECON4910 Environmental Economics — Seminar 5

March 31, 2014

"Buy Coal! A Case for Supply-Side Environmental Policy"

In this exercise, we use a simplified example that helps you go through and understand the core ideas in the "Buy Coal! ..." paper from the reading list (Harstad, 2012). To this end, you will have to solve for the first best allocation, non-cooperative allocation, non-cooperative allocation with unilateral demand-side (focusing on domestic consumption and international trade) and supply-side (focusing domestic extraction of energy) policies to address environmental harm, without trading deposit rights. The exercise is meant to provide you an opportunity to explore the challenges of achieving socially ideal allocations under non-cooperative environment with and without unilateral policies by those facing environmental harm. In the final question, we will introduce trades in extraction rights and fuel deposits to observe if the problems of achieving the first best allocations still persist.

To begin with, suppose there are two coalitions of countries with identical utility function except for the harm from pollution. Let the coalition of countries that face environmental harm be M and the one that does not face environmental harm be N.[1] The representative agent in both coalitions has $B(y_i)$ benefit from consuming energy and endowed with $C(x_i)$ cost of producing fuel from domestic fuel deposits for $i \in \{M, N\}$. The total harm M faces is $H(x_M + x_N)$. Thus, for a market price p of energy: $U_N = B(y_N) - C(x_N) - p(y_N - x_N)$ and $U_M = B(y_M) - C(x_M) - p(y_M - x_M) - H(x_M + x_N)$. To simplify the problem further, suppose $B(y_i) = y_i - \frac{y_i^2}{2}$, $C(x_i) = \frac{x_i^2}{2}$, and $H(x_M + x_N) = hx_M + hx_N$ for $h \in (0, 1)$.

For this problem set, we adopt a Sub-game Perfect (SP) Equilibrium concept to analyze the different scenarios. Timing of events within a period, without deposit trading, is as follows: first the coalition of countries facing environmental harm i.e. M chooses its consumption, production, and policy decisions; and next, a decision maker in the other coalition i.e. N chooses its consumption and production taking prices as given. But, the equilibrium price is the one that balances the total world consumption of energy (i.e. $y_M + y_N$) with the total global supply of energy (i.e. $x_M + x_N$). With deposits trading,

[1] You can implicitly assume that there are infinite number of agents with a unit mass in each coalitions but you need to abstract from the way members deal with their own collective action problem. Regardless, assume as if the coalitions are decision makers in the rest of this problem set.

the above timing is still valid except in the very initial period deposits are traded before M choses its decisions.

Problem 1: Determining socially ideal allocations

Question 1.1

Determine the first best allocation. Note that the utility of the planner is the sum of the utility of all agents i.e. $y_N - \frac{y_N^2}{2} - \frac{x_N^2}{2} + y_M - \frac{y_M^2}{2} - \frac{x_M^2}{2} - h[x_M + x_N]$.

Question 1.2

(a) Using the first best values of x_M and x_N, solve for the total environmental harm under first best allocations.

(b) Using the first best values of x_M, y_M, and the total environmental harm you have just computed, solve for the indirect utility for M under first best allocations.

Question 1.3 Check if the conditions in equation (1) of the the paper are satisfied by the solutions you have found in (1.1) and (1.2).

Problem 2: Determining allocations under non-cooperative environment

Question 2.1

At the last stage, the decision maker in N chooses its production and consumption decision *without internalizing* the harm hx_N it inflicts on others.

(a) Solve for y_N and x_N as a function of price. Recall that y_N and x_N as functions of price are the $D(p)$ and $S(p)$ in the paper.

(b) Do the $D(p)$ and $S(p)$ functions have the right sign of slope?

(c) What is the market clearing price for a given y_M and x_M?

Question 2.2

At the first stage, M would choose its production and consumption decision, taking into account the equilibrium price being a function of y_M and x_M i.e. using the market clearing price you have obtained in 2.1.c.

(a) Solve for values of x_M and y_M. Use the values of x_M and y_M into the expression you have found in (2.1.c)

(b) Solve for equilibrium values of x_N and y_N.

(c) Next, use the equilibrium values of x_M and x_N, and solve for the total environmental harm and compare it with the one you have calculated under first best environment. Which one is higher? What is the economic intuition?

(d) Using the values of y_M, y_M, and the environmental harm, solve for the indirect utility for M under noncooperative environment. Compare it with the U_M^{FB}. Which one is higher and why?

Question 2.3

Check if the conditions in equations (6) and (7) of the paper are satisfied by the solutions you have found in (2.1) and (2.2).

Problem 3: Non-cooperative environment with unilateral policies

In addition to the assumptions in question 2, suppose that the government in M takes unilateral policy to provide incentive to agents under its jurisdiction to internalize their externalities. For this question, assume that these unilateral policies take the form taxing domestic consumption and domestic production of fuel.

Question 3.1

(a) Do you think the optimal decision in the second stage, is the same as with what you found in (2.1). Why?

(b) At the first stage, M would choose its production and consumption decision by taxing domestic consumption and domestic production excise tax rates of τ_{y_M} and τ_{x_M}respectively while taking into account the equilibrium price being a function of y_M and x_M i.e. using the market clearing price you have obtained in 2.1.c. Solve for y_M and x_M as a function of τ_{y_M} and τ_{x_M}. [Hint: Use $U_M = y_M - \frac{y_M^2}{2} - \frac{x_M^2}{2} - p(y_M - x_M) - \tau_{y_M} y_M - \tau_{x_M} x_M$. Note that I am implicitly suggesting you to abstract from the use of the tax revenue. You would also arrive at the same conclusion if you assume that the tax revenue is refunded back as lump sum, and hence it does not affect relative prices, instead of abstracting away from the use of tax revenue.][2]

[2]If you are wondering what has happened to the environmental harm term, you need to think of this as the problem of a representative agent in coalition M whose share is so small, as expressed in footnote 1, that it does not take into account the environmental harm it generates; and the decision maker in M is using taxes to provide incentive for such agents to internalize the negative externality they cause to members of the coalition M.

Question 3.2

(a) Using the values of y_M and x_M, solve for the equilibrium price, again, as a function of τ_{y_M} and τ_{x_M}.

(b) Next, using the market clearing price, solve for y_N and x_N as a function of τ_{y_M} and τ_{x_M}. Are the properties of y_N, x_N, y_M, x_M, and p in relation to τ_{y_M} and τ_{x_M} natural? Can you find economic intuition?

(c) Use the values of x_M and x_N solve for the indirect utility for M under unilateral policy as a function τ_{y_M} and τ_{x_M}.

(d) What are the values of τ_{y_M} and τ_{x_M} that maximize the indirect utility of M? Compare your answer with the second and third equations expressions of the optimal tax on page 90 of the paper.

Question 3.3

Let us focus on demand-side policies i.e. $\tau_{y_M} > 0$ and $\tau_{x_M} = 0$.

(a) Compare y_M under unilateral policy with the one you found in (2.2.a). Are they equal? What is the economic intuition?

(b) Calculate the market clearing price. Has it decreased in response to demand-side policy?

(c) Next, compare y_N under unilateral policy by M with the one under non-cooperative environment. Are they equal? What is the economic intuition?

(d) What are the economically optimal τ_{y_M} that maximize the indirect utility of M you have found in (3.2.d)

Question 3.4

Now let us focus on supply-side policies i.e. $\tau_{y_M} = 0$ and $\tau_{x_M} > 0$.

(a) Compare x_M under unilateral policy with the one under non-cooperative environment. Are they equal? What is the economic intuition?

(b) Calculate the market clearing price. Has it decreased in response to supply-side policy?

(c) Next, compare x_N under unilateral policy by M with the one under non-cooperative environment. Are they equal? What is the economic intuition?

(d) What is the economically optimal τ_{x_M} that maximize the indirect utility of M you have found in (3.2.d).

Question 3.5

Now that you have explored carbon leakage arising from unilateral policies by M, do you find a compelling *economic* argument of doing nothing? To answer this question, you need to first calculate global fuel extraction (i) using the values of optimal tax you have solved in (3.2.d) and (ii) using zero consumption and zero production taxes. Second, you need to compare global fuel extraction in each case with the first best global fuel extraction. Next ask yourself "Does the strategy of doing nothing result in a global fuel extraction that is closer to the first best than the strategy of unilateral policies you have found in (3.2.d)?" to arrive at the answer.

Problem 4: Tradable file deposits and unilateral policies

Let's relax the assumption that ownership of fuel deposits is exogenous i.e. now, countries can trade deposits in the very first stage. The way you will solve for SP equilibrium with deposit trading is conceptually the same as with the approach you have used in any of the questions (1), (2), or (3). However, fuel deposit trading will change the extraction costs of M and N and thus the analyses in the last stage, and the second to the last stage need to take into account such a change on extraction cost function.

Question 4.1

The functions mapping ground deposits of fuel to the extraction cost, without any trading fuel deposits, are $C(x_i) = \frac{x_i^2}{2}$, for $i \in \{M, N\}$. Implicit in the specification of the cost functions is that countries are endowed with continuum of deposits of fuel, which they can extract paying the cost of extraction. Being explicit about these assumptions behind the cost functions is important because you will explore the implications of trading fuel deposits for managing environmental harm in the following problems. First, let us explore the implications of deposit trading for marginal costs of extraction.

(a) Draw the marginal extraction cost functions for both M and N assuming that countries do not trade deposits.

(b) Draw the marginal extraction cost function for N assuming that the U.N. security council has decided that N can not extract any of its fuel deposit after its k^{th} fuel deposit and N has decided to accept the decision.

(c) Next, suppose M buys $N's$ k^{th} fuel deposit (i.e. the deposit between $x_N = k + \Delta$ and $x_N = k$ for a very small $\Delta > 0$) with the agreement that M cannot extract the fuel deposit it has bought from N. Draw the new marginal extraction cost functions for both M and N.

(d) Draw the marginal extraction costs for M and N assuming that M can extract the fuel deposit it has bought from N. Can you observe similarities or differences of these curves with the marginal extraction cost curves in figure-2 of the paper?

Question 4.2

Start from non-cooperative allocations you have explored in (2.1) - (2.3) and suppose countries can trade deposits.

(a) What is $N's$ marginal benefit of extracting the marginal fuel in noncooperative equilibrium?

(b) What is $M's$ marginal harm of $N's$ extraction of the marginal fuel in noncooperative equilibrium?

(c) Can the allocation of ownership of deposits in non-cooperative environment be an equilibrium allocation? Why?

(d) How is your answer in (c) related to equation (12) of the paper?

Question 4.3

The equilibrium in deposits market involves a situation in which no one gains by further trading fuel deposits. Can you construct a reasonable equilibrium of the deposits market?

Question 4.4

What is the SP equilibrium of the game i.e. equilibrium allocation of ownership of deposits, extraction of fuel, consumption of fuel, and the price of fuel for both M and N. Do you think the problem of leakage and free riding that plague unilateral policy under non-cooperative equilibrium still persist? What is the economic intuition for your answer? [Hint: Since we allow deposit trading in the first stage, hence the cost function might be different from $\frac{x_N^2}{2}$ in the 3^{rd} stage or $\frac{x_M^2}{2}$ in the 2^{nd} stage), you will find it useful to work with generic *equilibrium cost correspondence* $C(x_i)$. Nevertheless, you need to take some notes from your answers in (4.1) about the *continuity* and *differentiability* of post deposit trading extraction cost correspondence to avoid your analytical hands being tied down from the very beginning.]

Question 4.5

Finally, write a one-page essay summarizing the main lessons you have learned from doing the problems of Seminar 4.

References

HARSTAD, B. (2012): "Buy Coal! A Case for Supply-Side Environmental Policy," *Journal of Political Economy*, 120, 77–115.