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Social norms and the effect of unilateral actions on climate change

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Social norms and the effect of unilateral actions on climate change

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Abstract

We study the effect of a unilateral action on climate change when there is a social norm of emission abatement. We find a unilateral action can lead to emission abatement by the other country as well. We also find social welfare will increase if the leading country's marginal abatement cost is lower than the other country's.

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1 Introduction

To tackle the climate change problem, some countries take unilateral action in emission reduction. Examples include the joint declaration of China and the U.S. to reduce carbon emissions in 2015 before the Paris agreement and the EU's unilateral action in the Kyoto protocol. The reasons can include the desire to set a good example or emit a signal under asymmetric information about abatement cost or willingness to pay for climate damage (Brandt, 2004). The literature on unilateral action suggests it can either increase or decrease the abatement incentives of other countries through several mechanisms (Schwerhoff et al., 2017).

Herein we study the effect of unilateral action through a social psychology mechanism. Specifically, we extend the non-cooperative unilateral-action framework in Hoel (1991) by incorporating a behavioral dimension. Starting from a simultaneous-move Nash equilibrium with a preference for social-norm conformity, the expectation of unilateral action can cause the other country to reduce emissions as well so it can conform to the social norm. Global welfare increases if the country taking a unilateral action has an equal or lower marginal abatement cost compared to the other country. In contrast, Hoel (1991) finds unilateral action in the absence of an environmental agreement increases emissions by other countries and reduces total emissions at best, compared to when both countries act selfishly[1]. The different results reflect that, in the present model, the countries are sensitive to international social norms. The appendix shows that social norms also increase the probability that total emissions decrease in Hoel (1991) cooperative bargaining model.

2 Non-cooperative games

Assume there are two countries, $i = 1, 2$ each country's CO_2 abatement is X_1 and X_2. Given country 2' s abatement X_2, country 1 solves

$$MaxB_1(X_1 + X_2) - C_1(X_1 - N) \tag{1}$$

Where $N = (1 - \alpha)P + \alpha S$, and $S = \frac{X_1+X_2}{2}$. P is each country's own or "personal" norm about the amount of abatement. S measures the common social norm defined as the average of the two countries' abatement. α measures sensitivity to the common social norm. N is subtracted from X_1 as the social norm N can support abatement and conforming offsets the monetary abatement cost (Fischer and Huddart 2008; Qin and Shogren 2015). Hoel (1991) is a special case of our model when $P = \alpha = 0$, such that $N = 0$ and the countries disregard norms. $B(.)$ and $C(.)$ are benefit and cost functions with $B' > 0, B'' < 0, C' > 0, C'' > 0$.

The first order condition is

$$B_1''(X_1 + X_2) - C_1'(X_1 - N)(1 - \alpha/2) = 0. \tag{2}$$

This defines X_1 as a function of X_2, we call this function the response function of country 1, denoted $R_1(X_2)$. Due to the implicit function theorem, equation (2) implies

$$-R_1'(X_2) = \frac{-(1 - \frac{\alpha}{2})\frac{\alpha}{2}C_1''(X_1 - N) - B_1''}{(1 - \frac{\alpha}{2})^2 C_1''(X_1 - N) - B_1''} \in (-1, 1) \tag{3}$$

[1]Buchholz and Sandler (2017) show reciprocity and fairness concerns can generate upward-sloping response functions in unilateral action models. We study another type of social preference: social norms.

Dropping the subscripts, since $B'' < 0$ and $C'' > 0$, the denominator is positive. The sign of the numerator is ambiguous. If $\frac{\alpha}{2}C'' <\mid B'' \mid$ the numerator is negative with a smaller absolute value than the denominator[2], $-1 < R' < 0$; the abatement actions are strategic substitutes; If $\frac{\alpha}{2}C'' >\mid B'' \mid$, $0 < R' < 1$, and the abatement actions are strategic complements. Thus, $R' \in (-1, 1)$. Note that under Hoel (1991) assumptions, where $\alpha = 0$, they are always substitutes. The analysis of country 2's best response function is symmetric to that of county 1 in expressions (2) and (3).

The parameter condition that ensures the abatement decisions are strategic complements is intuitive: when α is small, countries weigh their individual norms more heavily than international norms. When country 1 increases abatement, therefore, it has only a small effect on country 2's marginal abatement cost. Given that country 1 contributes more to the public abatement good, country 2 prefers to free ride and decrease its abatement. Conversely, when α is large, the social-conformity effect can dominate the free riding effect. When $C''/ \mid B'' \mid$ is large, the marginal cost reduction country 2 experiences due to the social norm effect is large compared to the increase in its free-riding incentive.

We illustrate the response functions for a strategic substitutes case and a strategic complements case in Fig.1 and Fig. 2. The reaction functions are not generally linear; straight lines are drawn for convenience. The Nash equilibrium of the simultaneous game is given in both figures by the pair (X_1^*, X_2^*), i.e. by $X_1^* = R_1(X_2^*)$ and $X_2^* = R_2(X_1^*)$. It is also possible that one country's reaction function is positively sloped while the other country's reaction function is negatively sloped.

What will happen if one country takes a unilateral action and decides to abate more than its payoff function dictates? Following Hoel (1991), we model unilateral action by assuming that country 1 has the following modified payoff function[3]

$$B_1(X_1 + X_2) - C_1(X_1 - N) + h * (X_1 + X_2) \tag{4}$$

where $h > 0$. We can interpret this as an altruistic warm glow. The optimal solution implies:

$$B_1'(X_1 + X_2) + h = C_1'(X_1 - N)(1 - \alpha/2) \tag{5}$$

Instead of equation (2), (5) defines a new response function. We denote it $\tilde{R}_1(X_2)$. Clearly, $\tilde{R}_1(X_2)$ lies further to the right of $R_1(X_2)$. The new intersection of the two response functions is at D'. The slope of the response function is the same as in (3) .

Case 1: if $R_2'(X_1) \in (-1, 0)$, then, consistent with Hoel (1991), country 1 will abate more while country 2 will increase emissions. Since $R_2'(X_1) > -1$, total emissions will be lower. Figure 1 illustrates the results when $R_1'(X_2) \in (-1, 0)$, but the qualitative effects when $R_1'(X_2) \in (0, 1)$ are the same. Thus, the slope of country 1's reaction function is unimportant.

Case 2: If $R_2'(X_1) \in (0, 1)$, country 2's reaction function is positively sloped as in Figure 2. In this case, country 1's unilateral action increases country 2's abatement, but by a smaller amount as $R_2'(X_1) < 1$. Total emissions decrease more than in Case 1. The slope of country 1's reaction function is again irrelevant for the result. Case 2 occurs when $C_2''/ \mid B_2'' \mid$ is large. In CO_2 abatement, for example, the marginal cost increases fast and the marginal benefit decreases at a slower rate. The result for Case 2 contrasts

[2]The preceding calculation omits the term $\frac{\alpha^2}{4}$ as it is relatively small compared to $\frac{\alpha}{2}$

[3]Although we study the effects of morally induced unilateral action, all other outward shifts in country 1's benefit function would generate the same results as here. We are very grateful to an anonymous referee for pointing this out.

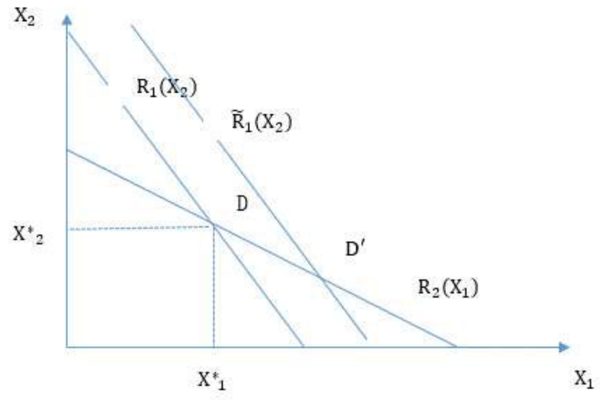

Figure 1: Abatements are strategic substitutes

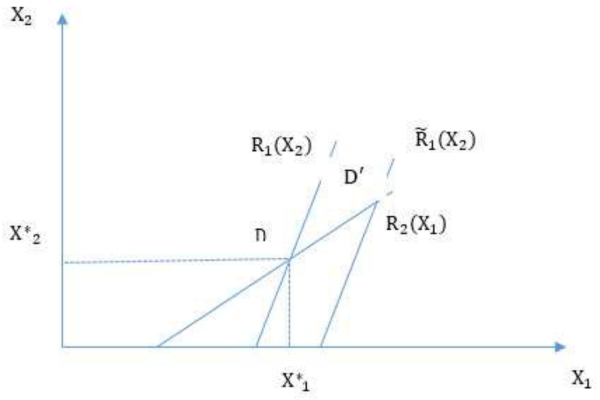

Figure 2: Abatements are strategic complements

with Hoel (1991) in our model, although more abatement from country 1 reduces country 2's marginal abatement benefit, the marginal benefit decreases less than the marginal cost due to the higher social norm created by country 1.

Proposition 1

1) if $R_2'(X_1) \in (-1, 0)$, a unilateral action by country 1 will increase country 2's emissions. Total emissions will be lower.

2) if $R_2'(X_1) \in (0, 1)$, a unilateral action by country 1 will reduce country 2's emissions. Total emissions will be significantly lower.

Next, we examine the social welfare effect when country 1 takes a unilateral action. Social welfare is the sum of the original payoffs and the moral payoff $h * (X_1 + X_2)$,

$$W = B_1(X_1 + X_2) + B_2(X_1 + X_2) - C_1(X_1 - N_1) - C_2(X_2 - N_2) + h * (X_1 + X_2) \quad (6)$$

Taking the comparative statics with respect to h, we get

$$\frac{dW}{dh} = \frac{dX_1}{dh}[-h + \frac{dX_2}{dX_1}(B_1' + \alpha/2C_1') + (B_2' + \alpha/2C_2') + h(1 + \frac{dX_2}{dX_1})] + (X_1 + X_2) \quad (7)$$

$B_2' + \frac{\alpha}{2}C_2' > 0, B_1' + \frac{\alpha}{2}C_1' > 0, \frac{dX_2}{dX_1} = R_2'(X_1)$ can be positive or negative, $-h < 0$, $\frac{dX_1}{dh} > 0$, so the sign of the right-hand side is ambiguous. However, we start with $h = 0$, and $R_2'(X_1) \in (-1, 1)$.

Case 1: $-1 < R_2'(X_1) < 0$, if $B_1' + \frac{\alpha}{2}C_1' < B_2' + \frac{\alpha}{2}C_2'$, $\frac{dW}{dh} > 0$ [4]. From (2) we have $B_1' + \frac{\alpha}{2}C_1' = C_1'$ and $B_2' + \frac{\alpha}{2}C_2' = C_2'$. If country 1's marginal cost is lower than or equal to country 2's, an increase in h will increase social welfare.

Case 2: $0 < R_2'(X_1) < 1$, $\frac{dW}{dh} > 0$, unilateral action always increases welfare as it increases both countries' abatement. Our results can be stated as follows:

Proposition 2:*Starting from following self-interest, unilateral action by country 1 increases social welfare if (a)* $-1 < R_2'(X_1) < 0$, *and country 1's marginal cost is less than or equal to country 2's; (b)* $0 < R_2'(X_1) < 1$, *such that the abatement decisions are strategic complements.*

3 Comparative statics

Proposition 3:

a. An increase in the personal abatement norm will increase both countries' abatement if both countries marginal cost curves are steep relative to the marginal benefit curves.

b. An increase in the warm glow of country 1 will increase country 1's abatement. It leads to more abatement by country 2 if the slope of country 2's marginal benefit curve exceeds $\frac{\alpha}{2}$ times the slope of its marginal cost curve.

Proof: see appendix.

4 Conclusion

Hoel (1991) shows a unilateral abatement action will reduce other countries' abatement. Abatements are substitutes. This note shows if countries conform to international social

[4] This is a sufficient condition as we have another positive term $(X_1 + X_2)$ at the right hand side.

norms, abatements can be complements. In our non-cooperative game, social welfare increases if the leading country's marginal abatement cost is no greater than the other country's. Our results suggest social norms and norm-creating campaigns can help to mitigate climate change.

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A Appendix

A.1 Proof of Proposition 3

From the first order conditions we have:

$$B_1'(X_1 + X_2) + h = C_1'(X_1 - N)(1 - \frac{\alpha}{2}) \tag{A.1}$$

$$B_2'(X_1 + X_2) - C_2'(X_2 - N)(1 - \frac{\alpha}{2}) = 0 \tag{A.2}$$

Substituting $X_1(P, \alpha, h)$ and $X_2(P, \alpha, h)$ into above equations, we get:

$$B_1'(X_1(P, \alpha, h) + X_2(P, \alpha, h)) - C_1'(X_1(P, \alpha, h) - N)(1 - \frac{\alpha}{2}) + h = 0 \tag{A.3}$$

$$B_2'(X_1(P, \alpha, h) + X_2(P, \alpha, h)) - C_2'(X_2(P, \alpha, h) - N)(1 - \frac{\alpha}{2}) = 0 \tag{A.4}$$

Substituting the expression of N into above equations, we have:

$$\begin{aligned} &B_1'(X_1(P, \alpha, h) + X_2(P, \alpha, h)) - C_1'(X_1(P, \alpha, h) \\ &\qquad - [(1 - \alpha)P + \alpha(X_1(P, \alpha, h) + X_2(P, \alpha, h))/2])(1 - \alpha/2) + h = 0 \end{aligned} \tag{A.5}$$

$$B_2'(X_1(P,\alpha,h)+X_2(P,\alpha,h)) - C_2'(X_2(P,\alpha,h)$$
$$- [(1-\alpha)P + \alpha(X_1(P,\alpha,h)+X_2(P,\alpha,h))/2])(1-\alpha/2) = 0 \quad \text{(A.6)}$$

The Hessian matrix of second-order derivatives is:

$$\begin{vmatrix} B_1'' - (1-\alpha/2)^2 C_1'' & B_1'' + (1-\alpha/2)\alpha/2 C_1'' \\ B_2'' + (1-\alpha/2)\alpha/2 C_2'' & B_2'' - (1-\alpha/2)^2 C_2'' \end{vmatrix}$$
$$= -(1-\alpha/2)[C_1''B_2'' + B_1''C_2'' - (1-\alpha/2)(1-\alpha)C_1''C_2''] > 0 \quad \text{(A.7)}$$

The comparative statics with respect to P are:

$$\begin{pmatrix} B_1'' - (1-\alpha/2)^2 C_1'' & B_1'' + (1-\alpha/2)\alpha/2 C_1'' \\ B_2'' + (1-\alpha/2)\alpha/2 C_2''' & B_2'' - (1-\alpha/2)^2 C_2'' \end{pmatrix} \begin{pmatrix} \frac{\partial X_1}{\partial p} \\ \frac{\partial X_2}{\partial p} \end{pmatrix}$$
$$= \begin{pmatrix} -(1-\alpha/2)(1-\alpha)C_1'' \\ -(1-\alpha/2)(1-\alpha)C_2'' \end{pmatrix} \quad \text{(A.8)}$$

$$\frac{\partial X_1^*}{P} = \frac{(1-\frac{\alpha}{2})(1-\alpha)\left[B_1''C_2'' - C_1''B_2'' + (1-\frac{\alpha}{2})C_1''C_2''\right]}{H} \quad \text{(A.9)}$$

$$\frac{\partial X_2^*}{P} = \frac{(1-\frac{\alpha}{2})(1-\alpha)\left[B_2''C_1'' - C_2''B_1'' + (1-\frac{\alpha}{2})C_1''C_2''\right]}{H} \quad \text{(A.10)}$$

When the countries are symmetric, $B_1''C_2'' = C_1''B_2''$, $\frac{\partial X_1^*}{P} > 0$, $\frac{\partial X_2^*}{P} > 0$. This implies an increase in the individual norm increases both countries' abatement. When the countries are asymmetric, if $(1-\frac{\alpha}{2})C_1'' >\mid B_1'' \mid$, $\frac{\partial X_1^*}{P} > 0$; if $(1-\frac{\alpha}{2})C_2'' >\mid B_2'' \mid$, $\frac{\partial X_2^*}{P} > 0$. This implies if the countries marginal cost curves are relatively steep compared to the marginal benefit curves, stronger individual norms increase both countries' abatement.

The comparative statics with respect to h are:

$$\begin{pmatrix} B_1'' - (1-\alpha/2)^2 C_1'' & B_1'' + (1-\alpha/2)\alpha/2 C_1'' \\ B_2'' + (1-\alpha/2)\alpha/2 C_2''' & B_2'' - (1-\alpha/2)^2 C_2'' \end{pmatrix} \begin{pmatrix} \frac{\partial X_1}{\partial h} \\ \frac{\partial X_2}{\partial h} \end{pmatrix}$$
$$= \begin{pmatrix} -1 \\ 0 \end{pmatrix} \quad \text{(A.11)}$$

$$\frac{\partial X_1^*}{\partial h} = \frac{(1-\frac{\alpha}{2})^2 C_2'' - B_2''}{H} > 0 \quad \text{(A.12)}$$

$$\frac{\partial X_2^*}{\partial h} = -\frac{(1-\frac{\alpha}{2})\frac{\alpha}{2}C_2'' - B_2''}{H} > 0 \quad \text{(A.13)}$$

$\frac{\partial X_1^*}{\partial h} > 0$, but the sign of $\frac{\partial X_2^*}{\partial h}$ is ambiguous. Ignoring the small term $\frac{\alpha^2}{4}$, if $\mid B_2'' \mid > \frac{\alpha}{2}C_2''$, $\frac{\partial X_2^*}{\partial h} > 0$; if $\mid B_2'' \mid < \dfrac{\alpha}{2}C_2''$, $\frac{\partial X_2^*}{\partial h} < 0$. This implies an increase in h increases country 1 abatement. It also increases country 2 abatement if the slope of country 2's marginal benefit curve exceeds $\frac{\alpha}{2}$ times the slope of its marginal cost curve (so the conformity effect dominates the free-riding effect).

A.2 Cooperative game

Following Hoel (1991), we study Nash-bargaining without side payments. The solution satisfies

$$max\{log[B_1(X_1+X_2)-C_1(X_1-N_1)-D_1] \\ +log[B_2(X_1+X_2)-C_2(X_1-N_2)-D_2]\} \quad (A.14)$$

Where D_1 and D_2 are outside options:

$$D_i = B_i(X_1^*+X_2^*)-C_i(X_i^*-N_i) \quad (A.15)$$

and X_1^* and X_2^* are the non-cooperative equilibrium abatements.

What happens if, in the no-agreement case, country 1 takes unilateral action (Hoel, 1991)? Applying the implicit function theorem to equation (7), we get:

$$\frac{dX_2}{dX_1} = \frac{H - C_1''[(1-\alpha)C_2' - B_2']}{-H + C_2''[(1-\alpha)C_1' - B_1']} \quad (A.16)$$

$$H = B_1''C_2' + B_2''C_1' - B_1'C_2''\alpha/2 - B_2'C_1''\alpha/2 + (1-\alpha)\alpha/2(C_1'C_2'' + C_1''C_2') \quad (A.17)$$

Since $(1-\alpha)\alpha/2(C_1'C_2''+C_1''C_2')$ is small relative to the other terms, we omit it. As $B_i' > 0, B_i'' < 0, C_i' > 0, C_i'' > 0$,we get $H < 0$. We have $-1 < \frac{dX_2}{dX_1} < 0$ iff

$$\frac{(1-\alpha)C_2' - B_2'}{C_2''} < \frac{(1-\alpha)C_1' - B_1'}{C_1''} \quad (A.18)$$

When B_i and C_i are identical, if $X_1 > X_2$, then $-1 < \frac{dX_2}{dX_1} < 0$, unless $C_i''' > 0$ and large . When $\frac{dX_2}{dX_1} > 0$, an increase in country 1's abatement increases country 2's abatement. If $-1 < \frac{dX_2}{dX_1} < 0$, an increase in country 1's abatement reduces country 2's abatement. Total emissions are lower. If C_1''' is sufficiently large, $\frac{dX_2}{dX_1} < -1$ and country 1's unilateral action creates higher total emissions in the cooperative agreement. Compared with Hoel (1991), equation (A18) is more likely to hold in our paper as C_i''' is smaller[5]. Intuitively, unilateral action without the norm effect weakens country 1's threat point and increases country 2's bargaining power (Hoel, 1991). In our model, the norm effect also increases country 2's abatement incentive without an agreement. Thus, country 2's threat point also weakens. Thus, it agrees to abate more.

Proposition A4: *In a cooperative game without side payment, when two countries' benefit and cost functions are identical, a unilateral action by country 1 will more likely lead to lower total emissions than without social norm effect.*

[5] $C(X_1-N) = C[(1-\alpha/2)X_1 - (1-\alpha)P - \alpha/2X_2], C'(X_1-N) = (1-\alpha/2)C', C''(X_1-N) = (1-\alpha/2)^2C'', C'''(X_1-N) = (1-\alpha/2)^3C'''$, given that $\alpha > 0$ in our paper relative to Hoel (1991).