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Clean technology adoption and its influence on tradeable emission permit prices

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Abstract

In this paper we give an example in which the price of tradeable emission permits increases despite firms' adoption of a less polluting technology. This is in contrast with Montero (2002) and Parry (1998), among others. If two Counot players switch to a cleaner technology, the price for permits may increase due to an increase in the net demand for permits and a decrease in net supply of permits after the clean technology is adopted. This is only the case when output demand is elastic.

Keywords: environmental innovation, tradable emission permits, Cournot interaction.

JEL Classification: D43, L13, Q55

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1. INTRODUCTION

Hereafter we analyze the change in tradable emission permit prices due to the adoption of a cleaner production technology when there are two Cournot competitors in the output market. This paper relates to the literature on environmental innovation. This literature's conclusions are generally based on the argument that environmental innovation produces a decrease in permit prices. Moreover, this literature generally neglects the interaction between the tradable permits market and the output market, or only a single monopoly firm is considered whereas our results are due to strategic interaction in the output market. Dowing and White (1986), Milliman and Prince (1989), Tietenberg (1985) and Wenders (1975) show that market-based instruments such as tradable permits provide higher incentives to invest in environmental innovation than command-and-control instruments. More recently, other authors like Parry (1998) and Requate (1998) have explicitly introduced a competitive output market in their analysis. To the best of our knowledge, only Montero (2002) considers the impact of strategic interaction in the output market on incentives for environmental innovation and finds that investment in a clean technology produces a *decrease* in the tradable permit price that has, on the one hand, a direct effect on the innovator's profits (positive or negative, depending on whether the firms is a buyer or a seller of permits) and, on the other hand, an indirect effect due to the decrease in production costs which allows the innovator and his rival to increase output. Then, incentives to innovate depend on the net effect. In fact, one expects the buyer of permits to decrease his demand (or the seller of permits to increase his supply) after implementing a cleaner technology. This is the case because with the clean technology firms are able to produce the same amount of output they were producing with the dirty technology but using less permits. The seller would have a larger number of permits available, increasing permits supply and the demander would buy less permits.

Instead, we identify when it is the case that the price of permits *increases* after the adoption of a cleaner technology. In our model two symmetric Cournot competitors in the output market can produce using either a clean or a dirty technology taking the price of the input (permits) as given. This last assumption is also present in Malueg (1989) and (1990), Sartzetakis (1997a) and (1997b) and is inspired on the fact that firms trading in a region-wide market for emission permits operate in different local markets, making each single firms' influence in the region-wide market very low. As in Bréchet and Jouvet (2008) we define the clean technology as a technology that has a lower degree of pollution intensity per unit of output than the dirty one. This means that the clean technology is less intense in emissions per unit of output. In this context, we show that previous literature's intuition regarding a fall in the permits price after the implementation of a clean technology is true when output demand is inelastic. Instead, when the cap on emissions is binding and/or the decrease in the polluting intensity of output after the implementation of the clean technology is low enough, the price of permits may increase with the implementation of a clean technology. In particular, this is the case when output demand elasticity is enough high to induce firms to use the increase in efficiency due to the implementation of the clean technology to increase output production. When this is the case the Cournot equilibrium after the implementation of the clean technology as opposed to the dirty one is realized for a higher demand and lower supply of permits. These push the price of permits upwards.

Our results are in line with Malueg (1989) and (1990) in the sense that the link between markets is due to the fact that permits price reflects in the cost of output production. Given the technology used by each firm and the corresponding marginal input (permits) productivity, the permits price is both the unit cost (or revenue) of trading permits and the unit cost of output production.

2. THE MODEL

Assume that two symmetric firms (i, j) competing *à la* Cournot are producing an homogenous good and face a linear output demand, i.e. $p(y_i + y_j) = 1 - y_i - y_j$. Production of good y generates emissions e as a by-product with an intensity k. We assume a linear production function $y = ke$ where the polluting intensity of output is $k = 1$ in the case of the dirty technology and $k > 1$ in the case of the clean technology. Firms are subject to environmental regulation that establishes a binding cap S on total emissions and requires firms to hold permits for the exact amount of pollution emitted. A fraction α of total permits S is allocated for free to firm i and a fraction $(1 - \alpha)$ to firm j. The total amount of permits available S and the fractions α and $(1 - \alpha)$ are common knowledge. We assume that firms comply with the environmental regulation, hence, emission levels and use of permits coincide. If the amount of permits received for free is different from the optimal amount of permits needed for output production, firms engage in permits trading.

Finally, we assume that the parameters of the model satisfy $k \leq 2$ and $\frac{k-1}{2k-1} \leq Sk \leq \frac{2}{3}$. These conditions guarantee that both firms make non-negative profits in any possible outcome[1]. It is worth noting that the domain $\{k, S\}$ satisfying these restrictions is non-empty.

2.1. Using the dirty technology

Taking the price of permits as given, firms maximize profits given by:

$$\begin{aligned} \Pi^i\left(y^i, y^j\right) &= (1 - y^i - y^j)y^i - r(e^i - \alpha S), \\ \Pi^j\left(y^i, y^j\right) &= (1 - y^i - y^j)y^j - r(e^j - (1 - \alpha)S), \end{aligned}$$

where r is the price for permits and $(e^i - \alpha S)$ and $(e^j - (1 - \alpha)S)$ represent the amount of permits exchanged in the market for permits for each firm respectively. If for instance $\alpha \in (0, \frac{1}{2})$, then $e^i - \alpha S$ represents the demand for permits.

Output market equilibrium

Given the fact that both firms are using the dirty technology, profit of firm i can be expressed as

$$\Pi^i(e^i, e^j) = (1 - e^i - e^j)e^i - r(e^i - \alpha S). \tag{1}$$

Similarly, profit for firm j is

$$\Pi^j(e^i, e^j) = (1 - e^i - e^j)e^j - r(e^j - (1 - \alpha)S). \tag{2}$$

After computing the first order conditions and solving the system of equations we find the optimal use of permits for both firms:

$$e_1^i(r) = e_1^j(r) = \frac{1 - r}{3}. \tag{3}$$

[1] The condition $k \leq 2$ is necessary for the existence of equilibrium in the permits market. This condition yields a positively sloped supply of permits. Secondly, we will see that equilibrium price of permits is non-negative if $Sk \leqslant \frac{2}{3}$ while equilibrium levels of emissions are non-negative if $Sk \geqslant \frac{k-1}{2k-1}$.

Permits' market equilibrium

Firms claim their position as a buyer or seller of permits, given their output production choice. Notice that we assume that firms do not take into account that r is a function of $e^i + e^j$ when maximizing profits in the output market. This is compatible with a market for permits with participants from many sectors and countries such that these firms are price-takers in the permits market.

Firms will buy or sell the difference between their production needs summarized in (3), and the permits they received for free, αS or $(1-\alpha)S$ respectively. If for instance $\alpha \in (\frac{1}{2}, 1)$, firm i is a supplier of permits and total supply is $\alpha S - \frac{1-r}{3}$, while total demand of permits is $\frac{1-r}{3} - (1-\alpha)S$. Then, the clearing market condition in the market for permits yields the equilibrium price r^*:

$$r^* = 1 - \frac{3}{2}S. \tag{4}$$

Now, substituting (4) in (3) we obtain the optimal use of permits for both firms:

$$e^{*i} = \frac{S}{2} = e^{*j}. \tag{5}$$

Then, we find the optimal level of firms output as:

$$y^{*i} = y^{*j} = \frac{S}{2}. \tag{6}$$

2.2. Using the clean technology

The analytical solution for this symmetric Cournot case is the same as the previous one. The difference is that now both firms use the clean technology and therefore maximize respectively:

$$\begin{aligned} \Pi^i(e^i, e^j) &= (1 - ke^i - ke^j)ke^i - r(e^i - \alpha S), \\ \Pi^j(e^i, e^j) &= (1 - ke^i - ke^j)ke^j - r(e^j - (1-\alpha)S). \end{aligned}$$

Accordingly, the optimal use of permits is $e_c^{*i} = e_c^{*j} = \frac{(k-r_c)}{3k^2}$, where the c stands for *clean*, and which gives the equilibrium price in the permits market[2]:

$$r_c^* = k(1 - \frac{3}{2}kS). \tag{7}$$

Consequently, when both firms innovate $e_c^{*i} = \frac{S}{2} = e_c^{*j}$. And the optimal output for each firm obtains

$$y_c^{*i} = y_c^{*j} = k\frac{S}{2}. \tag{8}$$

Then, the symmetric Cournot equilibrium is now realized for a higher output production with respect to production with the dirty technology. The following proposition states what happens with permit prices.

PROPOSITION 1. *When both firms use the clean technology as opposed to the dirty one, the price for permits r_c^* increases if the decrease in the polluting intensity of output k is lower than the threshold value $k < \frac{2}{3S} - 1$. This thresholds implies that output demand is not inelastic.*

[2] Even if firms are price takers in the permits market, the price of permits changes due to the change in the marginal productivity of emissions with the clean technology.

Proof. By direct comparison of permits prices in (4) and (7) we find that the difference is positive, i.e. $r_c^* - r_1^* > 0$, if $k < \frac{2}{3S} - 1$. ∎

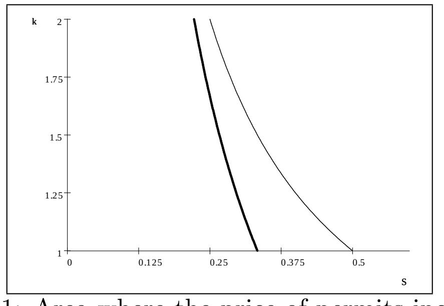

Figure 1: Area where the price of permits increases.

Let us use Figure 2.2 to understand the intuition behind our proposition. Permit prices increase after innovation for the pairs $\{k, S\}$ that satisfy $k < \frac{2}{3S} - 1$, i.e. that are in the area to the left of the thick line in Figure 2.2. On the other hand, output demand is elastic for the pairs $\{k, S\}$ that satisfy $k < \frac{1}{2S}$, i.e. that belong to the area to the left of the thin line in Figure 2.2. This result may seem counterintuitive. In fact, one expects the buyer of permits to decrease his demand (or the seller of permits to increase his supply) after implementing the clean technology. Firms could produce the same amount of output they were producing with the dirty technology but using less permits. The seller would have a larger number of permits available, increasing permits supply and the demander would buy less permits. This is what happens in the area to the right of the thin line in Figure 2.2 because in this area output demand is inelastic and firms have no incentives to use the new technology to increase output production.

But when firms switch to the clean technology, the new symmetric Cournot equilibrium may be such that both firms want to increase their output production proportionally to the increase in efficiency due to the utilization of the clean technology. Then, the gap of permits of the buyer (say firm i) with the dirty technology, namely $e^{*i} - \alpha S$, becomes even larger when the buyer switches technologies, $e_c^{*i} - \alpha S$. For the same reason, the positive gap of the seller of permits with the clean technology, $e_c^{*j} - (1-\alpha)S$, is smaller than the corresponding gap $e^{*j} - (1-\alpha)S$ with the dirty technology. Thus, in this case, the demand for permits increases and supply of permits decreases. This is verified for the pairs $\{k, S\}$ to the left of the thick line in Figure 2.2: output demand elasticity is so high that firms have big incentives to increase output production even if this generates a pressure on permit prices that produces an increase in their production costs. To this end, all the increase in production efficiency due to the implementation of the clean technology is used to increase output production ending up with a permits equilibrium price higher than when the dirty technology was in use.

For the pairs $\{k, S\}$ that are between the two curves in Figure 2.2, output demand is elastic but the price of permits decreases when implementing the clean technology. This is the case because in that area elasticity is not so high and therefore the increase in firm's profits coming from the output market when increasing production would not be enough to compensate an increase in the price of permits (i.e. their production costs). Then, firms will use part of their extra permits due to the implementation of the clean technology to increase production and another part to decrease their need of permits in the permits market (decrease demand or increase supply). To this end the price of permits decreases after innovation.

The previous result underlines the importance of output demand characteristics and its influence in the input (permits) market outcome. Moreover, it establishes the effect on permit prices of the interaction between the decrease in the polluting intensity of output due to the implementation of a cleaner technology k, the characteristics of output demand and our policy variable: the cap on emissions S.

3. CONCLUDING REMARKS

In contrast to previous literature results, we have given an example in which the price of tradeable emission permits increases after firms adoption of a clean technology. In particular, we show that, if two Counot players switch from a dirty to a clean production technology, the price for permits may increase due to an increase in the net demand for permits and a decrease in the net supply of permits. This is the case when the cap on emissions is binding and/or the decrease in the polluting intensity of output after implementing the clean technology is low enough. In particular, these conditions are only realized when output demand is elastic.

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