Environmental policy and wage setting

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SUMMARY: This paper studies the interaction between the performance of firms and unions and the environmental policy chosen by governments when there is a negative environmental externality from production of a good which only affects the country where the firm is located. I assume that governments choose an upper limit on emissions, unions choose the wage rates and firms choose the employment level. Specifically, I analyze the effect that unionized labor markets have on environmental policy.

KEYWORDS: Monopoly union model, emission standards.

JEL classification: J30, J51, Q28.

Política medioambiental y negociación salarial

RESUMEN: En este artículo estudiamos el efecto del comportamiento de empresas y trabajadores sobre la política medioambiental, cuando existe contaminación local. Suponemos que el gobierno elige la política medioambiental, basada en un límite sobre las emisiones, mientras que los sindicatos (si hay) eligen el salario y las empresas el nivel de empleo. En concreto, analizamos el efecto de que los trabajadores estén o no sindicados en la política medioambiental.

PALABRAS CLAVE: Sindicato monopolista, estándares medioambientales.

Clasificación JEL: J30, J51, Q28.

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1.   Introduction

Concerns about environmental quality have always been important in the decisions of governments. But in recent years concern about environmental problems has been growing (see, for example, Hoel (1997b) or Ulph (2000) among others). Governments may be interested in toughening their environmental policies because increased pollution produced by the expansion of consumption, production and trade leads them to protect the environment. But, on the other hand, governments may have incentives to relax their environmental policy to give their domestic producers an advantage in competitive international markets. The resulting reduction in cost may lead to increased investment by producers, thus increasing output and employment.

The aim of this paper is to examine the interaction between environmental policy and union-firm bargaining. In particular, the paper analyzes the effect that unionized labor markets have on the environmental policy set by governments. Carraro *et al.* (1996) show that when union bargaining power is lower and, therefore, labor markets are more competitive employment is higher but the control of polluting emissions is weaker.

In debates about environmental policy the possible effects of environmental regulations on employment often play an important role. That is, the institutional features of labour markets are important determinants of environmental policies. Hoel (1998) examines the effect that environmental taxes and other forms of quotas and direct regulations have on employment. He gets the result that if wages are exogenous, employment is higher with environmental taxes than with other forms of environmental regulations. In a context with perfect competition and transboundary pollution, Hoel (1997a) analyzes whether there may be reasons for coordinating environmental policies across countries when wages are determined through bargaining between firms and unions. An important conclusion is that policy coordination is unnecessary in many cases. Bárcena-Ruiz and Garzón (2003) study how the existence of wage incomes influences the choice of environmental policy by governments when the location of firms is endogenous. Governments want polluting firms to locate in their countries because of the positive incomes that these firms generate, even though they damage the environment.

There is an extensive literature about the interaction between environmental policy and the labor market due to the fact that many European economies suffer from high levels of unemployment. Fredriksson and Gaston (1999) show that when the union is concerned with both the wages and employment of its members, its welfare is negatively related to pollution taxes. Bovenberg and Van der Ploeg (1998) analyze the effects of environmental tax reform on environmental quality and employment.

In this paper, I adopt the same framework considered by Ulph (1996) but assume that all workers are unionized. He studies the choice of environmental policy when both governments and producers can act strategically. In this framework I analyze the choice of environmental policy by governments when firms compete in an international market. These firms are unionized and unions set wages (i.e., I consider the mo-

nopoly-union model). For the sake of reference, I compare this case with the situation in which wages are exogenous. I assume that environmental damage is strictly local [1] and the environmental policy used in this analysis is emissions standards.

The results obtained in the paper depend on market size, which in turn depends on (i) valuation of the environment, (ii) reservation wage and (iii) valuation of employment. I assume that unions set the same value on wage and employment. If the market size is small enough the environmental policy set by governments is weaker if unions choose wages than if wage is exogenous. The government allows greater environmental damage due to the increase of the union's utility than can be compensated for by the lower consumers' and producers' surplus and, as a result, social welfare is higher if the union chooses the wage. If the market size is large enough, the environmental policy is stricter when the union chooses the wage than when the wage is exogenous, with lower social welfare resulting in the former case. Although the union's utility is higher and the environmental damage is lower when the union chooses the wage, the welfare will be higher if wages are exogenous since the consumer and producer surpluses are greater in the second case.

The results obtained in the paper do not change if countries differ in their valuation of the environment, if the reservation wage differs from one country to the other or if unions have different valuations of employment.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 examines the choice of environmental standard if the union chooses the wage, while section 4 analyses the situation if wages are exogenous. Section 5 presents the main result of the paper, comparing the two cases, and section 6 concludes.

2.   The model

There are two firms, 1 and 2, that produce a homogeneous good with the same technology. Each firm is located in a different country (1 and 2) [2]. Both firms sell their good on a world market. For the sake of simplicity, the cost of transport and other costs related to the selling of the product abroad are taken as being zero. I assume that both firms are unionized and wage bargaining takes place at firm level.

The inverse demand function of both countries is linear: $p = a - 2y_i$, $i = 1,2$, where p is the world market price of the good, a is the market size and y_i is the amount of the good sold in country i. Assume that environmental pollution does not modify market demand. The demand of the world market is given by the sum of the demands of countries i and j: $p = a - y$, where $y = y_i + y_j$. In equilibrium, the quantity demanded is equal to the quantity supplied, thus the world inverse demand function is: $p = a - q_i - q_j$, $i \neq j$, $i, j = 1,2$, where $y_i + y_j = q_i + q_j$; q_i is the output level of firm i ($i = 1,2$).

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[1]   Examples of local damage include firms emitting gases and chemical substances or producing noise.

[2]   I assume that the location of firms is fixed. For analyses of the effect of environmental policy on the location of firms see, for instance, Hoel (1997b), Markusen (1997) and Bárcena-Ruiz and Garzón (2003).

Consumers buy the good on the world market. The consumers' surplus of country *i* is given by the difference between the price paid by consumers in that country and the price they would be willing to pay, which is given by the demand function of the country; therefore

$$CS_i = \frac{(a-p)\,y_i}{2} = \frac{2y_i^2}{2} = (y_i)^2, \qquad i = 1,2 \tag{1}$$

where $p = a - 2y_i$, which depends on the output of both firms.

There is a pollutant associated with the production of the good. Specifically, each unit of output produces one unit of pollutant. Once environmental policy is introduced, firms either reduce their output or engage in abatement, which mainly represents end-of-pipe emission reduction. Technology exhibits a constant return to scale such that $q_i = L_i$, where L_i denotes the employment level that firm *i* hires in country *i*. Net emissions of this firm, e_i, are: $e_i = q_i - x_i$, where q_i are the emissions generated by firm *i* as function of the level of output, and x_i is the level of abatement of firm *i* (Ulph (1996)). Thus, to control environmental damage government *i* chooses the environmental standard, an upper limit on the emissions that may be emitted by firm *i*[3].

Firm *i* must not exceed the limit in the standard set by the government *i*, thus it has to pay a pollution abatement cost[4]. Following Ulph (1996), total costs of abatement are $C(x_i) = \frac{1}{2}\,(x_i)^2$, $x_i \geq 0$. On the other hand, each firm hires L_i workers with a wage rate w_i. It therefore bears a wage cost $L_i w_i$, so the profit function of firm *i* is:

$$\pi_i = [a - q_i - q_j - w_i]\,q_i - \frac{1}{2}\,(q_i - e_i)^2, \ \ i \neq j, \ i,j = 1,2 \tag{2}$$

The next step is to specify the union's utility function (see, for example Malcomson (1987)). It is reasonable to assume that the union cares about both wages and employment[5]. The union is assumed to have a quasi concave utility function that depends on both variables. I adopt a modified Stone-Geary utility function to represent the union's preferences. Hence, the utility function of the union can be written as:[6]

$$UR_i = (w_i - r)^{\alpha}\,L_i^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{3}$$

where w_i is the wage per unit of employment, and $r \geq 0$ represents the alternative wage which workers may expect to earn elsewhere, which is the same for all workers. The parameter α is the weight that union *i* gives to wages relative to employment.

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[3]   The total emissions of firm *i* are equal to the maximum emissions allowed by the government, so that profits increase with emission levels because pollution abatement costs are lower.

[4]   Investments made to diminish emissions include, for example, the use of filters that decrease the toxicity of solid waste.

[5]   Empirical studies of unionized labor markets have used total rent (Brown and Ashenfelter (1986)), or a Stone-Geary utility function (Dertrouzos and Pencavel (1981)) to represent the objective function of the labor union.

[6]   This utility function is used in many papers analyzing wage bargaining. See for example, De Fraja (1993) and Dobson (1994) among others.

In the relevant literature decisions on employment and wage have been modeled in different ways. Generally, the union has more power in decisions about wages than about employment. To model this, I can use the *right-to-manage* model, in which unions and firms bargain over wages and firms choose the employment level that maximizes profits. A special case of this model is the *monopoly-union-model,* where the union sets the wage while the employer sets employment [7].

I assume that the environmental damage function is a quadratic form and that it depends only on the emissions generated in the relevant country [8]; i.e. the pollutant causes damage only to the local economy. The total environmental damage of country *i* due to emissions generated in that country is

$$D_i = \lambda \frac{1}{2} (e_i)^2, \qquad i = 1,2 \qquad\qquad [4]$$

where λ is a parameter that measures the valuation of the environment by the government. I assume that both governments have the same valuation of the environment.

To set its environmental policy the government maximizes social welfare, which comprises the consumer surplus (CS_i), the producer surplus (PS_i) and the union rents (UR_i), less environmental damage (D_i), as is standard in the relevant literature. Social welfare is given by the following function

$$W_i = CS_i + PS_i + UR_i - D_i, \qquad i = 1,2 \qquad\qquad [5]$$

The above welfare function includes the union rents as that part of the producer surplus which is absorbed by the union (see, for example, Brander and Spencer (1988), Mezzetti and Dinopoulos (1991), Naylor (1998) and Bughin and Vannini (1995)). The inclusion of union rents in the social welfare function can be interpreted as follows. It could be assumed that each union is a firm that supplies an intermediate input to produce a final good and the price of this input is *w*. I assume that producing this intermediate input involves no cost. Thus, the producer surplus has to comprise the profit of the firms that supply the intermediate input. This means that the union rents can be understood as the profit of the firms that supply an intermediate input [see, Horn and Wolinsky (1988)].

In equation [5], given that there is only one firm in each country and there are no fixed costs, $PS_i = \pi_i$. When wages are exogenous, $UR_i = 0$, because I assume that workers obtain their reservation wage and therefore this component does not exist in the social welfare function.

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[7] An alternative model is the efficient bargaining model. This model has the drawback that at the negotiation stage there would have to be complete agreement between union and firm owners that employment should be set at its profit maximizing level. Then the interaction between product market and labor market imperfections would be lost. On the other hand, the empirical evidence suggests that this model does not reflect the way in which firms actually behave [Oswald and Turnbull (1985)].

[8] This function assumes that environmental damage is a convex function of the emission level. See, for example, Falk and Mendelsohn (1993), Van der Ploeg and Zeeuw (1992) and Ulph (1996).

I analyze the effect of the environmental policy set by the governments when wages are endogenous. In order to highlight the results of the model, I will compare it with the case of exogenous wages.

The timing of the game is as follows. In the first stage, each government sets emission standards. In the second stage, the unions choose the wage (if it is not exogenous) and in the third stage the firms choose their output (employment). I solve by backward induction to obtain a subgame perfect Nash equilibrium.

3.   The unions choose the wage

In this section, I assume that the governments of countries 1 and 2 set their environmental standards independently and simultaneously before the unions choose the wages. As a benchmark, I also analyze the case in which the cost of production is exogenous (that is, the wage is fixed). Given that there is no international cooperation, the emission level is set by the Nash equilibrium of a non-cooperative game where both countries choose their emissions by maximizing their social welfare function.

I shall first solve the third stage of the game in which firms choose their output (employment) level. Firm i chooses the output level that maximizes its profit function, given by [2]. Deriving this expression respect to the output, we obtain

$$a - 3q_i - q_j + e_i - w_i = 0, \qquad i \neq j, \, i, j = 1,2 \tag{6}$$

Solving equation [6] the output levels for both firms are obtained,

$$q_i = L_i = \frac{2a - 3w_i + w_j + 3e_i - e_j}{8}, \qquad i \neq j, \, i, j = 1,2 \tag{7}$$

The standard set by the government affects both the firm's output and abatement emissions. If the government sets a high standard the firm increases its output and employment. However, the higher the standard set by government the lower the abatement emissions[9]. Thus, the higher the pollution allowance level the higher the output of that country and the lower the output of the other country. Also we can see that the higher the wages paid to workers are, the lower the output of the firm and the higher the output of the rival firm.

In the second stage, union i chooses the wage rate that maximizes its utility function subject to the labour demand constraint imposed by profit maximizing firm i.

$$w_i \, (w_j) = arg \max_{w_i} \, [w_i - r]^{\,\alpha} \, [q_i]^{1-\alpha} \qquad i = 1,2 \tag{8}$$

where q_i is given by [7]. Solving [8], the wage reaction functions are obtained:

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[9] $\dfrac{\partial(q_i - e_i)}{\partial e_i} = -\dfrac{5}{8} < 0.$

$$w_i = r + \frac{\alpha(2a + w_j + 3e_j - e_i - 3r)}{3} , \qquad i \neq j, \, i, j = 1,2 \qquad [9]$$

From [7] and [9], the manner in which wages and employment will react to changes in the emission standards chosen by the government is obtained.

$$w_i = \frac{2a\alpha(3 + \alpha) + 9(1 - \alpha)r + \alpha[3(1 - \alpha)(r - e_j) + e_i(9 - \alpha)]}{9 - \alpha^2}, \quad i \neq j, \, i, j = 1,2 \quad [10]$$

$$L_i = q_i = \frac{3(1 - \alpha)[2a(\alpha + 3) - (9 - \alpha)(r - e_i) + 3(1 - \alpha)(r - e_j)]}{8(9 - \alpha^2)}, \quad i \neq j, \, i, j = 1,2 \quad [11]$$

Equation [10] shows that the higher the pollution allowance level chosen by government *i* and the lower the standard chosen by government *j,* the higher the wage chosen by union *i* [10].

Equation [11] shows that there is a positive relationship between the standard chosen by the government *i* and the output (employment) level of firm *i* The higher the weight given to wages by the union, the lower the increase in employment will be. Moreover, an increase in the standard chosen by government *j* will decrease the output of firm *i*. The lower the weight given to wages by the union, the higher this decrease will be [11].

It remains to solve the first stage of the game. Due to the existence of free trade each government takes into account the decision of the other government when it chooses its environmental standard. Therefore, there is strategic interaction between the two countries because the decision taken by one country affects the other. In the first stage, both governments simultaneously choose the environmental standard that maximizes their social welfare as given by equation [5].

Substituting [10] and [11] in [5], I obtain the social welfare of country *i,* as a function of the standards, e_i and e_j, whose expressions are shown in appendix A.1. Maximizing equation [5] with respect to e_i for country *i* (*i* = 1,2), I obtain the standard reaction function, that shows the negative relationship between the standards of the two countries. The standards are strategic substitutes, i.e. if one country decides to increase its standard, the best answer of the other country is to decrease its own standard. The reaction functions are downward sloping because when government *j* toughens its emission limit that will force firm *j* to cut its output and allow firm *i* to expand its output. From the reaction functions I obtain the equilibrium standards chosen by each government ($e_i^S, \, e_j^S$). I use superscript *S* to denote the variables if the unions choose the wage. The expressions of the standards chosen by governments are collected in appendix A.2.

[10] $\dfrac{\partial w_i}{\partial e_i} = \dfrac{\alpha(\alpha - 9)}{\alpha^2 - 9} > 0, \quad \dfrac{\partial w_i}{\partial e_j} = \dfrac{3\alpha(1 - \alpha)}{\alpha^2 - 9} < 0.$

[11] $\dfrac{\partial L_i}{\partial e_i} = \dfrac{3(\alpha - 1)(9 - \alpha)}{8(\alpha^2 - 9)} > 0, \quad \dfrac{\partial L_i}{\partial e_j} = \dfrac{3(\alpha - 1)(3\alpha - 3)}{8(\alpha^2 - 9)} < 0.$

4. Exogenous cost of production

In this section I solve the case in which the wage is fixed. That is, I assume that the costs of production are exogenous and equal to the workers' reservation wage, r. Now, the game has two stages: In the first stage, both governments choose the standard and in the second stage, both firms choose the output level.

In the second stage, firms maximize their profits as given by [2]. Solving the first order condition, the equilibrium output levels given by [7] are obtained, assuming $w_i = w_j = r$, so that wages are exogenous.

In the first stage, both countries' governments choose the environmental standard. The social welfare function is given by $W_i = CS_i + PS_i - D_i$, $i = 1,2$ [12]. From the first order conditions, the standard reaction function is obtained

$$e_i = \frac{22a - 22r - 7e_j}{35 + 64\lambda} \ , \qquad i \neq j, \ i, j = 1,2$$

I use superscript E to denote the variables if costs are exogenous. Therefore, the standards chosen by both governments are

$$e_i^E = \frac{11\,(a - r)}{21 + 32\,\lambda} \ , \qquad i = 1,2 \qquad\qquad [12]$$

5. Comparison of the two cases considered above

In this section I compare the results obtained in sections 3 and 4. I assume that each firm's union has the same valuation of wage and employment, that is, $\alpha = 0.5$, but the results are robust to changes in α since the effects are the same.

When wages are exogenous the workers' utility is zero because they obtain a wage equal to the reservation wage. But if the union chooses the wage, workers obtain a positive utility because their wage is higher than the reservation wage. Therefore, workers' utility is higher when the union chooses the wage. The expressions of the different terms of the social welfare function for the two cases are collected in appendix A.4.

Let $a_1 = r + \dfrac{17\sqrt{6}\,(21 + 32\lambda)}{1072(1 + \lambda)}$ and $a^* = r + \dfrac{578\sqrt{6}}{255 + 840\lambda}$ is the minimum market size [13], that is, $a_1 > a^*$.

Lemma 1: *When unions have the same valuation of wage and employment in equilibrium:*

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[12]   The expressions of each component of social welfare function are in appendix A.3.

[13]   It is assumed that $a > a^*$ to assure that output and pollution abatement level are positive. I assume, without loss of generality, that $\lambda > 1.3$ in order to eliminate cases when λ is small enough for the market size to be lower than the minimum market size, a^*, and therefore the abatement is negative.

(i) $CS^E > CS^S$,

(ii) $PS^E > PS^S$,

(iii) $e^E \geq e^S$ and $D^E \geq D^S$ if and only if $a \geq a_1 > a^*$.

Given that the production costs are lower when the union does not choose the wage, the output is higher in that case and therefore the consumers' surplus is also greater. Firms' profits are higher if production costs are exogenous, because although the output is greater the production costs are lower. As a result, the producer's surplus is higher in this case.

Given λ and r, the higher a is, the higher the standard chosen by the government i will be, $\left(\dfrac{\partial e^i}{\partial a} > 0, \, i = E, S \right)$. The government sets a higher standard for firms so that they produce more, due to the weight of the consumer surplus in the social welfare function. When wages are exogenous, the standard varies more in line with market size if the union chooses the wage $\left(\dfrac{\partial e^E}{\partial a} > \dfrac{\partial e^S}{\partial a} \right)$, so that the output and consumer surplus, in the first case, will be greater.
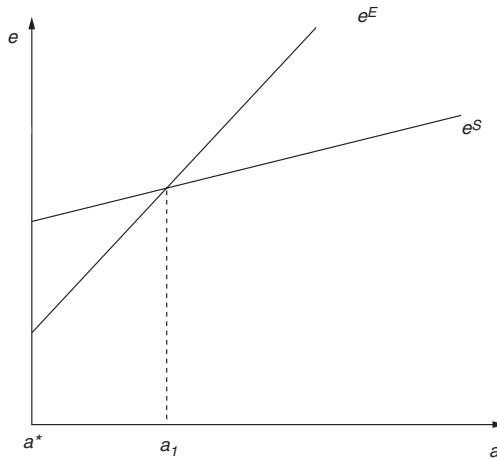

Figure 1.

As figure 1 shows, for small enough market sizes, $a < a_1$, the standard chosen by the government is higher when the union chooses the wage than if the wage is exogenous, $e^S > e^E$. By (i) and (ii) we have that both consumer surplus and producer surplus are higher when wages are exogenous. But when the market is small enough, the greater weight of workers' utility on social welfare when the union chooses the wage means that the government sets a higher standard, allowing greater environmental damage. The increase in the output level reached with a lax standard produces higher consumer and producer surpluses, and increases workers' utility. This last term of the social welfare function allows environmental damage to be greater when the union chooses the wage than if the wage is exogenous.

When the market is large enough, $a > a_1$, this result changes. As market size increases consumer surplus and firms' profits increase too. This rise is greater if the wages are exogenous than if the union chooses the wage. Moreover, environmental damage also is greater when wages are exogenous because output grows by a higher proportion in that case (in spite of firms abating their emissions more). When wages are exogenous the standard chosen by the government is higher, $e^E > e^S$, due to the increase in consumer surplus and producer surplus, in spite of workers' utility being greater in the other case. As a result, when the union chooses the wage the environmental damage is lower.

Let $a_2 = r + \dfrac{\psi(\lambda)}{\phi(\lambda)}$, where $a^* < a_1 < a_2$. The expressions of $\psi(\lambda)$ and $\phi(\lambda)$ are shown in appendix A.4.

Proposition 1: *If unions have the same valuation of wage and employment, $W^E \geq W^S$ if and only if $a \geq a_2$.*

Next, I compare the different terms of the social welfare function to explain why social welfare is higher when wages are exogenous, for a large enough market. The result obtained in proposition 1 is illustrated in figure 2.
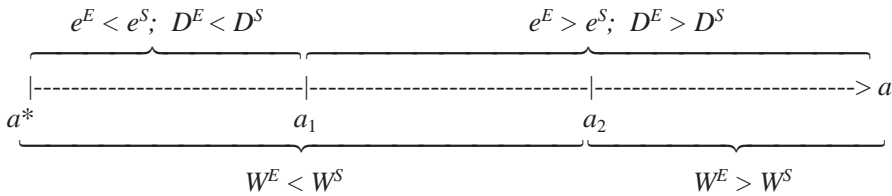

$$e^E < e^S; \ D^E < D^S \qquad\qquad e^E > e^S; \ D^E > D^S$$

$$|\text{----------------}|\text{----------------}|\text{----------------}> a$$

$$a^* \qquad\qquad a_1 \qquad\qquad a_2$$

$$W^E < W^S \qquad\qquad W^E > W^S$$

Figure 2.

If the market is small enough ($a < a_1$), when the production costs are exogenous the consumer and producer surpluses are higher than if the union chooses the wage, but the difference is small. By contrast, when the union chooses the wage the workers' utility is higher. Environmental damage, as we have seen in lemma 1, is higher when the union chooses the wage. Thus, the higher workers' utility balances the lower consumer and producer surpluses and the greater environmental damage. As a result, when the unions choose the wage, social welfare is higher, $W^S > W^E$.

For intermediate market sizes, ($a_1 \leq a < a_2$) the difference between consumer surplus and producer surplus increases in both cases, due to the increase in production. When the union chooses the wage the workers' utility increases due to the increase in the number of workers hired and in wages. Moreover, as we have seen in lemma 1, environmental damage increases when production costs are exogenous. As a result, the difference between welfare in the two cases decreases, but nevertheless I find that $W^S > W^E$. This result arises from the fact that when production costs are exogenous environmental damage is higher.

The last case can be observed when $a \geq a_2$. As market size increases the output grows higher in proportion when production costs are exogenous. This causes consumer and producer surpluses to increase with respect to the case in which the union chooses the wage. Although workers' utility is higher and environmental damage is lower, when the union chooses the wage, the weight of the consumer and producer surpluses means that, if production costs are exogenous, social welfare will be higher, $W^E > W^S$.

The results obtained in this section are robust to changes in α, (if unions value employment and wages differently).

6. Conclusions

I have developed a simple model of oligopolistic product markets and unionized labor markets. I have analyzed the interaction between variables that affect environmental policy and variables in the labor market. The study blends two different themes: on the one hand the choice of environmental policy by governments, and on the other hand the effects on interaction in the product market of the wage process determined by unions.

Environmental policy affects producers' behavior, so that if a government sets a high (low) environmental standard then firms produce more (less). On the other hand, the existence of unions that choose wages affects firms when they determine their level of output.

The outcomes obtained show that if unions have the same valuation of wage and employment, the environmental policy chosen by the governments depends on market size, and on whether the unions choose the wage or not. On the one hand, if the market is large enough and unions do not choose the wage, the governments will set higher environmental standards than if the unions choose the wage. On the other hand, if the market is small enough and unions choose the wage, environmental policy is lax and the governments will set higher environmental standards than if production cost is exogenous.

Therefore, the existence of unions that choose wages increases social welfare if the market is small enough. This is because workers' utility is higher than when production costs are exogenous. But if the market is big enough, social welfare is higher when production cost is exogenous, due to the increase in consumer and producer surpluses.

The main results of the paper do not change if I assume that the government imposes environmental taxes instead of emission standards. The producer will abate pollution to the point where marginal abatement cost equals the emission tax.

The conclusions reached with the model studied are robust if I consider different asymmetries. For example, considering that countries' environmental valuation is different or countries have different reservation wages, or that unions value employment and wages differently, does not alter the main results. Nor do the results vary if governments choose environmental policy cooperatively.

Appendix

Appendix A.1

This appendix provides expressions for the different functions. The social welfare function of country i when the union chooses the wage is: $W_i = CS_i + PS_i + UR_i - D_i$, $i = 1,2$, where

$$CS_i = \frac{9\,(-1 + \alpha)^2\,(2\alpha - 2r + e_i + e_j)^2}{64\,(-3 + \alpha)^2} \,,$$

$$PS_i = \frac{1}{128(\alpha^2 - 9)^2}\,(108(a^2 + r^2)(\alpha - 1)^2\,(3 + \alpha)^2 - (2997 + \alpha(4860 + \alpha(-4338 +$$

$$\alpha(540 + 37\alpha))))e_i^2 - 162(\alpha - 9)(\alpha - 1)^3\,e_i e_j + 243(\alpha - 1)^4\,e_j^2 + 108(\alpha - 1)^2\,(3 + \alpha)$$

$$r((\alpha - 9)e_i - 3(\alpha - 1)e_j\,9 - 108\alpha(\alpha - 1)^2\,(3 + \alpha)(2(3 + \alpha)r + (\alpha - 9)e_i - 3(\alpha - 1)e_j)).$$

$$UR_i = \frac{1}{\alpha^2 - 9}\,((-1)^\alpha \left(\frac{3}{8}\right)^{1-\alpha}(\alpha - 1)^{1-\alpha}\,\alpha^\alpha(2(3 + \alpha)(a - r) + e_i(9 - \alpha) + 3e_j\,(\alpha - 1))).$$

$$D_i = \frac{1}{2}\,\lambda(e_i)^2 \,, \qquad\qquad\qquad i \neq j,\, i,\, j = 1,2$$

Appendix A.2

When the government chooses the environmental standard and unions choose wages, the standards set are:

$$e_i^S = -(3^{1-\alpha}(\alpha - 1)^{1-\alpha}(27(-1)^\alpha 2^{2+3\alpha}\,\alpha^\alpha - 3(-1)^\alpha 2^{4+3\alpha}\,\alpha^{1+\alpha} + (-1)^\alpha\,2^{2+3\alpha}\,\alpha^{2+\alpha} +$$

$$3^{1+\alpha}\,a(\alpha - 1)^\alpha(33 - 34\alpha + \alpha^2) - 3^{2+\alpha}11(\alpha - 1)^\alpha\,r + 3^{1+\alpha}34\alpha(\alpha - 1)^\alpha\,r - 3^{\alpha+1}\,(\alpha - 1)^\alpha$$

$$\alpha^2 r))/(\alpha(315 - 288\lambda) + 27(21 + 32\lambda) + \alpha^3\,(41 + 32\lambda) - 3\alpha^2\,(137 + 32\lambda)), \quad i = 1,2$$

Appendix A.3

Social welfare function of country i when production costs are exogenous:

$$W_i = CS_i + PS_i - D_i \,, \; i = 1,2, \text{ where}$$

$$CS_i = \frac{1}{64}\,(2a - 2r + e_i + e_j)^2 \,.$$

$$PS_i = \frac{1}{128}\,(12a^2 + 12r^2 - 37e_i^2 - 18e_i e_j + 3e_j^2 + 12r(-3e_i + e_j) - 12a(2r - 3e_i + e_j)).$$

$$D_i = \frac{1}{2}\,\lambda(e_i)^2, \qquad\qquad i \neq j,\, i,\, j = 1,2.$$

Appendix A.4

Environmental standards when the union chooses the wage (e^S) and when the wage is exogenous (e^E) are:

$$e^S = \frac{136\sqrt{6} + 117(a - r)}{1003 + 1120\lambda} \quad , \qquad e^E = \frac{11(a - r)}{21 + 32\lambda} \quad .$$

Environmental damage when the union chooses the wage (D^S) and when the wage is exogenous (D^E) are:

$$D^S = \frac{(136\sqrt{6} + 117a - 117r)^2\lambda}{2(1003 + 1120\lambda)^2} \quad , \qquad D^E = \frac{121(a - r)^2\lambda}{2(21 + 32\lambda)^2} \quad .$$

Consumer surpluses when the union chooses the wage (CS^S) and when the wage is exogenous (CS^E) are

$$CS^S = \frac{36(17\sqrt{6} + 140a(1 + \lambda) - 140r(1 + \lambda)^2)}{25(1003 + 1120\lambda)^2} \quad , \quad CS^E = \frac{64(a - r)^2 (1 + \lambda)^2}{(21 + 32\lambda)^2} \quad .$$

Firms' profits when the union chooses the wage (π^S) and when costs are exogenous (π^E) are

$$\pi^S = \frac{1}{50(1003 + 1120\lambda)^2} (3(-862376 - 4080\sqrt{6}r(-23 + 24\lambda) + 225a^2 (2629 +$$

$$6272\lambda + 3136\lambda^2) + 225r^2 (2629 + 6272\lambda + 3136\lambda^2) + 30a(136\sqrt{6}(-23 + 42\lambda)$$
$$-15r(2629 + 6272\lambda + 3136\lambda^2)))),$$

$$\pi^E = \frac{(a - r)^2 (71 + 384\lambda + 192\lambda^2)}{2(21 + 32\lambda)^2}$$

Social welfare functions when the union chooses the wage (W^S) and when costs are exogenous (W^E), are

$$W^S = \frac{1}{10(1003 + 1120\lambda)^2} (408(799 + 880\lambda) - 400\sqrt{6}r(2839 + 5975\lambda +$$

$$3136\lambda^2) + 45a^2 (14159 + 29839\lambda + 15680\lambda^2) + 45r^2 (14159 + 29839\lambda +$$
$$15680\lambda^2) + 10a(1 + \lambda)(40\sqrt{6}(2839 + 3136\lambda) - 9r(14159 + 15680\lambda))),$$

$$W^E = \frac{(a - r)^2 (199 + 519\lambda + 320\lambda^2)}{2(21 + 32\lambda)^2}$$

The expressions of the market size a_2 are:

$$\psi(\lambda) = \sqrt{6}\,(25(21 + 32\lambda)^2\,(2839 + 5975\lambda + 3136\lambda^2) + \sqrt{5}\,(21063 + 76679\lambda + 91456\lambda^2 + 3584\lambda^3)\sqrt{563165 + 1528192\lambda + 1003520\lambda^2}),$$

$$\phi(\lambda) = 160\,(1 + \lambda)^2\,(562495 + 1529376\lambda + 1003520\lambda^2).$$

Bibliografía

Bárcena-Ruiz, J.C. and Garzón, M.B. (2003). «Strategic Environmental Standards, Wage Incomes and the Location of Polluting Firms». *Environmental and Resource Economics,* **24**(2):121-139.

Brander, J.A. and Spencer, B. (1988). «Unionized Oligopoly and International Trade *Policy».* *Journal of International Economics,* **24**:217-234.

Brown, J.N. and Ashenfelter, O. (1986). «Testing the Efficiency of Employment Contracts». *Journal of Political Economy,* **94**:540-587.

Bovenberg A.L. and Van der Ploeg F. (1998). «Tax Reform, Structural Unemployment and the Environment». *Scandinavian Journal of Economics,* **100**(3):593-610.

Bughin, J. and Vannini, S. (1995). «Strategic Direct Investment under Unionized Oligopoly». *International Journal of Industrial Organization,* **13**:127-145.

Carraro, C., Galeotti, M. and Gallo, M. (1996). «Environmental Taxation and Unemployment: Some evidence on the Double Dividend Hypothesis in Europe». *Journal of Public Economics,* **62**:141-181.

De Fraja, G. (1993). «Unions and Wages in Public and Private Firms: A Game-Theoretic Analysis». *Oxford Economic Papers,* **45**:457-469.

Dertouzos, J.N. and Pencavel, J.M. (1981) «Wage and Employment Determination Under Trade Unionism: The International Typographical Union». *Journal of Political Economy,* **89**:1162-1181.

Dobson, P. (1994). «Multifirm Unions and the Incentive to Adopt Pattern Bargaining in Oligopoly». *European Economic Review,* **38**:87-100.

Falk, I. and Mendelsohn, R. (1993). «The Economics of Controlling Stock Pollutants: An Efficient Strategy for Greenhouse Gases». *Journal of Environmental Economics and Management,* **25**:75-88.

Fredriksson, P.G. and Gaston, N. (1999). «The "Greening" of Trade Unions and the Demand for Eco-taxes». *European Journal of Political Economics,* **15**:663-686.

Hoel, M. (1997a). «Coordination of Environmental Policy for Transboundary Environmental Problems». *Journal of Public Economics,* **66**:199-224.

Hoel, M. (1997b). «Environmental Policy with Endogenous Plant Locations». *Scandinavian Journal of Economics,* **99** (2):241-259.

Hoel, M. (1998). «Emission Taxes versus Other Environmental Policies». *Scandinavian Journal of Economics,* **100** (1):79-104.

Horn, H. and Wolinsky, A. (1988). «Bilateral Monopolies and Incentives for Merger». *RAND Journal of Economics,* **19**(3):408-419.

Malcomson, J.M. (1987). «Trade Union Labor Contracts». *European Economic Review,* **31**:139-148.

Markusen, J.R. (1997). «Costly Pollution Abatement, Competitiveness and Plant Location Decisions». *Resource and Energy Economics,* **19**:299-320.

Mezzetti, C. and Dinopoulos, E. (1991). «Domestic Unionization and Import Competition». *Journal of International Economics,* **31** 79-100.

Naylor, R. (1998). «International Trade and Economic Integration when Labour Markets are Generally Unionised». *European Economic Review,* **42**:1251-1267.

Oswald, A.J. and Turnbull, P.J. (1985). «Pay and Employment Determination in Britain: What Are Labour». *Oxford Review of Economic Policy,* **1** (2):80-97.

Ulph, A. (1996). «Environmental Policy and International Trade when Governments and Producers Act Strategically». *Journal of Environmental Economics and Management,* **30**:265-281.

Ulph, A. (2000). «Harmonization and Optimal Environmental Policy in a Federal System with Asymmetric Information». *Journal of Environmental Economics and Management,* **39**:224-241.

Van Der Ploeg, F. and De Zeeuw, A.J. (1992). «International Aspects of Pollution Control». *Environmental and Resource Economics,* **2**:117-139.