Trade union structure with environmental concern and firms' technological choice

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Abstract

I investigate the influence of the union structure on firms' environmental technological choice when the unions care for the environmental protection. Specifically, I compare the decentralised with the centralised structure under a Cournot duopoly. I show that the decentralised structure could always provide higher incentives to the firms for the adoption of a better (less polluting) technology. In addition, the firms prefer the decentralised unionisation than the centralised although the unions prefer the centralised structure. Furthermore, there is an inverse U-shape relation between the firm's emissions and the size of the market. Finally, the emissions could be less under the centralised case compared to the decentralised for relatively low market's size.

Keywords: trade unions; environmental concern; emissions; technological choice.

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1 Introduction

Recently a small but increasing number of social studies recognises the environmentalism as a strong motivation which could influence the trade unions' decisions and strategies. As Obach (1999) reports 'Starting with the wave of environmentalism that began in the late 1960s, we see that a number of unions were supportive of this environmental mobilization' and according to Silverman (2006) 'Union environmentalism is based in the particularist purpose of unions to protect members and in their more-universalist purpose to promote class mobilization based on solidarity'. Furthermore, in the literature there are examples from the real world experience with respect to the unions environmentalism as well as trade unions alliances with the environmental groups for common targets (e.g. Obach, 1999, 2002, 2004; Rose, 2004 and Mayer, 2009).[2]

Therefore, the strong evidence for the union environmentalism could drives the economists to ask 'How the trade unions could react to the firms' level of pollution when the organised workers participate in the production process? How the unions environmental interest could influence the firms' decision for the technological choice, the level of the production and the profits? What will happen to the unions' wages and utility? Which unions structure could provide the lower level of emissions?' The aim of this research is to explore and to shed more light on the previous issues.

In the economic literature the influence of the trade union structures on the firms' technological choice is a main research issue in labour and technological economics and has been analysed extensively.[3] However, both

[2]An other important evidence for the interest of the labour community for the environmental protection is the document from the United Nations Environmental Program (UNEP) and the International Labour Organisation (ILO) under the title 'Labour and the Environment: A Natural Synergy'. Available at http://www.unep.org/labour_environment/PDFs/UNEP-labour-env-synergy.pdf

[3]For some examples see Ulph and Ulph, 1998 and Dobson, 1994 and for a survey see Menezes-Filho and Van Reenen, 2003.

empirical and theoretical studies have given ambiguous results with respect to the dimensions of the unionisation's influence on firms' technology, innovation or R&D. For example a strong negative relation has been reported in North America between the unionisation and innovation but the European studies have not confirmed this strong relation (e.g. Menezes-Filho and Van Reenen, 2003; Haucap and Wey, 2004 and Manasakis and Petrakis, 2009).

In this paper, following the recent theoretical studies on oligopoly, union structure and innovation, I explore the firms' technological choice under the case of decentralised unions (independent union for each firm) and centralised union (industry-wide union) in a Cournot market. However, contrary to the literature, I introduce the case of the union's direct interest for environmental protection, which has been neglected, although it is an essential issue for environmental economics and policy.[4] I show that, the decentralised structure could always provide higher incentives to the firms for the adoption of a better (less polluting) technology. Also, although firms prefer the decentralised unionisation (because the profits are higher) than the centralised, the unions prefer the industry-wide union case (where the union's utility is higher). Furthermore, the level of the firms' emissions depends on the size of the market, therefore, it could be lower under the centralised structure (compared the decentralised) for relatively small market size. Therefore, this study on the one hand, could partially cover the gap in the literature with respect to the environmental issue and the role of the trade unions. On the other hand, may encourage further theoretical and empirical investigation for the relation between the union structure, the environmental issue and the technological choice or innovation.

The model is based on a duopolistic market where firms compete à la

[4] Also, for the relation between the unionised workers and the application of the environmental policy see for example Stavins, 1998 and Fredriksson and Gaston, 1999. Furthermore, in the literature there are cases where the unions opposed to the environmental policies under the threat of higher unemployment. However, it is less interesting to focus on the case of trade unions without environmental interest given that already exists in the literature.

Cournot and both firms are unionised. In the same spirit, Ulph and Ulph (1989) use a duopolistic model where each firm faces an independent union. In their model the firms participate in a patent race to gain a new technology (tournament model) where only one firm could use the new technology (innovator). They conclude that the strength of the union and the timing of the firms-unions negotiations could discourage the firms' incentives for R&D investment. Also in a similar study, Ulph and Ulph (1994) compare the Right to Manage case (bargaining over wages) with the Efficient Bargaining case (bargaining over wages and employment). In this model however, like in the previous, there are only decentralised unions and the firms participate on a tournament race for a labour-saving technology where only one firm could be the innovator.

Also Tauman and Weiss (1987) following a Cournot market, consider the role of the unionisation on the firms' decision for the adoption of labour-saving technology. In their model two firms; one unionised and the second non-unionised, compete in the product market as well as in the tournament race. The authors conclude that the unionised firm has more incentives to adopt a new technology in order to defend against higher costs (wages) from the unionised workers. However they assume that only one firm is unionised.

Additionally, Calabuig and Gonzalez-Maestre (2002) focus on the structure of the union -centralised and decentralised- and the influence on the firms' technological choice for labour-saving technology. The authors following the Right to Manage bargaining model, analyse three possible technological choices; only one firm innovates, both firms innovate, both firms choose not to innovate. They conclude that the centralisation may provide stronger incentives to the firms for innovation, but this argument is strong under a small market size. In their model there are only two possible levels of technologies; the old and the new, but the firms face a linear cost function. Contrary to Calabuig and Gonzalez-Maestre (2002), I assume the existence of a spectrum of available technologies where the firms' cost function is quadratic.

Furthermore, Haucap and Wey (2004) analyse three possible union structures. Specifically, they consider the case of the decentralised unions, the case of the "coordination" where the single union sets individual wages (wages discrimination) to each firm and finally the centralised union where there is only one wage (uniform) for all firms in the industry. The firms compete in R&D tournament race for a labour-saving technology. They show that the firms' incentives for investment or innovation are larger under the centralisation. Also the decentralised case encourages more innovation than coordination. Moreover, decentralisation offers higher levels of employment to the unions than coordination where centralisation offers a lower employment level. Therefore the innovation incentives are non-monotone in the degree of the centralisation. In their article, as in Ulph and Ulph (1989, 1994), the model is based on a patent race for labour-saving technology and with one innovator.

Recently, Manasakis and Petrakis (2009) explore the incentives of the firms to invest on cost-reducing R&D under different union structure. The authors compare the R&D investment with the presence of the R&D spillovers when the two firms do not cooperate in technology and when they cooperate under the form of Research Joint Ventures (RJV). They argue that if the spillovers are low and under the absence of the cooperation, the centralised union (with uniform wage) encourages more R&D investment than the decentralised structure. Besides, in the case of the RJV the incentives for R&D investment are always higher under the decentralisation structure than under the industry-wide union. However, in my study I focus on the case without the existence of the spillovers and on the use of the environmental technology.

The previous papers, except the technical differences and characteristics with this study, have neglected the environmental issue and as a result the unions' reaction against pollution and their possible influence on the firms' anti-pollution technological choice. Specifically, I assume that both firms are unionised. Like in Calabuig and Gonzalez-Maestre (2002), I compare the decentralised with the centralised structure (wage discrimination). The firms compete in the output market only and both can adopt an environmental (anti-polluting) technology from a spectrum of available technologies. Also the union(s)' utility function is characterised by the environmental concern because the unions' may have a degree of "environmentalism" or because the unionised workers would be harmed from the firms' emissions.[5]

Following the timing of the game from Haucap and Wey (2004), the firms' decision for the technological choice, which is a long run decision, is included in the first stage. Then the firms negotiate with the union(s) for the wages, which could happen in a shorter time and finally in the third stage the firms choose output, a much shorter period's decision. I solve the game by backwards induction to analyse the Subgame Perfect Nash Equilibrium (SPNE).

The next section includes the solution of the models for the two possible cases of union structure; the decentralised and centralised. The results from the two cases are compared in the section 3. Finally discussion and conclusions are in section 4.

2 The model

The model is made as simple as possible in order to focus on the effect of the unions structure on the level of the emissions. Therefore, I consider a classic Cournot oligopoly model with two unionised firms indicated by $i, j = 1, 2$ with $i \neq j$ and a homogeneous product. Following the usual assumption the firms produce with constant returns to scale $q_i = L_i$ where q_i, L_i is the firm's i output and labour respectively. The price in the product market (inverse demand function) is given by $p = a - q_i - q_j$ where $a > 0$ is the size of the market. Also $k_i \in (0, 1]$ is the level of the firm's i anti-pollution technology

[5] For example, the CO_2 emissions from the firms could influence negatively the workers' health.

which is more efficient against the pollution (cleaner or greener) for values close to 0 and less efficient (dirtier or browner) for values near to 1. Like in the real market, I assume the absence of the perfect technology which can stop all the emissions from the production. Therefore, $k_i > 0$. Furthermore, following Asproudis and Gil-Molto (2009) the technological cost is quadratic, reflects the diminishing returns to investment and is equal to $\gamma(1-k_i)^2$. Also the parameter $\gamma > 0$ implies that the adoption of a less polluting (greener) technology involves higher cost to the firms than the adoption of a more polluting (browner) technology. For the sake of simplicity and without loss of generality, I assume that firms do not incur any other production costs. Thus, the total cost for the firm i becomes $C_i = w_i L_i + \gamma(1-k_i)^2$, where w_i is the level of the wages set by the union to the firm i. That is, the firms' profits are given by

$$\Pi_i = pq_i - C_i \tag{1}$$

Besides, the unions will set the level of the wages and then the firms have the right to decide the level of employment according to the Right to Manage model.[6] Furthermore, I start from the usual utility equation $U_i = w_i L_i$ (see Oswald, 1985; Booth, 1995 and Dobson, 1994) and from the assumption that, the unions have total power to set wages but the firms have the bargaining power to decide the number of workers (e.g. Manasakis and Petrakis, 2009).[7][8] Additionally, I assume that the reservation wage or the wage that the workers could gain in a competitive industry is equal to zero (e.g. Lommerud et al., 2005; Mukherjee et al., 2007 and Manasakis and Petrakis, 2009). Finally, I hypothesize that each union cares for the

[6]For some studies with respect to the Right to Manage model see Nickell and Andrews, 1983; Espinoza and Rhee, 1989; Lopez and Naylor, 2004 and Mukherjee, 2008.

[7]This is the Monopoly Union model (Dunlop, 1944) a special case of the Right to Manage model. See also Oswald, 1982 and 1985 and Petrakis and Vlassis, 2004.

[8]Another usual assumption is that all the workers are organised members, they are homogeneous and they have equal opportunity to be employees (e.g. Oswald, 1985).

environmental protection (or for the unionised members' health which could be harmed from the firms' pollution) and reacts against the firm's emissions. Hence each trade union objective is to reduce the level of the environmental damage (through the firm's damage function) which emanates from the firm's pollution.[9] For the firm i the damage equation or the workers' disutility from the pollution (see Eshel and Sexton, 2009) is equal to $D_i(y_i) = ey_i$, an increasing function of the emissions. Also, e is the damage's parameter for each unit of emissions or pollution (e.g. the environmental damage for each tonne of CO_2), therefore the marginal damage with respect to the emissions is constant.[10] Also, given that $k > 0$ then always $e > 0$. The y_i indicates firm's i level of emissions where $y_i = k_i q_i$. Thus, each firm's level of emissions depends on the 'greenness' of the technology and the level of production. So, I introduce the damage function in the trade union's utility function and therefore the equation becomes $U_i = w_i L_i - D = w_i L_i - ey_i$.

I explore two possible structures of the unions. In the first case there is one union for each firm, the decentralised case, where initially the firms choose technology simultaneously. Then, the unions set the wages simultaneously following a sequential Right to Manage bargaining model and finally the firms decide simultaneously on production (and employment).[11] The last stage is common with the second case where there is only one union, the centralised union, which will set wages for both firms.

There are some common conditions for the two models, which are necessary in order to be sure that the results are the optima and to be compared

[9] A possible extension of this approach is the case where each union cares for the total level of the emissions or the emissions at industry level, then each union will deal with the total damage function or the damage which emanates from the pollution of both firms.

[10] For linear damage or constant marginal damage function see Kennedy (1999), Kennedy and Laplante (1999) and Requate (2005). An other possible extension of the model is the using of a quadratic damage equation. However, the results are much more ambiguous and complex.

[11] In Calabuig and Gonzalez-Maestre (2002) the unions bargain simultaneously with the firms over the wages. In my model the bargaining is sequential, so the union(s) set the wages and then the firms decide for the level of the employment (or output).

under the same spectrum of values.

Conditions: $\frac{14.46\gamma}{e} > a > e$, $9\gamma > e^2$, $ae^2 < 4.82\gamma(a+2e)$, $ae^2 < 9\gamma(a+e)$

2.1 Stage three: Firms decide on the output

After some manipulations the firms' profits equations become

$$\Pi_i = (a - q_i - q_j)q_i - w_i q_i - \gamma(k_i - 1)^2 \tag{2}$$

where following the standard calculation of the First Order Condition (FOC) each firm's reaction function becomes $q_i^{RF} = (a - q_j - w_i)/2$. Solving simultaneously the equations of the reaction functions the Cournot - Nash equilibrium output, employment and profits respectively are given by

$$\begin{aligned} q_i^* &= L_i^* = \frac{a - 2w_i + w_j}{3}, \\ \Pi_i^* &= (q_i^*)^2 - \gamma(k_i - 1)^2 \end{aligned} \tag{3}$$

Note that the equilibrium output is decreasing in its firm's wage but is increasing in the rival's firm level of wage and as usual is increasing in the size of the market.

This stage is common stage for the two possible union structure, decentralised and centralised. In the next subsection I analyse the model for the case of the decentralisation where each firm will bargain with one union over the wages.

2.2 Decentralised unions

2.2.1 Stage two: Unions set wages

In this stage the two unions will move together and will set the level of the wages for each firm (bargaining at the firm level). For the decentralised case the unions' utility is given by

$$U_i^D = w_i L_i - e y_i \tag{4}$$

and after the substitution of the equilibrium output (and employment) the utility function becomes $U_i^{D*} = (w_i - ek_i)q_i^*$. From the calculation the FOC I obtain[12]

$$\frac{\partial U_i^{D*}}{\partial w_i} = \frac{1}{3}(a + 2ek_i - 4w_i + w_j) = 0 \tag{5}$$

where $\frac{\partial^2 U_i^{D*}}{\partial w_i \partial w_j} > 0$, thus, the wages are strategic complements. Like in Petrakis and Vlassis (2004) if the union j sets higher wages to firm j the level of the output from the specific firm will reduced ($\frac{\partial q_j^*}{\partial w_j} < 0$) but firm i will produce more ($\frac{\partial q_i^*}{\partial w_j} < 0$). So it becomes more attractive for the union i to set higher wages to firms i when the rival firm deals with higher wages from the union j.[13]

Solving simultaneously the FOCs the equilibrium wage is[14]

$$w_i^D = \frac{1}{15}(5a + 2e(4k_i + k_j)) \tag{6}$$

where the level of the wage setting from each union depends positively on the firms' decision for the greenness of the technological choice. Simply, the better (with less emissions) the technology adopted by both firms, the less will be, the level of the wages demanded by the unions.[15]

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[12] The SOC is $-4/3$, therefore the utility function is a risk-averse utility ($\partial^2 U_i^{D*}/\partial w_i^{D^2} < 0$, see also Booth, 1995).

[13] For example, the union i will set higher wages when the union j set higher wages to the firm j. Then the firm i may produce the same output as before the increasing of the rival firm's level of wages (firm j). So, the number of the workers in firm i could be the same but with higher wages, which means that the firm i finally will not produce more but will pay for higher wages.

[14] It is interesting to observe that, solving the FOC with respect to the wage the reaction function of the unions will be $w_i^{RF} = \frac{1}{4}(a + 2ek_i + w_j)$. Hence, each union will decide for the level of the wage taking into account the other union's decision for the wage.

[15] The wages are increasing due to the rent-seeking behavior. The union seeks higher level of wages when the firm's returns from an investment become higher.

Proposition 1 *The more polluting the firms' technology (at industry level) is, the higher the level of the wages demanded by the unions.*

2.2.2 Stage one: Firms choose technology

In this stage the firms will decide on the level of technology given the decentralised unions' decisions for the level of wages. After the substitution of (6) to (3); the equilibrium output, employment and profits respectively are equal to

$$\begin{aligned} q_i^{D**} &= L_i^{D**} = \frac{2}{45}(5a - 7ek_i + 2ek_j), \\ \Pi_i^{D**} &= (q_i^{D**})^2 - \gamma(k_i - 1)^2 \end{aligned} \tag{7}$$

Also note that, on the one hand, the equilibrium output is decreasing in its firm's technological choice ($\frac{\partial q_i^{D**}}{\partial k_i} < 0$). Thus, the production is increasing if the firm adopts a greener technology. On the other hand, the equilibrium output for each firm is increasing in the rival firm's technological choice ($\frac{\partial q_i^{D**}}{\partial k_j} > 0$). Hence, the output is increasing if the rival firm chooses a 'dirty' than if will adopt a 'green' technology.

From the equilibrium profits I calculate the derivative with respect to the technology and solving these equations simultaneously, I obtain the firms' optimum technological choice[16]

$$\overline{k}_i^D = \frac{ae - 14.46\gamma}{e^2 - 14.46\gamma} \tag{8}$$

where the optimum technology is positive given the necessary conditions of the model. Also, given that $\overline{k}_i^D$ is decreasing in the size of the market ($\frac{\partial \overline{k}_i^D}{\partial a} < 0$), this implies that the bigger the market's size, the greener (less

[16] The FOC is $\frac{\partial \Pi_i^{**}}{\partial k_i} = -\frac{2(140ae + 2025\gamma(k_i - 1) + 28e^2(2k_j - 7k_i))}{2025}$ and the SOC is $\frac{\partial^2 \Pi_i^{**}}{\partial k_i^2} = \frac{392e^2}{2025} - 2\gamma$ which is negative given the conditions of the model.

polluting) the adopted technology is. Actually, the increasing of the market will raise the production of the firms ($\frac{\partial q_i^{D**}}{\partial a} > 0$) but this implies the adoption of a better technology ($\frac{\partial q_i^{D**}}{\partial k_i} < 0$). Furthermore, the optimum technology is decreasing in the parameter γ or as usual, the increasing adoption costs discourage the firms' to adopt a better technology ($\frac{\partial \overline{k}_i^D}{\partial \gamma} > 0$).

Thus, after the necessary substitutions the optimum profits are

$$\overline{\Pi}_i^D = \frac{784(a-e)^2(10.33\gamma - e^2)\gamma}{(28e^2 - 405\gamma)^2} \tag{9}$$

and the optimum output and employment is

$$\overline{q}_i^D = \overline{L}_i^D = \frac{3.21(a-e)\gamma}{14.46\gamma - e^2} \tag{10}$$

Therefore the level of the emissions from each firm is given by

$$\overline{y}_i^D = \frac{2520(a-e)(14.46\gamma - ae)\gamma}{(28e^2 - 405\gamma)^2} \tag{11}$$

Interestingly, the derivative of the emissions with respect to the size of the market $\frac{\partial \overline{y}_i^D}{\partial a}$ could be positive or negative but depends on the market's size. Specifically, there is a critical value for the size of the market $a_{cv}^D = \frac{e^2 + 14.46\gamma}{2e}$ according to which for $a < a_{cv}^D$ the emissions are increasing in the size of the market $\frac{\partial \overline{y}_i^D}{\partial a} > 0$ and for the opposite case the opposite holds. The intuition for this is the existence of the two effects. Particularly, on the one hand the increase in the market's size drives the firms to produce more ($\frac{\partial q_i^{D**}}{\partial a} > 0$), hence, the level of the emissions becomes higher (direct effect). On the other hand, under the increase of the market's size (and the rise of the production) the firms will adopt a better (less polluting) technology because then the production is rising, ($\frac{\partial \overline{k}_i^D}{\partial a} < 0$ and $\frac{\partial q_i^{D**}}{\partial k_i} < 0$). Thus, the level of the emissions is reducing (indirect effect). That is, for size of the market less than the critical value the first effect dominates the second. However for size of the market larger than the critical value the second effect dominates the first. Diagrammatically, an inverse U-shape could characterise the level of the emissions with the size of the market.

Proposition 2 *There is an inverse U-shape curve between the level of pollution and the size of the market.*

Furthermore the wages for each union will be

$$\overline{w}_i^D = \frac{4.82(a+2e)\gamma - ae^2}{14.46\gamma - e^2} \tag{12}$$

where each union's optimum utility becomes

$$\overline{U}_i^D = \frac{12150(a-e)^2\gamma^2}{(28e^2 - 405\gamma)^2} \tag{13}$$

2.3 Centralised unions

2.3.1 Stage two: Union sets wages

In the case of the centralised union, only one union, the central union, set wages

$$U^C = w_i L_i + w_j L_j - e(y_i + y_j) \tag{14}$$

and after the substitution of the equilibrium output the utility equation is equal to $U^{C*} = (w_i - ek_i)q_i^* + (w_j - ek_j)q_j^*$, so the FOC is[17]

$$\frac{\partial U_i^{C*}}{\partial w_i} = \frac{1}{3}(a + 2ek_i - ek_j - 4w_i + 2w_j) \tag{15}$$

and the Nash equilibrium wages after the simultaneously solving for the FOCs will become

$$w_i^C = \frac{1}{2}(a + ek_i) \tag{16}$$

[17] Again the SOC is $-4/3$, so risk-averse utility.

where similar to the decentralised case, the level of the wages under centralisation depends positively on the firm's technology but contrary to the decentralised structure depends only on each firm's level of technology and not on the both firms' technological choice.

Proposition 3 *The wage set by the union is increasing in each firm's technological choice.*

2.3.2 Stage one: Firms choose technology

After the substitution of the previous centralised equilibrium values in q_i^*, L_i^*, Π_i^* the firms' output, employment and profits respectively, are:

$$\begin{aligned} q_i^{C**} &= L_i^{C**} = \frac{1}{6}(a - 2ek_i + ek_j), \\ \Pi_i^{C**} &= (q_i^{D**})^2 - \gamma(k_i - 1)^2 \end{aligned} \tag{17}$$

where, like in the case of decentralisation, the equilibrium output (or employment) is decreasing in k_i and increasing in k_j. Again solving the system of the equations from the FOCs, the firms optimum technological choice for the case of the centralised union is[18]

$$\overline{k}_i^C = \frac{ae - 18\gamma}{e^2 - 18\gamma} \tag{18}$$

Again, the firms' technological choice under the unionised structure is decreasing in the size of the market ($\frac{\partial \overline{k}_i^C}{\partial a} < 0$), so it becomes greener and is rising in the parameter γ ($\frac{\partial \overline{k}_i^C}{\partial \gamma} > 0$), thus, it becomes more polluting. Hence, after the substitution of the optimum technology to the profits' equation, the optimum profits under the centralised union are

[18] The FOCs are equal $\frac{\partial \Pi_i^{C**}}{\partial k_i} = \frac{1}{9}(-ae - 18\gamma(k_i - 1) + e^2(2k_i - k_j))$ also the SOC is $\frac{\partial^2 \Pi_i^{C**}}{\partial k_i^2} = \frac{2}{9}(e^2 - 9\gamma)$ which is negative given the initial conditions of the model.

$$\overline{\Pi}_i^C = \frac{(a-e)^2(9\gamma - e^2)\gamma}{(e^2 - 18\gamma)^2} \tag{19}$$

and the output (and employment) equilibrium is

$$\overline{q}_i^C = \frac{3(a-e)\gamma}{18\gamma - e^2} \tag{20}$$

therefore each firm's level of emissions is

$$\overline{y}_i^C = \frac{3(a-e)(18\gamma - ae)\gamma}{(e^2 - 18\gamma)^2} \tag{21}$$

and like in the case of decentralisation, the optimum level of emissions have an inverse U-shape relation with the size of the market, where the critical value now is $a_{cv}^C = \frac{e^2+18\gamma}{2e}$. Therefore, there are two effects; the increasing of the emissions which emanate from the increasing of the output and the reduction of the emissions which originating from the adoption of a better, less-polluting, technology. Again, the level of the optimum emissions is increasing for markets' size less than the critical size (first effect dominates the second) and is decreasing for markets' size larger than the critical value (second effect dominates the first). Also, the wages from each firm will be

$$\overline{w}_i^C = \frac{9(a+e)\gamma - ae^2}{18\gamma - e^2} \tag{22}$$

and the union's utility equal to:

$$\overline{U}_i^C = \frac{54(a-e)^2\gamma^2}{(e^2 - 18\gamma)^2} \tag{23}$$

3 Comparison

In this section I will compare the optimum results from the two cases. It is necessary to note that the results are positive for the given conditions of the models.

3.1 Firms' output (employment) and wages

Let's start from the firms' output (or employment). For the decentralised case the firms' output is $\overline{q}_i^D$ and for the centralised is $\overline{q}_i^C$ where the $\overline{q}_i^D > \overline{q}_i^C$. Then, the level of the production under the bargaining at the firms' level is higher than under the single industry-wide union bargaining.[19] From the employees' viewpoint the level of the employment is higher under the decentralised structure than under centralisation which is a typical result in the case of the bargaining over wages (RTM).

Moreover, another typical result is the higher level of wages under centralisation compared to the decentralisation structure ($\overline{w}_i^C > \overline{w}_i^D$).[20] However, the unions are characterised by a risk-averse utility, thus, they care for the number of employees (which is the same with the output) as well as for the level of the wages. These objectives are obvious through the use of comparative statics. Specifically, under decentralisation there is the same critical value of the damage parameter $e_{cv}^D = \frac{1}{14}(14a - \sqrt{7}\sqrt{28a^2 - 405\gamma})$ for the case of the optimum decentralised wages and output (employment). Particularly, for $0 < e < e_{cv}^D$, the optimum wages are increasing but the optimum output is decreasing in the parameter e and for $e_{cv}^D < e < a$ the wages are decreasing and the production (or employment) is increasing in e.[21] Simply there is an inverse U-shape relation between wages and the damage parameter and a U-shape between output (employment) and the parameter e as it is shown

[19] After the calculation of the difference between $\overline{q}_i^D - \overline{q}_i^C$ and solving with respect to e^2/γ the result is $\overline{q}_i^D > \overline{q}_i^C$ if $e^2/\gamma < 67.5$ but from the conditions e^2/γ is always less than 9, thus the decentralised optimum output is higher than the centralised output.

[20] The centralisation gives more bargaining power to the union to set higher wages as a monopolist in the labour market.

[21] For the case of the decentralisation the derivatives of the optimum output and wages with respect to damage parameters respectively are $\frac{\partial \overline{q}_i^D}{\partial e} = \frac{90(56ae - 28e^2 - 405\gamma)\gamma}{(28e^2 - 405\gamma)^2}$, $\frac{\partial \overline{w}_i^D}{\partial e} = \frac{270(28e^2 - 56ae + 405\gamma)\gamma}{(28e^2 - 405\gamma)^2}$. Also for the case of the centralisation the critical values of the damage parameter is $e_{cv}^C = a - \sqrt{a^2 - 18\gamma}$.

in the next figures.

Figure 1: U-shape between $\overline{q}$ and e

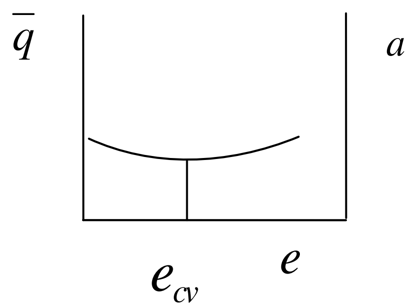
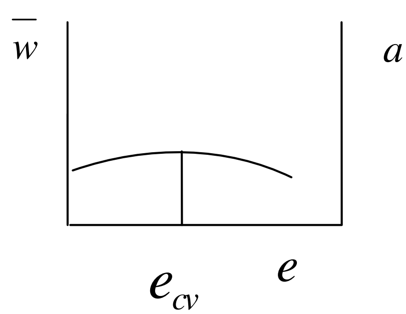


Figure 2: Inverse U-shape between $\overline{w}$ and e



The intuition behind this is that, on the one hand the increasing of the damage parameter for values less than the critical drives the unions to set higher wages but then the firms in order to deal with the higher labour costs, will produce less ($\frac{\partial q_i^*}{\partial w_i} < 0$). Hence the level of employment is reduced. On the other hand, the unions in order to raise the number of employees (under the threat of higher unemployment) and for values of the damage parameter higher than the critical, will reduce the level of wages. Then the firms will gain from the lower labour cost and will produce more, thus the level of the employment is increasing.[22]

[22] See also Booth (1995) for more detail analysis on the unions' possible utilities.

Proposition 4 *a) The output (employment) is higher under the decentralised structure than under the centralised but the wages are higher under the centralised structure. b) The optimum wages and output (employment) are characterised by an inverse U-shape and an ordinary U-shape relation respectively with respect to the values of the damage parameter.*

3.2 Profits and unions' utility

Also the firms' profits are higher under decentralisation than under the centralised case. Therefore $\overline{\Pi}_i^D > \overline{\Pi}_i^C$ for each $e^2 < 9\gamma$.[23] So, according to the results, the firms prefer bargaining over the wages with the unions at firm level rather than under the single centralised union.

However the unionised structure offers higher level of utility to the union (or to the organised workers) than the decentralised structure. Specifically, $\overline{U}_i^C > \overline{U}_i^D$ so, in this case, the unions have reasons to prefer one, single and centralised union, than two different unions, in order to bargain with the firms for the level of wages.

Proposition 5 *The firms prefer the decentralised structure where the profits are more but the unions prefer the centralised structure where the utility is higher.*

3.3 Technology and emissions

After some necessary calculations I obtain that the decentralised optimum technology $\overline{k}_i^D$ is always lower than the centralised optimum technological choice $\overline{k}_i^C$ for the given common conditions of the two models. Therefore the firms' technological choice under the decentralised unions is greener than the optimum technology under the case of the single union.

[23] The decentralised profits are higher than the centralised for $e^2/\gamma < 44.05$ but from the conditions $e^2/\gamma < 9$.

Proposition 6 *The firms' technological choice is more green- less polluting- under decentralisation than under the industry-wide union.*

Actually the centralised structure, with wage discrimination, discourages the firms to adopt a better technology and they prefer a more polluting technology. Therefore, any movement, or change in the institutions of the labour market, from decentralisation to centralisation will drive the firms to adopt a worse (more polluting) technology.

Additionally, I compare the level of the emissions from each firm under the case of the decentralised and centralised union structure. Interestingly, the result depends on the size of the market. In particular, for market's size less than $35\gamma A/eB$ where $A = (501.6\gamma^2 - e^2(e^2 + 14.86))$ and $B = (e^3(e - 135\gamma) + 1930.9e\gamma^2)$, the level of the emissions under the centralised structure is less than under the decentralised. However, for size of the market higher than $35\gamma A/eB$, the emissions are lower under decentralisation compared to the emissions from the cenralised case. Thus, for relatively low market's size, the pollution at industry level is lower under the industry-wide union and for the opposite case the opposite holds.

Proposition 7 *The level of the emissions is lower under the centralised union than under the decentralised for relatively low market's size. For relatively higher market's size (higher than* $35\gamma A/eB$*) the decentralised structure provides the lower level of emissions.*

3.4 Simulations

In this subsection I calibrate the results in order to focus on the influence of the market's size on the level of the firms' emissions. Specifically, for the same and given values of the parameter e and γ a small change in the market's size can change significantly the optimum results. In the next two tables are included the numerical results for the case of the two union structure (decentralised and centralised) when the size of the market changes from 7 to 6 and for values of damage parameter equal to 4 and for parameter γ equal to 2. [24]

Table 1: Simulations under relatively small size of the market

$a = 6$, $e = 4$, $\gamma = 2$	Decentralised	Centralised
$\overline{k}$	0.38	0.6
$\bar{q}$	0.99	0.6
$\overline{\Pi}$	0.22	0.04
$\overline{y}$	0.379	0.36
$\overline{w}$	0.3	4.2
$\overline{U}$	1.48	2.16

Table 2: Simulations under relatively large size of the market

$a = 7$, $e = 4$, $\gamma = 2$	Decentralised	Centralised
$\overline{k}$	0.07	0.4
$\bar{q}$	1.49	0.9
$\overline{\Pi}$	0.50	0.09
$\overline{y}$	0.107	0.36
$\overline{w}$	2.52	4.3
$\overline{U}$	3.33	4.86

It is obvious that for relatively small market's size (table 1, $a = 6$), under the centralised structure the level of the emissions ($\overline{y} = 0.36$) is lower than under the decentralised case ($\overline{y} = 0.379$). However, in the second case (table 2) where the size of the market is larger than before ($a = 7$), under decentralisation the firms will pollute less than under the centralised structure. Therefore, if the only objective of the decision maker is the reduction of the emissions, then he prefers different union structure, according to the size of the market. Hence, if it is possible to change the institutions in the labour market, then the regulator prefers any change from large market's

[24] The specific values can satisfy the conditions of the two models.

size to small to be accompanied with a transformation from decentralised to centralised union structure.

4 Discussion and conclusions

In this paper I have examined how the different union structures (centralised and decentralised) could influence the firms' environmental technological choice when the unions care for environmental protection. Specifically, I assume that the unions focus not only on the level of wages and employment but also on the reduction of the emissions which emanate from the firms' production as a by-product result.

The results with respect to the firms' profitability and unions' wages reconfirm the theoretical and empirical results from previous studies. Particularly, the survey from Menezes-Filho and Van Reenen (2003) expressly describes the previous argument "Unions have a clear positive effect on wages and a clear negative effect on profitability" p.26.

Additionally, the centralised (higher unionisation) structure, compared to the decentralised, discourages the firms' adoption (or innovation) of a better technology. This result agrees with the analogous results from the North America studies (see Menezes-Filho and Van Reenen, 2003).

Moreover, in addition to the literature, I focus on the trade unions' structures effect on the level of the emissions. I argue that, the centralisation could lead to lower level of pollution compared to the decentralisation for relatively low size of the market. However, for relatively higher market's size the decentralised structure could reduce the level of the firms' pollution more than the centralised case. This issue has been neglected by the empirical and theoretical studies (according to my knowledge) and therefore further investigation may be reasonable.

Besides, there is an inverse U-shape relation between i) the level of pollution and the size of the market and between ii) the optimum wages and the damage parameter. Also, a U-shape exists between the optimum output (employment) and the value of the damage parameter. Furthermore, the union(s) set(s) higher level of wages the more polluting the firm's technology is.

Finally, if the regulator's objective is the reduction of the firms' pollution then, he prefers a change in the union structure from decentralised to centralised, when the size of the market is relatively small. However for large market's size, the decentralisation is preferable with respect to the environmental protection.

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