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Self-protection as a limit to strategic delegation in the context of global pollution problems

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ABSTRACT
This paper analyses the outcome of non-cooperative national efforts in combatting global pollution problems when governments are elected by their citizens. It is well-known that the latter tend to vote governments that are less 'green' than the median voter in order to commit to lower national mitigation efforts, which further increases the inefficiently high amount of global emissions. However, the present paper shows that the option of self-protection against environmental damages, which has been invariably neglected in the relevant literature to date, alleviates or even completely offsets such strategic delegation and the related adverse effects.

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1. Introduction

The solution of global pollution problems necessarily requires joint action. Otherwise, countries do not take into account the negative externalities their emissions impose on the rest of the world. Such non-cooperative outcome is typically characterised by an inefficiently high level of global emissions (Buchholz et al. 2005). However, since mitigation of emissions is a global public good and thus provides free-riding incentives, international environmental agreements – if implemented at all – hardly go beyond non-cooperative mitigation efforts (Barrett 1994).

Considering that national governments are not exogenously given, but rather elected by heterogeneous citizens, a number of recent studies suggests that even more pessimism is indicated (Siqueira 2003; Buchholz et al. 2005). These studies argue that voters have an incentive to elect representatives with weaker environmental preferences compared to the median voter. Through such strategic delegation, a country commits itself to a lower contribution to the global public good of mitigation, thus shifting the burden of reaching a higher environmental quality to the rest of the world. For obvious reasons, this leads to a further increase in global emissions relatively to the non-cooperative equilibrium with exogenously given governments.

To date, the literature on strategic delegation has invariably abstracted from the possibility of self-protection against environmental damages. However, as can be seen from the prime example of global pollution problems, the emission of greenhouse gases, this might mean a severe qualification of results. Here, self-protection, i.e., adaptation to climate change, currently undergoes a significant boost on the agenda of climate policy (Berg 2012).

Against this backdrop, the present paper re-evaluates the role of strategic delegation in non-cooperative international environmental policy whilst taking into account self-protection. More precisely, we consider a two-country setup with three stages. In the first stage, the citizens of either country elect their respective government following the median voter approach. In stage two, governments fix the domestic emission level before they engage in self-protection (stage 3).[1]

The rest of the paper is organised as follows. Section 2 sets up the model. Section 3 determines the subgame-perfect equilibrium. Section 4 reveals the role of self-protection as a limit to strategic delegation. Section 5 provides some concluding remarks on the associated consequences in terms of global efficiency.

2. The model

Following much of the literature (e.g. Hoel 1991; Ebert and Welsch 2012), we employ a two-country setup, whereas uppercase (lowercase) letters denote functions and variables of the home (foreign) country.[2] Home's emissions E, serving as an essential input for production, yield national economic benefits equal to the sum of consumers' and producers' surplus $B(E)$ with usual properties $B_E > 0$, $B_{EE} < 0$. On the contrary, emissions – no matter what origin – harm the ecological system at home and abroad in equal manner. Besides reducing domestic emissions, which imposes a positive external effect on its neighbour and thus constitutes a global public good, home can alleviate its environmental damages through expenditures for self-protective measures A.[3] We follow the prevalent view in the literature that self-protection – contrary to

[1] For a motivation of this specific sequence of decisions see Ebert and Welsch (2012) and Section 3.

[2] In the remainder of this paper, only the formulas referring to the home country are depicted for the sake of conciseness. Those for the foreign country apply in an analogous manner.

[3] Since self-protection usually comprises a variety of heterogeneous measures that cannot be scaled by a single physical unit, it is captured in terms of expenditures within our model framework (see Ebert and Welsch 2012).

mitigation of emissions – features private good characteristics since it largely provides national benefits only (see e.g. Zehaie 2009). This gives rise to home's damage cost function $D(E+e,A)$ with usual properties $D_E = D_e > 0$, $D_{EE} > 0$, $D_A < 0$, $D_{AA} > 0$, $D_{EA} = D_{AE} < 0$ (see e.g. Ebert and Welsch 2012).[4]

Home is populated by a continuum of individuals of mass 1, indexed by I. Assume that all individuals have identical stakes in the benefits $B(E)$ and contribute to self-protection expenditures in equal measure. However, each individual attaches a different weight to environmental damages,[5] reflected by the parameter θ^I, which is continuously distributed on the bounded interval $[0; \theta^{MAX}]$ (see Buchholz et al. 2005). Thus, I's net benefit, which similarly represents the home country's welfare with damage costs weighted by θ^I, reads

$$W^I(E,e,A) = B(E) - \theta^I D(E+e,A) - A. \tag{1}$$

Environmental policy is decided by an elected government or representative, respectively. Both the electorate and pool of potential representatives are given by the sum of all the country's inhabitants. Following Buchholz et al. (2005), we assume that the representative in power, denoted by index G, can directly determine the domestic levels of emissions and expenditures for self-protection. Thus, environmental policy maximises her payoff (1) and is fully characterised by her preference parameter θ^G. The stylised election process follows a simple majority rule, implying that the choice of the policy maker is up to the median voter (Roelfsema 2007).

3. Subgame-perfect equilibrium

In case of non-cooperative behaviour, the sequence of decisions with respect to emissions and self-protection matters (Zehaie 2009). Following Ebert and Welsch (2012), we assume that emissions are essential for economic activity and hence cannot be postponed after self-protective measures have been employed. It will be seen that, within our framework, fixing emissions before self-protection is perfectly equivalent to simultaneous decision making. However, for analytical convenience, we refer to the sequential choice and thus consider the three-stage game described in Section 1 (Stage 1: strategic voting – Stage 2: emission level – Stage 3: self-protection level).

Employing backwards induction, we start out with solving Stage 3. Home's policy maker maximises domestic welfare with respect to A, i.e. $\max_A W^G(E,e,A) = B(E) - \theta^G D(E+e,A) - A$, which requires bringing in line marginal benefits in terms of reduced damage costs and marginal costs:

$$-\theta^G D_A - 1 = 0, \tag{2}$$

Since (2) does not depend on the neighbour's decision, representatives choose adaptation in dominant strategies, given the global emission level and their environmental preferences determined at the previous stages, i.e., $A(E+e,\theta^G)$, $a(E+e,\theta^g)$. Simple comparative statics show that 'greener' policy makers choose higher levels of self-protection, i.e. $\partial A/\partial\theta^G > 0$, $\partial a/\partial\theta^g > 0$. Moreover, increased emission levels – no matter what origin – induce a compensation of high-

[4] The latter property implies that mitigation of emissions and self-protection are substitutes (rather than complements) in alleviating environmental damages, which reflects the prevalent view in the literature (see e.g. Pittel and Rübbelke 2013).

[5] This may be for the reason that damages actually differ among individuals and/or the latter feature varying environmental preferences.

er damages through augmented self-protective efforts, i.e. $\partial A/\partial E = \partial A/\partial e > 0$, $\partial a/\partial E = \partial a/\partial e > 0$.[6]

In Stage 2, home's optimal emission level solves $\max_E W^G\big(E, e, A(E+e, \theta^G)\big)$; i.e. while fixing E, home anticipates the respective impact on self-protection in Stage 3. Taking account of (2), the related first-order condition states that marginal benefits and national[7] marginal damage costs related to an increase in E have to be balanced

$$B_E - \theta^G D_E = 0.^8 \tag{3}$$

From this immediately follows that home and foreign emissions are strategic substitutes, i.e., $dE/de < 0$. Moreover, augmented environmental preferences of the home country's government lead to a decrease in home's equilibrium emission level $E(\theta^G, \theta^g)$ and thus to an increase in the foreign level $e(\theta^G, \theta^g)$, i.e., $\partial E/\partial\theta^G < 0, \partial e/\partial\theta^G > 0$. Since the former effect dominates the latter, the overall impact on global emissions is negative, i.e., $\partial(E+e)/\partial\theta^G < 0$.[9]

In Stage 1, the median voter chooses the policy maker such that her pay-off is maximised, given the equilibrium outcome of the previous stages: $\max_{\theta^G} W^M(\theta^G, \theta^g) = B\big(E(\theta^G, \theta^g)\big) - \theta^M D\big(E(\theta^G, \theta^g) + e(\theta^G, \theta^g), A(E(\theta^G, \theta^g) + e(\theta^G, \theta^g), \theta^G)\big) - A(E(\theta^G, \theta^g) + e(\theta^G, \theta^g), \theta^G)$. The respective first-order condition highlights that choosing a slightly greener candidate comes along with a marginal decrease (increase) in emissions (self-protection)[10] and thus has an ambiguous overall impact in terms of welfare:

$$\underbrace{B_E \frac{\partial E}{\partial \theta^G}}_{<0} \underbrace{-\left(A_E \frac{\partial(E+e)}{\partial\theta^G} + \frac{\partial A}{\partial\theta^G}\right)}_{<0} \underbrace{-\theta^M \left(D_E \frac{\partial(E+e)}{\partial\theta^G} + D_A\left(A_E \frac{\partial(E+e)}{\partial\theta^G} + \frac{\partial A}{\partial\theta^G}\right)\right)}_{>0} = 0 \tag{4}$$

On the one hand, it causes an increase in costs in terms of decreased benefits and increased expenditures for self-protection; on the other hand, it reduces damage costs. The subgame-perfect equilibrium is characterised by the selected candidates $\tilde{\theta}^G(\theta^M, \theta^m)$, $\tilde{\theta}^g(\theta^M, \theta^m)$.[11] Clearly, increased environmental preferences of the home's median voter induce her to select a greener candidate, i.e., $\partial\tilde{\theta}^G/\partial\,\theta^M > 0$, whereas the respective impact on the selected foreign candidate is ambiguous, i.e., the sign of $\partial\tilde{\theta}^g/\partial\,\theta^M$ is indeterminate.[12]

4. Self-protection as a limit to strategic delegation

According to the prevalent view in the literature, the median voter empowers a representative with weaker environmental preferences compared to herself ($\tilde{\theta}^G < \theta^M$) in order to commit to a lower contribution to the global public good of mitigation and hence to increase her pay-off (Siqueira 2003; Buchholz et al. 2005). However, the respective studies invariably neglect the

[6] In other words, mitigation serves as a substitute to self-protection in reducing a country's damage costs.
[7] Due to non-cooperative behaviour, countries neglect their emissions' detrimental impact on the respective neighbour, leading to the well-known result of an inefficiently high level of global emissions (see e.g. Cornes and Sandler 1996). The level of self-protection is inefficiently high as well (see e.g. Zehaie 2009).
[8] Obviously, (2) and (3) perfectly correspond to the first-order conditions in case of simultaneous decision making on emissions and self-protection. Thus, similarly to Zehaie (2009), there is no difference between fixing (E, e) before or simultaneously with (A, a) in our framework.
[9] For the proof see Appendix 1.
[10] The increase in self-protection grounds on the assumption that θ^G's direct impact on A, $\partial A/\partial\theta^G>0$, outweighs its indirect impact via the global emission level, $A_E(\partial(E+e)/\partial\theta^G) < 0$.
[11] In what follows, "~" marks the functions and variables occurring in the subgame-perfect equilibrium.
[12] For the proof and explanation see Appendix 2.

option of self-protection. For scrutinizing the latter's impact in terms of strategic voting, solve (4) for $\theta^M/\tilde{\theta}^G$, having regard to (2) and (3):

$$\frac{\theta^M}{\tilde{\theta}^G} = \frac{B_E\frac{\partial E}{\partial \theta^G} - \left(A_E\frac{\partial (E+e)}{\partial \theta^G} + \frac{\partial A}{\partial \theta^G}\right)}{B_E\frac{\partial (E+e)}{\partial \theta^G} - \left(A_E\frac{\partial (E+e)}{\partial \theta^G} + \frac{\partial A}{\partial \theta^G}\right)} =: \frac{\alpha-\beta}{\gamma-\beta}, \tag{5}$$

where $\alpha := B_E \frac{\partial E}{\partial \theta^G} < 0$, $\beta := A_E\frac{\partial (E+e)}{\partial \theta^G} + \frac{\partial A}{\partial \theta^G} > 0$, $\gamma := B_E \frac{\partial (E+e)}{\partial \theta^G} < 0$. From this immediately follows

Proposition 1. *Suppose, within a non-cooperative setting, measures of self-protection are available as an additional option to tackle global pollution problems besides mitigation of emissions.*

(i) Countries still engage in strategic delegation, i.e. median voters empower candidates with weaker environmental preferences compared to themselves, i.e., $\theta^M > \tilde{\theta}^G$, $\theta^m > \tilde{\theta}^g$.

(ii) However, self-protection limits the extent of strategic delegation, i.e. the gap between $\theta^M, \tilde{\theta}^G$ *and* $\theta^m, \tilde{\theta}^g$*, respectively, shrinks compared to case where countries solely rely on mitigation.*

Proof. (i): $|\partial E/\partial \theta^G| > |\partial (E+e)/\partial \theta^G|$ (see Section 3) implies $|\alpha| > |\gamma|$ and thus $\theta^M > \tilde{\theta}^G$. (ii): In case without self-protection, $\beta = 0$. Since $\partial\left(\theta^M/\tilde{\theta}^G\right)/\partial\beta < 0$, the option of self-protection weakens the extent of strategic delegation. Analogous reasoning for the foreign country. ■

(i) is obvious since allowing for self-protection does not change the fact that strategic delegation is the only device for the countries to commit to a lower mitigation effort. However, self-protection makes strategic delegation less attractive for the following reason (ii). From the single country's and median voter's isolated view, respectively, strategic delegation distorts both the optimal extent of emissions and self-protection: since $\theta^M > \tilde{\theta}^G(\theta^M, \theta^m)$ and $\partial E/\partial \theta^G < 0$, $\partial A/\partial \theta^G > 0$, emissions (expenditures for self-protection) are inefficiently high (low). Contrary to the increase in emissions, which forces the neighbour to raise its contribution to the global public good of mitigation, countries do not profit from the associated downturn in self-protection. That is because the latter is a purely private good and thus offers no scope for beneficial manipulation of the neighbour's decision. For this reason, self-protection reduces the profitability of choosing a candidate with weaker environmental preferences compared to the median voter. As a direct consequence, state

Corollary 1. *In case self-protection responds very sensitively to changes in environmental preferences compared to emissions, strategic delegation vanishes, i.e.,* $lim_{\beta\to\infty}\frac{\alpha-\beta}{\gamma-\beta} = 1 \Leftrightarrow \theta^M = \tilde{\theta}^G$.

As can be seen from the comparative statics with respect to (2) and (3), this constellation applies when self-protection features a considerable higher effectiveness in reducing damage costs compared to mitigation of emissions.[13] In that case, the cost of strategic delegation concerning the distortion of self-protection outweighs the gain from the associated increase in domestic emissions.

[13] The proof of this statement is straightforward and can be obtained from the author upon request.

5. Conclusion

Many global pollution problems, such as anthropogenic climate change, either suffer from the sheer absence of joint action or from unambitious international agreements that hardly go beyond non-cooperative mitigation efforts. Such efforts are well-known to be inefficiently low from the global perspective. This outcome even deteriorates when it is taken into account that countries might strategically delegate environmental policy to representatives with weaker environmental preferences compared to the median voter in order to commit to higher emission levels. However, the present paper shows that this pessimistic view has to be put into context to some extent. This is for the reason that the option of self-protection against environmental damages, which has been neglected throughout the respective literature so far, restricts the incentives for strategic delegation. The latter distorts both the decision with respect to emissions and self-protection from the single country's view. While the former distortion entails benefits for either country because it forces the respective neighbour to boost its contribution to the global public good of mitigation, distorting the decision on the private good of self-protection comes along with a pure cost. Consequently, self-protection serves as a limit to strategic delegation and thus improves global efficiency due to the associated downturn in total emissions.[14] Nevertheless, the latter remain inefficiently high since self-protection can at best offset (but not overcompensate) strategic delegation, for what reason global emissions cannot fall below the non-cooperative level.

Appendix 1: Comparative statics – (E, e) with respect to (θ^G, θ^g)

Home and foreign emissions respond to a marginal increase in the policy makers' environmental preferences as follows:

$$\begin{pmatrix} \frac{\partial E}{\partial \theta^G} & \frac{\partial E}{\partial \theta^g} \\ \frac{\partial e}{\partial \theta^G} & \frac{\partial e}{\partial \theta^g} \end{pmatrix} = -\frac{1}{\det} \begin{pmatrix} w_{ee}^g & -W_{Ee}^G \\ -w_{eE}^g & W_{EE}^G \end{pmatrix} \begin{pmatrix} W_{E\theta^G}^G & W_{E\theta^g}^G \\ w_{e\theta^G}^g & w_{e\theta^g}^g \end{pmatrix}, \tag{A1.1}$$

where det denotes the determinant of the Hessian which origins from the countries' minimisation problem in terms of (E, e). Since $\det > 0$ holds for a unique and stable Nash equilibrium in emissions (Tirole 1988), calculating (A1.1) yields

$$\begin{aligned} &\frac{\partial E}{\partial \theta^G} = -\frac{1}{\det}(b_{ee} - \theta^g d_{ee})(-D_E) < 0, \frac{\partial E}{\partial \theta^g} = -\frac{1}{\det}\theta^G D_{Ee}(-d_e) > 0, \\ &\frac{\partial e}{\partial \theta^G} = -\frac{1}{\det}\theta^g d_{eE}(-D_E) > 0, \frac{\partial e}{\partial \theta^g} = -\frac{1}{\det}(B_{EE} - \theta^G D_{EE})(-d_e) < 0, \\ &\frac{\partial (E+e)}{\partial \theta^G} = \frac{1}{\det} b_{ee} D_E < 0, \frac{\partial (E+e)}{\partial \theta^g} = \frac{1}{\det} B_{EE} d_e < 0. \end{aligned} \tag{A1.2}$$

[14] A full analysis of the self-protection option's impact on global efficiency would require assessing – besides the impact on global emissions – the welfare effects of introducing self-protection itself. This effect is yet ambiguous. On the hand, introducing an additional control variable generally allows for a higher level of global welfare. On the other hand, the level of self-protection is distorted. An explicit trade-off of these effects cannot be carried out given the general form of the model employed.

Appendix 2: Comparative statics – $\left(\tilde{\theta}^G, \tilde{\theta}^g\right)$ with respect to θ^M

Analogously to Appendix 1, the selected candidate's environmental preferences respond to a marginal increase in those of the median voter as follows:

$$\begin{pmatrix} \frac{\partial\tilde{\theta}^G}{\partial\theta^M} & \frac{\partial\tilde{\theta}^G}{\partial\theta^m} \\ \frac{\partial\tilde{\theta}^g}{\partial\theta^M} & \frac{\partial\tilde{\theta}^g}{\partial\theta^m} \end{pmatrix} = -\frac{1}{\det}\begin{pmatrix} w^m_{\theta^g\theta^g} & -W^M_{\theta^G\theta^g} \\ -w^m_{\theta^g\theta^G} & W^M_{\theta^G\theta^G} \end{pmatrix}\begin{pmatrix} W^M_{\theta^G\theta^M} & W^M_{\theta^G\theta^m} \\ w^m_{\theta^g\theta^M} & w^m_{\theta^g\theta^m} \end{pmatrix}, \tag{A2.1}$$

where $\det > 0$ denotes the determinant of the Hessian which origins from the countries' minimisation problem in terms of (θ^G, θ^g). As second-order conditions require $W^M_{\theta^G\theta^G}, w^m_{\theta^g\theta^g} < 0$, calculating (A2.1) yields for home (analogously for foreign):

$$\frac{\partial\tilde{\theta}^G}{\partial\theta^M} = -\frac{1}{\det} w^m_{\theta^g\theta^g}\left(-\left(D_E\frac{\partial(E+e)}{\partial\theta^G} + D_A\left(A_E\frac{\partial(E+e)}{\partial\theta^G} + \frac{\partial A}{\partial\theta^G}\right)\right)\right) > 0,$$

$$\frac{\partial\tilde{\theta}^G}{\partial\theta^m} = -\frac{1}{\det}\left(-W^M_{\theta^G\theta^g}\right)(-d_e)\left(-\left(d_e\frac{\partial(E+e)}{\partial\theta^g} + d_a\left(a_e\frac{\partial(E+e)}{\partial\theta^g} + \frac{\partial a}{\partial\theta^g}\right)\right)\right) \tag{A2.2}$$

$$\begin{cases} > 0 \text{ if } W^M_{\theta^G\theta^g} > 0 \Leftrightarrow \partial\theta^G/\partial\theta^g > 0 \Leftrightarrow \theta^M < \hat{\theta}^M \\ = 0 \text{ if } W^M_{\theta^G\theta^g} = 0 \Leftrightarrow \partial\theta^G/\partial\theta^g = 0 \Leftrightarrow \theta^M = \hat{\theta}^M. \\ < 0 \text{ if } W^M_{\theta^G\theta^g} < 0 \Leftrightarrow \partial\theta^G/\partial\theta^g < 0 \Leftrightarrow \theta^M > \hat{\theta}^M \end{cases}$$

A less green foreign government basically forces home to reduce emissions for compensating the increased damages. Given the median voter's environmental preferences are relatively weak, i.e. $\theta^M < \hat{\theta}^M$, home responds by empowering a less green policy maker in order to maintain the emission level and associated benefits. Analogous reasoning for the reverse case $\left(\theta^M > \hat{\theta}^M\right)$.

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