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Abstract

We consider a Cournot duopoly consisting of two geographically separated firms, each associated with a local environmental-friendly trade union that exhibits climate solidarity. In the basic model, firms choose abatement technologies prior to bargaining over wages and employment with the unions. We show that the trade unions would lower the wage with the degree of reciprocal solidarity, providing additional incentives for firms to adopt greener technology and hence improving the social welfare. In the alternative model where trade unions decide the wages prior to the firms' abatement and employment decisions, the firms always choose the dirtiest available technology while output will increase with the degree of solidarity. These results suggest that establishing the social norm and practice of reciprocal solidarity across trade unions in appropriate manner will help the internalisation of global environmental issues, which could mitigate the global regulation difficulties that require strong cross-border coordination among governments.

Keywords: green trade unions, reciprocity, climate solidarity, emissions, environmental technology

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1. Introduction

The cross-border cooperation of trade unions has been long studied in the literature (*e.g.*, Driffill and Van de Ploeg, 1993; Gordon and Turner, 2000). The choices and consequences of transnational trade union solidarity actions have been extensively discussed particularly in the context of multinational firms and/or labour equality issues across countries (*e.g.*, Gajewska, 2009; Greer and Hauptmeier, 2008 and 2012; Fougner and Kurtoğlu, 2011; Dufour Poirier and Hennebert, 2015).

The political challenges of the global coordination on climate change has been increasingly recognised and particularly escalated after the current US administration announced its withdrawal from the Paris Agreement. At the same time, there is a growing discussion on the strategic engagement of trade unions in issues such as the climate change and environmental protection (*e.g.*, Felli, 2014; Stevis and Felli, 2015). Some voices calling for climate solidarity among trade unions have been raised to deal with the social and environmental problems (*e.g.*, Hampton, 2015; Brecher, 2018). Examples of labour organizations that characterised by climate solidarity are the Trades Union Congress (TUC)[2] and the International Trade Unions Confederations. [3]

Historically, trade unions collaborate with environmental groups for the protection of the environment and they react together against to the environmental degradation. Studies highlighting the trade unions' interest for environment protection and collaboration with environmental groups include, among others, Truax, (1992), Gordon, (1998), Dewey, (1998), Obach, (1999, 2002, 2004), Bonanno, and Blome, (2001), Silverman, (2004, 2006), Mayer, (2009), Snell, and Fairbrother, (2010).

This paper proposes a theoretical model to explain how the climate solidarity between trade unions can affect firms' choice of anti-pollution technology, the market outcome and the social welfare. We introduce two geographically distinct firm-union pairs where, as an expression of climate solidarity between the trade unions, each union cares both about the environmental degradation on its own turf and the environmental damages suffered by the members of the other union. Therefore, the trade unions are characterised by climate solidarity with respect to the environmental degradation and pollution. This could be the case of a home and a foreign firm-union pair where each firm pollutes at a local level and each

[2] https://www.tuc.org.uk/sites/default/files/extras/greener_deals.pdf
[3] https://www.ituc-csi.org/IMG/pdf/climat_EN_Final.pdf

trade union cares for the level of the environmental damage in both countries (*i.e.*, transnational climate solidarity)

The impact of trade unions on firms' technological choice and/or innovation has been explored in Dowrick and Spencer, (1994), Tauman and Weiss, (1987), Ulph and Ulph, (1988, 1989, 1994, 1998 and 2001). However, with the exception of the study by Asproudis and Gil Molto (2015), the impact of trade unions on firms' anti-pollution or environmental technology choice has been overlooked. This paper extends the work of Asproudis and Gil Molto (2015) (A&GM hereafter) who embedded the environmental concerns of the local trade union into the wage bargaining process with a local firm, where the firm is a competitor in a Cournot duopoly. More specifically, A&GM assumes that the utility of the local trade union is negatively affected by the emissions of the local firm. .

Following the well-established literature, we adopt the Monopoly Union model which is part of the Right to Manage approach for the wage bargain process within each firm-union pair (see for example Oswald, 1982; Petrakis and Vlassis, 2004; Nickell and Andrews, 1983; Espinosa and Rhee, 1989; Booth, 1995; Lopez and Naylor, 2004 and Mukherjee, 2008). Moreover, each firm is solely responsible for choosing an appropriate abatement technology. We distinguish two different timing frames. In the basic model (BM), the firms choose abatement technology prior to the bargaining process with their respective union: In the first stage, the firms decide the abatement technology; in the second stage, trade unions decide the wages; in the third stage the firms decide the production level. This can be the case where the choice of abatement technology implies changes in the production method. For example, an electricity industry can choose a different mode to generate power to reduce the greenhouse gas emission and hence improve the workers welfare.

We show that in the basic model the wages demanded by the trade union is decreasing with the degree of the reciprocal climate solidarity. This provide sufficient cost-competitive incentives for the local firm to adopt greener abatement technology and yields higher output (and hence employment) and social welfare. Moreover, the degree of reciprocal climate solidarity leads to greener abatement technology choice in equilibrium than the one chosen in the world where trade unions only care about the local pollution. These results suggest that establishing the social norm and practice of reciprocal climate solidarity across trade unions will help the internalisation of global environmental issues within the ordinary individual business competitions, which could mitigate some current regulation difficulties (such as cross-border tax and transfers on emissions and pollutions) that require strong cross-border coordination among governments.

On the other hand, the effectiveness of reciprocal climate solidarity on abatement technology adoption depends on the appropriate incentive design. In the alternative model (AM) we assume that the trade unions decide the wages prior to the firms' decision on abatement technology and employment: In the first stage, the trade unions decide the wages; in the second and the third stage, firms decide the abatement technology and the production level, respectively. This can be the case where the choice of abatement technology does not imply changes in the production method. For example, a refinery firm adopts finer filters in the pipe (i.e. less substantial green technology adoption). We show that, in this case, the firms' choices of abatement technology are not responsive to the wage-employment bargains.

In other words, BM is the case where a firm can commit to an abatement level, whereas AM is where there is no such commitment. As a consequence, in BM, technology is a truly strategic variable (i.e., firms recognise it as a vehicle to influence the unions' choices of wages), whereas AM is equivalent to a model where technology is exogenous.

Comparing the different timing frames, we show that, in both the BM and the AM wages decrease and production increases with the intensity of trade union climate solidarity. However, the effect of trade union climate solidarity on wages and output is stronger in the BM. Moreover, in the BM the abatement technology improves with the intensity of trade union climate solidarity while in the AM the firms will choose the dirtiest available technology irrespectively of the degree of trade union climate solidarity. Lower environmental damages and greater production in the BM compared to the AM are sufficient to ensure that in the BM the social welfare in greater than in the AM. From a regulatory perspective, environmental regulation must be stricter in industries where the firms invest in abatement technology after the green trade unions decide the wages.

The rest of the paper is organised as follows: in section two, the basic and the alternative model are developed. In section three, the results of the two models are compared. Finally, section four concludes.

2. The basic model

Following A&GM we consider two geographically separated unionized firms $i, j = 1,2$ with $i \neq j$, producing a homogeneous product that is sold in a single market. The inverse demand function is $p = a - q_i - q_j$ where $a > 0$ is the market size parameter, and

q_i, q_i are the firms outputs. Production processes are characterized by constant returns to scale described by $q_i = L_i$, where L_i represents the number of workers employed by firm i. Each firm's cost is given by $C_i = w_i L_i + \gamma(1-k_i)^2$, where w_i denotes the wage of firm i, $k_i \in (0,1]$ is a technology index, and $\gamma > 0$ is a scale parameter. This cost represents diminishing returns to investment in abatement technology.[4] The closer to one the value of technology k_i is, the lower the adoption cost and the more polluting the technology will be. Therefore, the corresponding profits are $\pi_i = (a - q_i - q_j)q_i - w_i q_i - \gamma(1-k_i)^2$.

The production process generates emissions, y_i, according to $y_i = k_i q_i$.[5] Each trade union cares about environmental quality at both locations. Therefore, trade union i's perceived damage from pollution is denoted by $(DF_i + zDF_j) = (ey_i + zey_j)$, where $z \in [0,1]$ represents the degree of climate solidarity of trade union i, and $e > 0$ is a scale parameter.[6] Furthermore, a trade union cares about the well-being of its members as it is expressed by the over-the-outside-option aggregate earnings from being employed by the respective firm. If w_0 denotes the reservation wage these earnings are denoted by $(w_i - w_0)L_i$. In summary, the utility of trade union i can be expressed by $U_i = (w_i - w_0)L_i - (DF_i + zDF_j)$. For simplicity, for the remainder of this paper we have set the reservation wage equal to zero.

After proper substitutions and some slight modifications the trade unions utility is expressed by $U_i = L_i[w_i - (ek_i + zek_j)] - ze(L_j - L_i)k_j$.[7] The first term on the right-hand side shows that the trade unions utility increases with improvements in abatement technologies adopted by either of the two firms. The second term on the right-hand side expresses the competition effect showing the utility of trade union i's is decreasing in the difference between outputs of firms j and i.

Adopting the Monopoly Union model, we assume that the trade unions decide the wages while the firms decide the number of workers to be employed.

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[4] This type of the technology could include the filters for the reduction of CO_2 or 'scrubbers' for the reduction of SO_2 emissions. For more details see Chao and Wilson (1993).

[5] Hence, contrary to Puller (2006), an emission reduction is not only driven by an improvement in abatement technology but also by a reduction in output.

[6] Our model restrictions also require that $a > e$.

[7] $U_i=L_i\ [w_i- (w_o +ek_i)] -zeL_jk_j$ which we could rewrite to $L_i\ [w_i- (w_o +ek_i)] -ze(L_i - L_i +L_j)k_j =L_i\ [w_i- (w_o +ek_i)] -zeL_i k_j - ze(L_j -L_i)k_j = L_i\ [w_i- (w_o +ek_i + ze\ k_j)] - ze(L_j -L_i)k_j$.

2.1 Stage Three: Firms decide the production level

In the third stage, the firms decide their production levels. Assuming Cournot-type competition, the profit maximizing production levels, as it has been shown in A&GM, are

$$\hat{q}_i = L_i = \frac{a-2w_i+w_j}{3} \tag{1}$$

Therefore, the profits are $\hat{\pi}_i = \hat{q}_i^2 - \gamma(1-k_i)^2$.

Substituting the optimal quantity in the trade union's utility competition effect described earlier, yields $ze(w_i - w_j)k_j$. Thus, the relative production advantage of firm *j* to firm *i* is equal to the wage differential $(w_i - w_j)$. In other words, the trade unions are facing a trade-off between environmental protection and higher wage.

2.2 Stage two: Trade unions decide the wages

On stage two, the trade unions simultaneously decide the wages. After the necessary substitutions and calculations, the utility maximization problem for each trade union becomes

$$\max_{w_i}\left\{U_i = \frac{1}{3}(w_i - ek_i)\left(a - 2w_i + w_j\right) - ek_j\left(a - 2w_j + w_i\right)z\right\} \tag{2}$$

Taking the first order conditions of the maximization problem above yields the reaction function of each trade union that is its own wage as a function of the other union's wage:

$$w_i^{rf} = \frac{1}{4}\left(a + 2ek_i + w_j - ek_j z\right) \tag{3}$$

We observe that $\partial w_i^{rf}/\partial w_j > 0$, implying that the wages are strategic complements. The intuition of the strategic complementarity between the trade unions has been explained in Petrakis and Vlassis (2004), if the union *j* sets higher wages, the level of the output of firm *j* will decrease but firm *i* will produce more. This induces union *i* to set higher wages to firm *i* when the rival firm deals with higher wages from the union *j*. See also, Asproudis and Gil Molto (2015) for a similar result. Interestingly, since $\partial w_i^{rf}/\partial z < 0$, a trade union becomes less aggressive in the bargaining process with the degree of its climate solidarity. Intuitively, for any given wage trade union j chooses, union i reduces its own wage to strengthen firm i's competition effect. This drives firm i's output higher and firm j's output and, *ceteris paribus*, emissions lower.

Solving simultaneously the reaction functions of the trade unions yields the equilibrium wages[8]

[8] The SOC is negative and equal to -4/3.

$$w_i = \frac{1}{15}\left(5a + e\left[k_i(8-z) + 2k_j(1-2z)\right]\right) \quad (4)$$

Like in A&GM, $\partial w_i/\partial k_i > 0$, implying the wage chosen by union i decreases with improvements in abatement technology adopted by firm i. Moreover, we see that $\partial^2 w_i/\partial k_i \partial z = -e/15 < 0$. Thus, the more intense the climate solidarity is, the lower the trade union's incentive to penalize its respective firm for choosing dirtier technology.

However, contrary to A&GM the wages do not always increase with the rival firm's abatement technology: as $\partial w_i/\partial k_j = e(2-4z)/15$ it all depends on the level of the reciprocity. Hence, $\forall z \in [0, 1/2]$ a wage is increasing with the rival firm's abatement technology, while the opposite holds for $z \in [1/2, 1]$. Finally, as $\partial w_i/\partial z = -\frac{1}{15}e\left(k_i + 4k_j\right) < 0$, the wages are decreasing with the intensity of climate solidarity.

To compare our results with the results of A&GM where z=0, we can rewrite the wage as

$$w_i = \frac{1}{15}\left(5a + e\left[(8-z)\left(k_i + \frac{k_j}{4}\right) - k_j\left(\frac{7}{4}z\right)\right]\right)$$

The first part in the square brackets $e(8-z)\left(k_i + k_j/4\right)$ is always consistent with the predictions of A&GM, (*i.e.*, $\partial w_i/\partial k_i > 0$ and $\partial w_i/\partial k_j > 0$). The second part in the square brackets, $-k_j(7z/4)$, negatively contributes to the equilibrium wage (i.e. $\partial w_i/\partial k_j < 0$) when $z > 0$. This effect increases in magnitude with z and k_j. This is consistent with the cost-competition effects as noted in Stage Three, which serves as sufficient incentive offered by trade unions to the firms for adopting better abatement technology in Stage One. Moreover, we can calculate the quantity competition effect by substituting the wage as expressed in equation (4) in equation (1). This yields the difference $q_j - q_i = e(\mathrm{k}_i - \mathrm{k_j})(2+z)/5$. This implies that the relative production advantage of firm i to firm j is negatively linked to the improvements in abatement technology chosen in Stage One.

2.3 Stage 1: Firms decide abatement technology

In the first stage, the firms choose the abatement technology. After substituting (4) in (1) we get

$$\bar{q}_i = \frac{1}{45}\left(10a + e\left[k_j(4+7z) - 2k_i(7+z)\right]\right) \quad (5)$$

Like in A&GM the production is increasing with improvements in own abatement technology ($\partial \bar{q}_i/\partial k_i < 0$) and decreasing in improvements of the rival's abatement technology ($\partial \bar{q}_i/\partial k_j > 0$).

Profit maximization is expressed as

$$\max_{k_i}\{\bar{\pi}_i = \bar{q}_i^2 - \gamma(1-k_i)^2\} \quad (6)$$

and solving simultaneously the resulting FOCs for $i = 1,2$ yields optimal technologies[9] and, through proper substitutions, optimal output and wages:

$$k_i^* = \frac{405\gamma - 4ae(7+z)}{405\gamma + 2e^2(z-2)(7+z)} \quad (7)$$

$$q_i^* = \frac{45\gamma[2a + e(z-2)]}{405\gamma + 2e^2(z-2)(7+z)} \quad (8)$$

$$w_i^* = \frac{135\gamma[2a + e(z-2)]}{405\gamma + 2e^2(z-2)(7+z)} \quad (9)$$

Like in A&GM our model yields $\partial k_i^*/\partial \gamma > 0$, $\partial k_i^*/\partial a < 0$, $\partial q_i^*/\partial \gamma > 0$ and $\partial q_i^*/\partial a > 0$. However, $\forall a > 0, e > 0, \gamma > \frac{4e^2(7+z)^2}{2025}, 0 \leq z \leq 1$ we have that $\partial k_i^*/\partial z < 0$. Hence, the firms' abatement technology improves with the intensity of climate solidarity. In particular, this equilibrium abatement technology is a greener choice than the de-centralised equilibrium without reciprocal solidarity (i.e. z=0). Moreover, output increases with the intensity of climate solidarity ($\partial q_i^*/\partial z > 0$). Intuitively, when the optimal abatement technology increases with the intensity of climate solidarity the firm can benefit from the reduction on its own emissions and produce more. With respect to the wages we get $\partial w_i^*/\partial z < 0$, implying that wages are decreasing with the intensity of climate solidarity.

Result 1: In the Basic Model, the wages are decreasing, outputs and employment are increasing, and abatement technology is more environmental friendly with the intensity of climate solidarity.

Finally, we can calculate profits, emissions, trade union utility, and social welfare. The profits are

$$\pi_i^* = \frac{\gamma[2a + e(z-2)]^2[2025\gamma - 4e^2(7+z)^2]}{[405\gamma + 2e^2(z-2)(7+z)]^2} \quad (10)$$

The level of the emission from each firm is

$$y_i^* = \frac{45\gamma[2a + e(z-2)][405\gamma - 4ae(7+z)]}{[405\gamma + 2e^2(z-2)(7+z)]^2} \quad (11)$$

[9] The SOC is negative for $\gamma > \frac{4e^2(7+z)^2}{2025}$. Therefore, hereafter we assume that this restriction applies.

Like in A&GM there is a critical value which determines if the emissions are increasing or decreasing in the size of the market. Specifically the critical value is $a_{cv} = -\frac{1}{4}e(z-2) + \frac{405\gamma}{8e(7+z)}$ which is positive for $0 < z < 1$ where $\frac{\partial y_i^*}{\partial a} > 0$ if $0 < a < a_{cv}$ and $\frac{\partial y_i^*}{\partial a} < 0$ if $a_{cv} < a$.

Additionally, the damage function is $DF_i^* = ey_i^*$ and the Utility is

$$U_i^* = \frac{135\gamma[2a+e(z-2)][a(45\gamma+2e^2z(7+z)-45e\gamma(1+4z)]}{[405\gamma+2e^2(z-2)(7+z)]^2} \quad (12)$$

where for $0 < a < a^{cv}$ the utility is reducing in the market size and for $a > a^{cv}$ it is increasing in a with $a^{cv} = \frac{-2e^3(z-2)z(7+z)+45e\gamma(4+7z)}{180\gamma+8e^2z(7+z)}$. Finally, the SW[10] is

$$SW^* = \frac{2\gamma[2a+e(z-2)](a[14175\gamma+2e^2z(7+z)(41z-28)]-e(7+z)[2025\gamma+4e^2(z-2)(7+z)])}{[405\gamma+2e^2(z-2)(7+z)]^2} \quad (13)$$

Non-negativity of the above results requires that $a > (1/5)(e(7+z))$.

2.4 The alternative model

We change the timing of the model in order to explore the case where the trade unions decide the wages prior to the firms' decisions on employment and abatement technology: in the first stage trade unions decide the wages; in the second stage firms decide the abatement technology; in the third stage the firms decide the output. The third stage is no different between the two models, hence it is omitted here.

2.5 Stage two: firms decide the abatement technology

Provided the optimal choice of output and employment in the third stage, *i.e.*, $\hat{q}_i = L_i = (a - 2w_i + w_j)/3$, the profit maximization problem of firm i in the second stage is

$$\max_{k_i}\left\{\hat{\pi}_i = (a - 2w_i + w_j)^2/9 - \gamma(1-k_i)^2\right\}$$

Clearly, in the above problem the optimal choices of abatement are $k_i = k_j = 1$. Hence, when the trade unions decide the wages prior to the firms' decisions on the abatement technology,

[10] The formula of the SW = CS + PS + U_I^* + U_j^* + zDF_i^* + zDF_i^*

the firms adopt the more polluting technology. Simply, the trade unions do not have the power to influence the firms' choice of technology when the decision on the wages is a long-run commitment, stronger than the commitment on the abatement technology. From a regulatory perspective, environmental regulations must be stricter in industries characterized by long-term wage contracts and short-lived investments in abatement technology. In other words, the timing of the negotiations could be very important on the efficiency of chosen environmental policies.

Result 2: When the trade unions decide the wages prior to firms' decisions on abatement technology, the firms adopt the most polluting technology.

Finally, given the optimal choice of abatement of the firms in the second stage, profits be $\hat{\pi}_i = \left(a - 2w_i + w_j\right)^2/9$ and the emissions equal $\bar{y}_i = \left(a - 2w_i + w_j\right)/3$ so the damage function is given by $DF_i = e\left(a - 2w_i + w_j\right)/3$.

2.6 Stage one: Trade unions set the level of the wages

Substituting the results of stages three and two in the utility function of trade union i, the utility maximization problem of the union becomes

$$\max_{w_i}\left\{U_i = \frac{1}{3}(w_i - e)\left(a - 2w_i + w_j\right) - e\left(a - 2w_j + w_i\right)z\right\}$$

Taking the first order conditions yield the reaction function $w_i^{rf} = \left(a + 2e + w_j - ez\right)/4$. Solving simultaneously the two reaction functions yields the optimal wages

$$w_i^* = [a - e(z - 2)]/3 \tag{14}$$

Hence, output and emissions are

$$q_i^* = y_i^* = [2a + e(z - 2)]/9 \tag{15}$$

So, the damage function is $DF_i = e[2a + e(z - 2)]/9$. The price is $p_i^* = [5a + 2e(z - 2)]/9$ and the profits are

$$\bar{\pi}_i^* = \bar{q}_i^{*^2} = [2a + e(z - 2)]/81 \tag{16}$$

Finally, the trade unions utility after the substitutions equals

$$U_i^* = [2a + e(z - 2)][a - e(1 + 4z)]/27 \tag{17}$$

Similarly, with the basic model the Social Welfare is given by

$$SW^* = 2[2a + e(z-2)][7a - e(7+z)]/81 \quad (18)$$

3 Comparisons

In this section we compare the results of the two models. The superscripts BM and AM are used to indicate the results of the basic and the alternative model, respectively. With respect to differences in the choice of abatement technology, output and employment, wages, and prices we state the following

Result 3: Let $z \in (0,1), a > e(7+z)/5$ *and* $\gamma > 4e^2(7+z)^2/2025$. *Then firms in the BM choose greener technology, produce more output, pay lower wages, and charge less compared to firms in the AM, i.e.,*

(a) $k^{BM} - k^{AM} < 0$

(b) $q^{BM} - q^{AM} > 0$

(c) $w^{BM} - w^{AM} < 0$

(d) $p^{BM} - p^{AM} < 0$

Intuitively, when a firm's abatement choice precedes the decision over wages and employment, environmental-friendly trade unions can give a leeway to the firms by accepting lower wages provided that the firms will abate more. Lower wages will lead to higher employment, hence higher output and lower prices in the market. When a firm's abatement choice follows the decision over wages this trade-off (*i.e.*, lower wages in return for more abatement) is not available due to a commitment issue: given that wages have been determined in a previous stage, firms have no incentive to adopt costly abatement technologies. Since the trade unions know that, they will set a higher wage (leading to lower output and employment) compared to the case where there is no such a commitment issue.

Provided that both abatement and production are stronger in the BM than in the AM one cannot be sure about the difference in emissions between the two models: the former reduces emissions while the latter increases them. It is shown that the abatement effect overcomes the output effect on emissions if the market is sufficiently large. Therefore, with respect to differences in emissions we state the following

Result 4: Let $z \in (0,1), a > e(7+z)/5$ *and* $\gamma > 4e^2(7+z)^2/2025$. *Then firms in the BM pollute less compared to firms in the AM provided that the size of the market is sufficiently large, i.e.,*

$$y^{BM} - y^{AM} < 0 \ \ if\, a > \frac{e(z-2)(405\gamma + e^2(z-2)(7+z))}{405\gamma}.$$

Finally, with respect to differences in firms' profits, unions' utilities, and social welfare we state the following

Result 5: Let $z \in (0,1), a > e(7+z)/5$ *and* $\gamma > 4e^2(7+z)^2/2025$. *Then, compared to the AM, in the BM unions enjoy higher utility, firms earn higher profits, and the society achieves higher welfare, i.e.,*

(a) $U^{BM} - U^{AM} > 0$
(b) $\pi^{BM} - \pi^{AM} > 0$
(c) $SW^{BM} - SW^{AM} > 0$

Table 1 below summarizes the findings described in *Results 3-5*.

Table 1: Comparisons between the BM and the AM results

Technology	$k^{BM} < k^{AM}$
Production	$q^{BM} > q^{AM}$
Wages	$w^{BM} < w^{AM}$
Utility	$U^{BM} > U^{AM}$
Price	$p^{BM} < p^{AM}$
Profits	$\Pi^{BM} > \Pi^{AM}$
Social Welfare	$SW^{BM} > SW^{AM}$
Emissions	$y^{BM} \leq or \geq y^{AM}$

4 Conclusions

The paper studies how trade unions' climate solidarity or solidarity on environmental issues can eventually influence firms' choices of anti-pollution technology. Trade unions suffer from environmental degradations incurred by members of both trade unions but can influence their firm's technological choice, through the decision for the level of the wages.

Specifically, we are considering a Cournot duopoly consisting of two geographically separated firms where each firm is paired with a local environmental-friendly trade union. The trade unions are characterized by climate solidarity, *i.e.*, they care about the emissions at both locations. Firms at both locations have access to a wide range of abatement technologies. We adopt a Monopoly Union model where the trade unions decide the wages and the firms decide the employment level. We compare two models that differ in the timing of decision on wages and technological choices.

We showed that, under the basic model, where technological choices are made prior to trade unions decision on wages, firms will adopt greener technology under the culture with greater reciprocal climate solidarity between trade unions. This is incentivised by the subsequent lower wages offered by trade unions that could further enable higher employment and production output. Under this equilibrium, the abatement technology chosen by the firms is greener than the one chosen under the de-centralised equilibrium where trade unions only consider the local pollutions. This implies that well-established reciprocal climate solidarities between trade unions will contribute to additional enhancement for the adoption of better abatement technology that can also lead to higher social welfare (higher employment and production).

From policy perspective, the inter-governmental coordination on climate change issues have become increasingly difficult as it is often argued to limit the competitiveness of domestic firms and sometimes discourage local employment, whereas the social norms of being environmental considerate have been widely accepted across societies. Hence establishing the reciprocal climate solidarities across trade unions would be a good step of progression and could help internalise the environmental issues within the industry competitions.

On the other hand, it is important to note that the effectiveness of the reciprocal climate solidarity depends on the mechanism design. We showed that under the alternative model, where trade unions set the wages first, the firms will adopt the dirtiest technology available and the total social welfare is lower. In this case the trade unions cannot influence the firms' decision in order to choose greener technology so that even the local environmental concerns are undermined. In practical sense, embedding climate solidarity extends the objectives of trade unions in the wage process. For sectors with long-term rigid wage contract or weak power of trade union, the decision of adopting abatement technology will simply matter as cost-advantage on the supply side of the economy. The environmental regulations must be required fully in place and strict from regulatory institutions. In contrast, when regulators are facing coordination challenges across the boarders or directly with local firms, they can enhance the establishment of the reciprocal climate solidarity between trade unions so that the environmental accountability of firms' technology investment can be achieved internally.

References

Asproudis, E. and Gil-Molto, M. (2015). Green trade unions: Structure, wages and environmental technology. *Environmental and Resource Economics,* 60, 165-189.

Booth, A. L. (1995). The economics of the trade union. Cambridge University Press, Cambridge

Bonanno, A. and Blome, B. (2001). The environmental movement and labor in global capitalism: Lessons from the case of the Headwaters Forest. *Agriculture and Human Values*, 18, 365-381.

Brecher, J. (2018). Climate solidarity: Workers versus warming. *New Labor Forum*, 27, 96-104.

Chao H-P. and Wilson, R. (1993). Option value of emission allowances. *Journal of Regulatory Economics*, 5, 233-249.

Dewey, S. (1998). Working for the environment: Organized labor and the origins of environmentalism in the United States: 1948-1970. *Environmental History*, 1, 45-63.

Dowrick, S. and Spencer, B. J. (1994). Union attitudes to labor-saving innovation: When are unions luddites? *Journal of Labor Economics,* 12, 316-344.

Driffill, J. and van der Ploeg, F., (1993). Monopoly unions and the liberalisation of international trade. *Economic Journal,* 103, 379-385.

Dufour Poirier, M. and Hennebert, M-A. (2015). The transnationalization of trade union action within multinational companies. *Economic and Industrial Democracy,* 36, 73-98.

Espinosa, M. C. and Rhee, C. (1989). Efficient wage bargaining as a repeated game. *Quarterly Journal of Economics*, 104, 565-588.

Felli, R. (2014). An alternative socio-ecological strategy? International trade unions' engagement with climate change. *Review of International Political Economy,* 21, 372-398.

Fougner, T. and Kurtoğlu, A. (2011). Transnational labour solidarity and social movement unionism: insights from and beyond a women workers' strike in Turkey. *British Journal of Industrial Relations,* 49, 353-375.

Gajewska, K. (2009). Transnational labour solidarity: Mechanisms of commitment to cooperation within the European trade union movement. London: Routledge.

Gordon, R. (1998). Shell No! OCAW and the labor-environmental alliance. *Environmental History*, 3, 460-488.

Gordon, M. and Turner, L. (Eds.). (2000). Transnational cooperation among labor unions. Ithaca, NY: Cornell University/ILR Press.

Greer, I. and Hauptmeier, M. (2008). Political entrepreneurs and co-managers: Labour transnationalism at four multinational auto companies. *British Journal of Industrial Relations*, 46, 76-97.

Greer, I. and Hauptmeier, M. (2012). Identity work: Sustaining transnational worker cooperation at GM Europe. *Industrial Relations,* 51, 275-297.

Hampton, P. (2015). Workers and trade unions for climate solidarity: Tackling climate change in a neoliberal world. Routledge, London.

Lopez, M. C. and Naylor, R. A. (2004). The Cournot–Bertrand profit differential: a reversal result in a differentiated duopoly with wage bargaining. *European Economic Review,* 48, 681-696.

Mayer, B. (2009). Cross-movement coalition formation: Bridging the labor-environment Divide. *Sociological Inquiry*, 79, 219-239.

Mukherjee, A. (2008). Unionized labour market and strategic production decision of a multinational. *Economic Journal,* 118, 1621-1639.

Nickell, S. and Andrews, M. (1983). Unions real wages and employment in Britain 1951-1979. *Oxford Economic Papers,* 35, 183-206.

Obach, B. K (1999). The Wisconsin labor-environmental network. *Organization & Environment*, 12, 45-74.

Obach, B. K (2002) Labor-environment relations: An analysis of the relations between labor unionists and environmentalists. *Social Science Quarterly*, 83, 82-100.

Obach, B. K. (2004). Labor and the environmental movement: the quest for common ground. MIT Press, Cambridge.

Oswald, A. J. (1982). The microeconomic theory of the trade union. *Economic Journal,* 92, 576-595.

Petrakis, E., and Vlassis, M. (2004). Endogenous wage-bargaining institutions in oligopolistic industries. *Economic Theory,* 24, 55-73.

Puller, S. (2006). The strategic use of innovation to influence regulatory standards. *Journal of Environmental Economics and Management,* 52, 690-706.

Silverman, V. (2004). Sustainable alliances: The origins of international labor environmentalism. *International Labor and Working-Class History*, 66, 118–135.

Silverman, V. (2006). Green unions in a grey world: Labor environmentalism and international institutions. *Organization & Environment*, 19, 191-213.

Snell, D., and Fairbrother, P. (2010). Unions as Environmental Actors. *Transfer: European Review of Labour and Research,* 16, 411-424.

Stevis, D. and Felli, R. (2015). Global labour unions and just transition to a green economy. *International Environmental Agreements: Politics, Law and Economics,* 15, 29-43.

Tauman, Y. and Weiss, Y. (1987). Labor unions and the adoption of new technology. *Journal of Labor Economics,* 5, 477-501.

Truax, H. (1992). Workers and environmental protection. *Environmental Action*, 24, 11-13.

Ulph, A. and Ulph, D. (1988). Bargaining structures and delay in innovations. *Scandinavian Journal of Economics,* 90, 475-491.

Ulph, A. and Ulph, D. (1989). Labor markets and innovations. *Journal of the Japanese and International Economies,* 3, 403-423.

Ulph, A. and D. Ulph (1994). Labor markets and innovation: Ex post bargaining. *European Economic Review,* 38, 195-210.

Ulph, A. and Ulph, D. (1998). Labour markets, bargaining, and innovation. *European Economic Review,* 42, 931-939.

Ulph, A. and Ulph, D. (2001). Strategic innovation with complete and incomplete labour market contracts. *Scandinavian Journal of Economics,* 103, 265-282.