FACULTY OF LAW, ECONOMICS AND FINANCE

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Paper
2017-16

Economics

Center for Research in Economics and Management
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September, 2017

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On the impact of indirect competition for political influence on environmental policy*

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Abstract

Motivated by the history of climate politics in the US over the last decades, this paper aims at studying the impact of indirect competition for political influence, through environmental awareness raising vs disinformation campaigns, on environmental and economic performance. The analysis of the game in which groups devote efforts to bring the majority's concern closer to their views shows a strong asymmetry in the results. Strategic interaction may lead the economy to a better situation in the long run, compared to what would prevail in the absence of lobbying. But this only occurs when the environmental group exhibits a radical ideology and people's awareness is initially closer to that of the industrial group. By contrast, economies with very aggressive conservative groups and with people originally well aware of environmental problems can never benefit from the outcome of the game of political influence. The latter result is reinforced when one accounts for different lobbying powers and supremacy of industrial groups. This may explain why the US have failed to take action on global warming up to now.

Keywords: Public persuasion, environmentalists, industrialists, environmental awareness, information campaigns, disinformation, game of political influence.

JEL classification: D72, C73, Q54.

*The authors thank Geir Asheim, Raouf Boucekkine, Ujjayant Chakravorty, Mireille Chiroleu-Assouline, Julien Daubanes, Matthieu Glachant, Ingmar Schumacher, Mabel Tidball, Cees Withagen and participants in seminars and conferences in Athens, Bordeaux, Nanterre, Nice, Paris, and Sherbrooke, for helpful discussion.

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1 Introduction

Despite the large consensus among scientists about the fact that human activities are responsible for the ongoing warming of the Earth's climate, a large part of the public opinion and policy makers in the US sees climate science as highly uncertain (Oreskes, 2004). This "uncertainty" has been put forward by some stakeholders as an argument to prevent any strong measure to reduce carbon dioxide emissions, and somehow explains why the US climate policy lags behind the one conducted by the EU for instance.

Casting doubt about scientific evidence is recognized as an efficient strategy of industrial groups to delay or prevent a regulation that would threaten their interests (Freudenburg et al., 2008). This strategy opposes those of environmental groups whose aim is to promote better environmental protection. Overall, environmental regulation is the outcome of a struggle between opposing interest groups: in short, the industrialists vs the environmentalists. Within this second best world, pressure groups have two main ways to influence the environmental policy. Either, they can directly lobby the government to induce a change in the level of the environmental and/or technological legislation. Or, they can compete for political influence indirectly by engaging in information campaigns or public persuasion. In this paper, we focus on the second form of indirect competition for political influence and address the two following questions: what is the impact of strategic interaction f! or political influence on the climate policy? Does public persuasion make the economy closer to or, on the contrary, pull it away from efficiency?

The rise of environmental concerns in the US dates back to the publication of "Silent spring" (Carson, 1962).[1] Since then, the environmental movement have organized and formed voluntary nonprofit associations to collectively address environmental issues (Handy, 2001). Nowadays, environmental nongovernmental organizations (ENGOs) appear to be a major actor in the public and policy debate, that have contributed to many key achievements in US environmental protection.[2]

[1] "Silent spring" talks about declining bird population due to the use of DDT insecticide. This book was a best seller with over two million copies sold.

[2] They were at the origin of the design and implementation of the Clean Air Act, the Clean Water

In the 1970s, conservative groups began to challenge the growing influence of ENGOs, that had played a central role in the golden age of US environmental legislation (Collomb, 2014). Environmentalism was a new ideology orthogonal to the liberal views placing individual freedom, private property, laissez-faire (etc.) above any other consideration, thereby blaming any form of government's action. Environmental regulation also represented a direct threat to many polluting industries' highly profitable activities. As perfectly explained by McCright and Dunlap (2000), the opposition between environmental and conservative groups really started in the early 1990s and for the issue of climate change. At that time, ENGOs, with the support of the new born intergovernmental panel on Climate change (IPCC), quite successfully communicated the message that global warming was a reality and human activities were the dominant cause. In response to the rise of claims for actions to fight clim! ate change, a countermovement emerged, led by conservative think tanks funded by powerful corporations from the fossil fuel sector,[3] with the aim to confuse public opinion and delay public action. The continuous struggle between environmental groups and conservative industrial groups that has taken place in the US over the last twenty years (since the Kyoto Protocol) gives a perfect illustration of the interaction between opposite interest groups for indirect political influence and constitutes the core motivation of this paper.

We by no means suggest that the other form of direct lobbying has negligible impact on the environmental policy. It is well-known that major ENGOs indeed pursue a dual strategy.[4] They first adopt an insider strategy when they act as policy advisors and try to lobby governments directly to induce them to change their policies. They also follow an outsider or activist strategy when they seek to increase the voting public's environmental awareness, thereby fostering their demand for environmental protection, through information campaigns and educational programs (Handy, 2001). Which strategy is the most efficient is still an unsettled issue.[5] However, it is clear

Act, and the Clean Wilderness Act in the early sixties. This also led to the creation of the Environmental Protection Agency, in 1970.

[3]Among these think tanks are the National Center for Policy Analysis, the Marshall Institute, the Cato Institute etc.

[4]A non-comprehensive list of them comprises Greenpeace, Friends of the Earth, the World Wide Fund for Nature and Environmental Defense.

[5]It depends notably on both the arena of influence, national policy vs international negotiations, and

that due to highly unequal financial resources, ENGOs have very little chance to win the battle against conservative groups and corporations on the direct lobbying ground (Baron, 2003). In particular, Yu (2005), in his theory of direct vs indirect competition for political influence, argues that ENGOs are more powerful in changing people's environmental awareness than in lobbying directly governments. This ultimately comes from the fact that besides financial means, the efficiency in public persuasion depends on other factors such as credibility, trustworthiness and legitimacy that are more easily met by ENGOs than industrial lobbies. But the very reason why we choose to focus on public persuasion finds its origin in the tactics used by environmental! skeptics to challenge the growing scientific evidence, relayed by ENGOs, about the climate emergency. In the sixth chapter of their famous book "Merchants of doubt", Oreskes and Conway (2010) provide the reader with a broad look at the history of climate politics in the US. They notably document how a handful of scientists, with strong ties to particular industries and support from conservative think tanks, have undermined the scientific consensus, thereby preventing the US to undertake any action on global warming by systematic use of a strategy based on the following pillars: "discredit the science, disseminate false information, spread confusion, and promote doubt".[6] In short, this shows that conservative and industrial groups have also extensively relied on public persuasion for the particular issue of climate change.

This leads us to outline the aim of the paper. We are wondering whether the very existence of an indirect competition among opposite interest groups for political influence – through awareness raising vs disinformation campaigns – is necessarily bad news for an economy; and if not, what are the conditions under which it may be bene-

the time scale considered. See Handy (2001), Gulbrandsen and Andresen (2008), and Reiti! g (2011), for the few studies examining the role and impact of ENGOs (the two last specifically addressing the question of how efficient the ENGOs are in spreading their views during climate negotiations).

[6]Beyond the detailed and impressive review conducted by the authors, climate deniers' strategy has been dissected by studies in Sociology and Political Science, see among others McCright and Dunlap (2000, 2011), Lahsen (2005), Freudenburg et al. (2008), Jacques et al. (2008). In particular, Lahsen (2008) reports internal documents, from the International Council for t! he Environment (ICE), a group mostly composed of companies in the energy sector, in which the strategies for public campaigns to come are summarized as follows: "target print and radio media for maximum effectiveness", "reposition global warming as theory (not fact)", "use spokesman for the scientific community", and "target less educated segments of the population", which have been identified as the most receptive to its message.

ficial eventually.

As perfectly argued by Reitig (2011), shaping people's environmental preferences is a smooth process that deserves time. Studying this issue thus requires a dynamic framework: we consider an economy that faces a dynamic trade-off between production and pollution. It is composed of the majority of people and two minority groups that only differ in terms of their environmental concerns. The government represents the majority of people, i.e., takes all of the decisions on the basis of the median voter's preferences. The median voter equilibrium does not generally coincide with the efficient allocation, within a heterogenous population. Moreover, none of the pressure groups are satisfied with this outcome, which paves the way for lobbying activities. For the reasons stated above, we concentrate on the indirect form of lobbying intended to change (in any direction) people's mind about seriousness of environmental problems. Strategic competition for political influence is analyzed! by means of a differential game of lobbying *a la* Wirl (1994), whereby opposing interest groups, having different lobbying power, devote efforts to bring people's awareness closer to their preferred level. By doing so, each group expects to shift the balance of power in its preferred direction, thereby making the public policy more favorable to its own interests.

Our analysis emphasizes the role of two distinct forces, one related to the initial ranking between groups' environmental awareness, the other linked to minority groups' lobbying power. Neutralizing the latter force, we first find that the impact of strategic interaction on the economy stems from the interplay between both a direct effect and an indirect effect channeling through the preferences. We then show that indirect competition for political influence may result in a more efficient situation in the long run compared to what would prevail in the absence of lobbying. But this only occurs when the environmental group exhibits a radical ideology and/or people's awareness is initially closer to that of the industrial group. By contrast, economies with very aggressive conservative groups and/or with people originally well aware of environmental problems can never benefit from the outcome of the game of political influence. This strong asymmetry in the impact of public persu! asion also shows up once we account for different lobbying powers. In particular, those economies that face very aggressive and powerful industrial groups necessarily see the situation get worse as a result of the interaction for persuasion. This result may explain why the US have

failed to take action on global warming up to now. We finally obtain other mixed situations, that more accurately fit with the European case, in which indirect competition promotes efficiency gains under fairly general conditions.

The paper is organized as follows. A review of the related literature is carried out in Section 2. Section 3 presents the model and two benchmark situations. Then it displays the game of indirect competition for political influence. This game is solved in Section 4 where we also derive and discuss the main results as to the impact of the strategic interaction between opposing interest groups on the economy. Section 5 concludes.

2 Related literature

Besides the contributions of sociologists and political scientists mentioned in the Introduction, the current work can be related to different strands of literature. First, it contributes to the literature on lobbying or rent-seeking (see the seminal work of Tullock, 1967). Our paper is closely related to Wirl (1994), who has been the first to acknowledge the dynamic feature of the lobbying process. According to Wirl (1994), opposing interest groups do not compete for a given prize but invest in costly rent-seeking to change the legislation, and to influence the policy, in their favor. He develops a differential game of lobbying that incorporates the dynamic and strategic aspects of the interaction between two pressure groups, the government reacting passively to this pressure.[7]

Second, our work has a broad connection with the literature dealing with the interaction between private politics and public regulation (see Baron, 2001, 2003).[8] But all this literature is interested in the influence of ENGOs on firms' behavior while we deal

[7]His main finding is that at the Markov perfect equilibrium, lobbying efforts are lower than at the Open loop equilibrium (and so is the rent dissipation) because of a feedback ! effect.

[8]Private politics are non-market interactions between individuals, NGOs and firms. Baron notably emphasizes that non-market interactions may explain why firms has an incentive to self-regulate. Recent papers on this topic also include Daubanes and Rochet (2016)'s analysis of the effects of activism by a poorly informed environmental group on a regulated (polluting) sector in which the regulator is biased toward the industry. Egorov and Harstad (2017) analyze the interaction between public regulation, self-regulation by the firm, and boycotts by activists in a dynamic game without any assumption regarding the sequence of moves and without asymmetry of information.

with a specific form of interaction between enviro! nmental and industrial lobbies. Our work thus shares more similarities with Yu (2005)'s theory of direct vs indirect competition for political influence. He develops a three-stage game opposing an environmental lobby to an industrial one. Yu (2005) shows that higher environmental awareness induces the green group to devote more resources to indirect competition and to become less aggressive in direct lobbying. He finally concludes that the lack of direct lobbying by environmental groups may be more related to their greater effectiveness in increasing public awareness than to the lack of financial resources.

The third relevant literature is the one that is interested in the strategic use of information by informed parties in (static) signaling models. Asheim (2010) studies the situation where an environmental agency may decide – or not – to disclose information about the true state of the world in order to bring the Nash equilibrium of a public (environmental) good game, in which players display moral motivation, closer to the social optimum. In a recent paper, Chiroleu-Assouline and Lyon (2016) consider the interaction between industrial lobbies and green NGOs. In their setting, the industry has two main options in order to gain political influence (and to change the policy maker's beliefs about the state of Nature). Either, it can try to undermine the reputation of green NGOs (to pass them off as radical activists), or it can create a supportive think tank that will directly compete with green NGOs on scientific facts.

Last but not least, since public persuasion ultimately consists in changing the environmental concern of the public, our work also relates to the (more) narrow literature on endogenous preferences (Bowles, 1998). Focusing on environmental issues, there is now a growing evidence that environmental concerns may change as a response to the education level, wealth, or the exposure to pollution. A bunch of recent theoretical papers have then accounted for endogenous concerns in order to revisit the relationship between growth and the environment (see Prieur and Bréchet, 2013, Schumacher and Zou, 2015, and Schumacher, 2015). Finally, on the same topic but with a different perspective, Garcia-Gallego and Georgantzis (2009, 2011) study the impact of awareness raising campaigns on consumers' willingness to pay for green products. In a differentiated duopoly framework, they show that these campaigns do not necessarily enhance social welfare.[9]

[9]Welfare improvements occur onl! y if environmental awareness campaigns reduce consumers' heterogeneity by increasing the least environmentally conscious consumers willingness to pay for green

3 Model

3.1 Economic set-up and benchmarks

Let's consider one economy that derives a profit (surplus) from production, y, but also incurs a damage due to the accumulation of a pollution stock S. Denote the surplus by $\pi(y)$, with $\pi(\cdot)$ strictly concave, and the damage by $\gamma(S)$, which is strictly increasing and convex.

The economy is composed of the (majority) of people and two (minority) groups that do not share the same perception of the extent of the environmental damage for given pollution stock. Group i, $i = G, I, P$, *intrinsic* preferences are captured by a utility function which boils down to the difference between the profit and damage:

$$u_i(y, S) = \pi(y) - \mu_i \gamma(S), \tag{1}$$

with μ_i the relative weight of environmental damage in preferences. This parameter basically reflects group i's environmental awareness, which is more a matter of perception than of realization (of the damage). Environmental preferences will play a crucial role in the coming analysis as they represent the key source of heterogeneity among the three groups composing the population. Without loss of generality, we assume hereafter that environmental concern parameters satisfy the following ranking: $\mu_I \leq \mu_P(t) \leq \mu_G$ for all $t \geq 0$, meaning that G is the environmentalist or green group, while I forms the industrial or conservative group, and P is the majority of people.

The important point is that the majority, that displays an intermediate level of awareness, will be subject to public persuasion whereby minority groups will try to change its mind and instill their views through information campaigns vs disinformation tactics. So people's environmental awareness will be changing over time as a result of this specific form of political influence by the two groups (in a way that will be specified in Section 3.2). Population size is normalized to one, group i's size being denoted by $\rho_i \in (0, 1)$, with $\rho_I, \rho_G << 1 - \rho_G - \rho_I$. The average environmental awareness in the economy is:

$$\overline{\mu}(t) = \rho_I \mu_I + \rho_G \mu_G + (1 - \rho_I - \rho_G)\mu_P(t). \tag{2}$$

products.

In the absence of strategic interaction for political influence, people's awareness is set to a constant level: $\mu_P(t) = \mu_P(0) = \mu_P^0 \in (\mu_I, \mu_G)$ for all $t \geq 0$; the corresponding average concern in the population being denoted by $\overline{\mu}(0) = \overline{\mu}^0$. This is the scenario envisioned in the benchmarks analyzed just below.

Pollution dynamics are given by:

$$\dot{S} = \alpha y - \delta S, \tag{3}$$

with S_0 given, α, the emission/output ratio, and δ, the rate of pollution decay.

Let us briefly review two benchmark situations that may characterize our economy. For convenience, in the subsequent analysis, we use specific functional forms:[10]

$$\pi(y) = \theta y - \frac{\beta(y)^2}{2},\ \gamma(S) = \frac{S^2}{2},\ \text{with } \theta, \beta > 0. \tag{4}$$

First, we assume that a planner takes all of the decisions according to the criterion of the sum of the utility functions weighted by the relative group size, i.e., by solving:

$$\max_{\{y\}} \int_0^\infty \left\{ \sum_{i=G,I,P} \rho_i u_i(y, S) \right\} e^{-rt} dt, \tag{5}$$

subject to (3), with $S(0) = S_0$ given, and $r > 0$ the rate of pure time preference. In line with the (non-cooperative) differential games approach, this solution is defined as the *efficient outcome*, and serves as a first benchmark in the analysis. This definition of the efficient outcome is also consistent with the literature on lobbying competition for political influence. For instance, Lefebvre and Martimort (2016) use the unweighted sum of the median voter and (opposite) interest groups' payoffs.

Second, we consider that the policy is conducted by a (democratic) government rather than a benevolent decision maker. In this situation, a natural assumption is that the government takes care of the median voter's preferences. Since the median voter belongs to the majority, it implies that its optimization program is given by:

$$\max_{\{y\}} \int_0^\infty u_P(y, S) e^{-rt} dt, \tag{6}$$

[10]The analysis can be conducted with general functional forms provided that they yield steady state levels of output and production defined as monotone functions of the key preference parameter.

subject to (3), with $S(0) = S_0$ given. The resulting *median voter outcome* corresponds to the second benchmark.

Both problems are formally the same and can be solved easily for any constant preference parameter. In the remainder of the analysis, we will use the generic notation μ^k to refer to a situation where we work with a constant awareness parameter. For instance, for the benchmarks, we have $k = *, P$, with $\mu^* = \overline{\mu}^0$ in problem (5) and $\mu^P = \mu_P^0$ in problem (6). Then, we can establish the following:[11]

Proposition 1

- *The μ^k-type decision maker' actions drive the economy toward a unique steady state, which is saddle point stable. The levels of production and pollution are given by:*

$$\begin{cases} y_\infty^k = \frac{\delta\theta(r+\delta)}{\alpha^2\mu^k+\beta\delta(r+\delta)}, \\ S_\infty^k = \frac{\alpha\theta(r+\delta)}{\alpha^2\mu^k+\beta\delta(r+\delta)}. \end{cases} \tag{7}$$

- *Long term production and the stock of pollution are both decreasing in the degree of average environmental concerns.*

- *In the median voter economy, long term production and the pollution stock are higher (lower) than the efficient levels if and only if $\mu_P^0 < (>)\overline{\mu}^0$.*

Not surprisingly, the median voter outcome does not coincide in general with the efficient outcome simply because μ_P^0 is different from $\overline{\mu}^0$.[12] For the moment, we do not impose any restriction on the ranking between μ_P^0 and $\overline{\mu}^0$, which will play a key role in the remainder of the analysis. What is interesting to note at this stage is that none of the two minority groups are satisfied with the policy conducted by the government. Again this is due to diverging perception of the seriousness of environmental problems.[13] So both have a motive for influencing the policy through public persuasion and political activism.

[11] See the Appendix A.1.

[12] Both solutions, however, belong to the Pareto frontier.

[13] Replacing $u_P(y, S)$ with $u_i(y, S)$, for $i = I, G$, in (6) is sufficient to characterize group i's preferred solution, i.e., the solution it would choose if it were the decision maker in office.

In the next section, we scrutinize the situation in which groups I and G compete for political influence by engaging in (dis)information campaigns. This kind of strategy is aiming at changing the environmental concerns of uninformed people (or voters; see Baron, 1994), thereby affecting environmental regulation.

3.2 Game of indirect political influence

Under political influence, people's awareness μ_P will no longer be constant and the main issue is how to model its evolution. Here we depart from the literature that relies on static signaling games to depict situations in which informed parties try to reveal to the public the signals they receive (see the references in the Introduction). So we get rid of the issue of the credibility of information transmission under asymmetric information. Rather, we build the dynamic counterpart of the theory of public persuasion developed by Yu (2005). According to this approach, (opposite) interest groups devote efforts to either raise or lower the people's belief or perception. Put differently, they can indirectly change the objective function of the government through information campaigns intended to modify μ_P.

The simplest way to account for the impact of public persuasion consists in introducing a new state variable, $z \in [0, 1]$, that refers to the balance of power in the economy. Then, we can define the endogenous environmental awareness of the majority as a function of z. By convention, the larger z, the more the people share the industrialists' view (the more favorable the policy is to the industrial group). This leads to the following definition:

$$\mu_P(t) = \mu(z) \text{ with } \mu'(z) < 0 \text{ for all } z,\ \mu(0) = \mu_G, \text{ and } \mu(1) = \mu_I. \tag{8}$$

Note that if $\mu_P(t)$ hits one boundary of the interval $[\mu_I, \mu_G]$, then we obtain a corner solution at which one of the minority groups actually forms the new majority. In the event that this happens in finite time, the game of indirect political influence between the interest groups comes to an end. However, it can be shown that this situation cannot arise at the equilibrium.[14]

[14]The proof is available upon request.

The evolution of z is given by the following differential equation:

$$\dot{z} = \phi_I x_I - x_G, \tag{9}$$

where x_i, $i = I, G$ represents the persuasion effort of group i, and $\phi_I > 0$ corresponds to the relative persuasion power of the industrialists. So we extend Wirl (1994)'s approach by introducing heterogeneity in the capacity of pressure groups to influence people's mind. Arguments for why the size of ϕ_I should be high (> 1) or low (< 1) are mixed at first glance. Indeed, when it comes to the analysis of the impact of interest groups on people's environmental concern, one may argue that industrial or conservative groups are stronger than environmentalists simply because of higher financial means. But, on the other hand, environmental groups are generally seen as more credible than industrialists in spreading accurate information about environmental problems, which may place them in better position in the game. So we put no further restriction on ϕ_I and discuss the two cases.

Of course, in this particular problem, group I wants μ_P to be as close as possible to its own evaluation, μ_I, and thus pushes for increasing z. The converse is true for the environmentalist group. So both groups have an incentive to engage in the competition for indirect political influence. As to the definition of players' relevant payoffs, we assume that group i dislikes any departure from her own perception of environmental damage, μ_i, and define $D(\mu_i - \mu(z))$ as the cost of the existing distance between the implemented policy and the policy preferred by group i.[15] Finally, the effort is costly and captured by a quadratic cost function. In short, we use the following functional forms:

$$\begin{aligned} \mu(z) &= \mu_G - (\mu_G - \mu_I)z, \\ D(\mu_i - \mu(z)) &= \tfrac{(\mu_i - \mu(z))^2}{2}. \end{aligned} \tag{10}$$

[15]Intrinsic preferences cannot be used directly in the game as they do not depend on μ_P, or z. But they ultimately provide us with (micro)foundations of the minority groups' objective functions when they interact with each other for political influence. Moreover, one could argue that interest groups may have an incentive to cheat. In this reduced form game, this may be cap! tured by replacing μ_i in $D(.)$ with $\tilde{\mu}_i \neq \mu_i$. For instance, we would have $\tilde{\mu}_I < \mu_I$ to convey the idea that the industrial group is biased against any upward departure from μ_I. But, as long as both groups develop such behaviors, they tend to neutralize each other at the equilibrium. In line with Yu (2005), we then choose to disregard this eventuality.

In the game of public persuasion, group i's optimization program can be expressed as:

$$\min_{\{x_i\}} \rho_i \int_0^{\infty} \left[\frac{(\mu_i - \mu_G + (\mu_G - \mu_I)z)^2}{2} + \frac{\epsilon}{2} \left(\frac{x_i}{\rho_i} \right)^2 \right] e^{-rt} dt, \tag{11}$$

subject to (9) and given $z(0) = z_0$. In fact, z_0 is determined by the initial environmental concern of the people, μ_P^0, once we use the relationship between awareness parameters in (10): $z_0 = \frac{\mu_G - \mu_P^0}{\mu_G - \mu_I} \in (0, 1)$.

Before we go to the main analysis, it is worth clarifying our general approach. Hereafter we start by solving the game in order to get the equilibrium efforts of the two groups and the resulting dynamics of z and μ_P. For simplicity, we assume that groups G and I have the same size: $\rho_I = \rho_G = \rho$, the expression of the average awareness (2) simplifying to:

$$\overline{\mu}(t) = 2\rho\overline{\mu}_{-P} + (1 - 2\rho)\mu_P(t) \text{ with } \overline{\mu}_{-P} = \frac{\mu_I + \mu_G}{2}. \tag{12}$$

Once the equilibrium trajectory for the public's environmental concern, $\mu_P(t) = \mu(z(t))$, has been determined, we examine the outcome of the government's policy when it follows the preferences of the median voter, that are given by the sequence of non constant weights $\{\mu_P(t)\}_{t=0}^{\infty}$, but is subject to the indirect form of political influence. This boils down to considering that the government is totally passive and simply implements the policy preferred by the median voter while being subject to political influence. Most of the analysis will settle in the long run. In particular, our aim will be to compare the steady state level of production and pollution with and without public persuasion.

4 Equilibrium outcomes

We focus on the Open-Loop Nash equilibrium (OLNE). The information structure underlying the OLNE is very demanding but it is nevertheless interesting because it allows us to solve the game above with asymmetric persuasion power. Actually, it turns out that we can solve for the Markov-Perfect Nash equilibrium (MPNE) for the symmetric case only ($\phi_I = 1$, see the Appendix A.3 for a description of the solution). But since the steady state levels, for z and μ_P, are the same as those of the OLNE in

this case, we can just restrict our attention to the OLNE.[16] Whatever the equilibrium concept, the resolution extensively relies on standard techniques; so we refer to Wirl (1994) for details.

The OLNE is solved by means of the Pontryagin Principle. Let player i's Hamiltonian be defined as:

$$H_i = \rho \left(\frac{(\mu_i - \mu(z))^2}{2} + \frac{\epsilon}{2} \left(\frac{x_i}{\rho} \right)^2 \right) + \lambda_i(\phi_I x_I - x_G)$$

with λ_i the shadow value of z for player i, $i = I, G$. Direct manipulation of the necessary conditions allows us to present the persuasion efforts at the OLNE. Hereafter we present the closed-loop shaped open-loop strategies and the corresponding dynamics for z and μ_P.

Proposition 2

- *At the OLNE, interest groups' strategies are given by:*

$$\begin{aligned} x_I(t) &= \frac{\rho^2 \phi_I (r+b)(\mu_G - \mu_I)^2}{\epsilon r (r + (1+\phi_I^2)b)} - \phi_I b z(t), \\ x_G(t) &= \frac{\rho^2 \phi_I^2 b (\mu_G - \mu_I)^2}{\epsilon r (r + (1+\phi_I^2)b)} + b z(t), \\ \textit{with} \quad b &= \tfrac{1}{2(1+\phi_I^2)} \left(\sqrt{r^2 + \tfrac{4(1+\phi_I^2)\rho^2(\mu_G - \mu_I)^2}{\epsilon}} - r \right) > 0. \end{aligned} \tag{13}$$

- *The balance of power in the economy and the induced level of people's environmental awareness, at any instant t, are given by:*

$$\begin{aligned} z(t) &= z_\infty + (z_0 - z_\infty) e^{-(1+\phi_I^2)bt}, \\ \mu_P(t) &= \mu_P^\infty + (\mu_P^0 - \mu_P^\infty) e^{-(1+\phi_I^2)bt}, \end{aligned} \tag{14}$$

  with $z_\infty = \frac{\phi_I^2}{1+\phi_I^2}$ and $\mu_P^\infty = \frac{\mu_G + \phi_I^2 \mu_I}{1+\phi_I^2}$, the respective steady state values.

- *The convergence is monotone decreasing in term of $z(t)$ (respectively monotone increasing with respect to $\mu_P(t)$) if and only if $z_0 > z_\infty$ ($\Leftrightarrow \mu_P^0 > \mu_P^\infty$).*

[16] By the way, looking at the impact of asymmetric power on the steady state at the OLNE should give a good approximation of the results at the MPNE, that we can check numerically.

What comes out from this Proposition is the role of two types of conditions involving the main parameters of the model. The first type has to do with the relative ranking between environmental preferences when the game starts. Once we observe that the following equivalences hold, $\mu_P^0 \lesseqgtr \overline{\mu}^0 \Leftrightarrow \mu_P^0 \lesseqgtr \overline{\mu}_{-P} \Leftrightarrow \overline{\mu}^0 \lesseqgtr \overline{\mu}_{-P}$, there are two cases to consider: $\overline{\mu}_{-P} > \overline{\mu}^0 > \mu_P^0$ vs the opposite. This is gonna explain in particular how the long run value μ_P^∞ compares to the initial one $\mu_P(0) = \mu_P^0$. The second important determinant of the results is the relative persuasion power of the two groups. There is a clear dichotomy between two cases: $\phi_I > 1$ vs $\phi_I < 1$. As mentioned earlier, this is not obvious at first glance to tell which is the more relevant or realistic one, so we consider both. As apparent in the statement abov! e, the size of ϕ_I will be crucial to understand the absolute level to which $z \in [0,1]$ and $\mu_P \in [\mu_I, \mu_G]$ will converge in the long run.

Bearing all this information in mind, we can provide a description of the forces at work in the economy. Indeed, the main task is to explain the impact of strategic interaction between interest groups – and how it relates to the two conditions above ($\phi_I \lesseqgtr 1$ and $\mu_P^0 \lesseqgtr \overline{\mu}_{-P}$). Suppose that $\phi_I = 1$ (same persuasion power). Then, strategic interaction intrinsically acts as an homogenizing force. Whatever the initial imbalance, that is characterized by the ranking between μ_P^0 and $\overline{\mu}_{-P}$ (and $\overline{\mu}^0$), the interaction between lobbies is going to erase (part of) the difference by promoting the convergence toward the average concern of the minority groups, $\overline{\mu}_{-P}$. Why is it so? From (13), we observe that following any change in z, groups' efforts move in opposite directions: group I responds to an increase in z (a decrease in μ_P) by decreasing its effort while group! G reacts to the same change by increasing its own effort.[17] This all pushes the system to an average position in the long run; the initial imbalance explaining how the adjustment will take place. Now let us add $\phi_I \lesseqgtr 1$ to the picture. Things get more complicated because having $\phi_I \neq 1$ tends, on the contrary, to destabilize the balance of power in, and the outcome of, the game. In fact, $\phi_I < 1$ places the green group in a better position to influence people's awareness whereas the opposite is true for $\phi_I > 1$ (simply observe that μ_P^∞ is decreasing in ϕ_I).

Overall we want to understand the interplay between these two (opposite) effects

[17] Intuitively, each group exerts less efforts in good times, when people's awareness is closer to its own preferences, than in bad times, when the situation gets worse.

and how it depends on the main parameters of the model. Proceeding step by step, in the next Section 4.1, we first study the impact of strategic interaction when players share the same persuasion power. Then, in Section 4.2, we put all these elements together and further investigate the consequences of indirect political influence on the economy.

4.1 Identical persuasion power

When the two lobbyists have the same power ($\phi_I = 1$), Proposition 2 teaches us that people's environmental awareness converges to the average value of the minority groups, which also coincides with the average concern of the population: $\mu_P^\infty = \overline{\mu}_{-P} = \overline{\mu}^\infty$. So, the economy governed by the median voter but subject to indirect political influence will continuously deviate from the trajectory leading to (y_∞^P, S_∞^P), and end up in a new steady state $(y_\infty^\mu, S_\infty^\mu)$ (to get these expressions, simply replace μ^k with respectively μ_P^0 and $\overline{\mu}_{-P}$ in (7)).[18] As explained above, strategic interaction progressively erases the differences in preferenc! es between the majority and the minority groups. It brings the economy to a situation – in the long run – in which the policy maker, by obeying the majority's preferences, also follows the average environmental concern of the whole population.

At first glance, it seems that the economy may take advantage of the struggle between opposite interest groups for influencing people's mind. This is not entirely correct because if strategic interaction does lead to a situation where the policy maker uses the average environmental concern to solve its tradeoff eventually,[19] this steady state concern generally differs from the initial one, i.e., $\overline{\mu}^\infty \neq \overline{\mu}^0$.

Therefore, we now have to examine the impact of indirect competition for political influence on production and pollution. For that purpose, we use a simple criterion to measure efficiency gains. By convention, we say that there is an improvement of the economic performance if and only if the difference $y_\infty^\mu - y_\infty^*$ is lower than the difference $y_\infty^P - y_\infty^*$, both taken in absolute value. The same logic is at work to assess changes in

[18] The superscript $*$ stands for the efficient outcome, the equilibrium in the median voter economy is indexed by P when there is no indirect political influence and by μ otherwise.

[19] Recall that this is the main feature of the efficient solution (see Section 3.1).

environmental performance.[20]

Proposition 3 *When the government follows the median voter's preferences but is subject to indirect political influence intended to shape the people's environmental awareness,*

- *the steady state levels of output and pollution decrease compared to the situation without strategic behaviors and become lower than the efficient levels,* $y_\infty^\mu < y_\infty^* < y_\infty^P$ *and* $S_\infty^\mu < S_\infty^* < S_\infty^P$*, if and only if the initial ranking in preferences satisfies* $\mu_P^0 < \overline{\mu}^0 < \overline{\mu}_{-P}$*.*
- *A necessary condition for indirect political influence to be good for the economy is:*

$$\mu_P^0 < \frac{2\rho}{1-2\rho}\overline{\mu}_{-P}. \tag{15}$$

- *When* $\mu_P^0 < \overline{\mu}^0 < \overline{\mu}_{-P}$*, strategic interaction between lobbyists improves both the economic and environmental performance if and only if:*

$$\mu_P^0 < \frac{2\rho}{1-2\rho}\overline{\mu}_{-P} - \frac{1-4\rho}{1-2\rho}\frac{\beta\delta(r+\delta)}{\alpha^2}. \tag{16}$$

- *In the opposite situation, with* $\overline{\mu}_{-P} < \overline{\mu}^0 < \mu_P^0$*, public persuasion cannot result in better economic and environmental performance.*

Neutralizing the impact of different persuasion power allows us to concentrate on the role of the initial ranking between the awareness parameters, as explained earlier. The analysis reveals that this ranking is indeed of primary importance. Assume that the economy is initially characterized by $\mu_P^0 < \overline{\mu}^0 < \overline{\mu}_{-P}$, which basically means that the people are initially closer to the industrialists' view because, for instance, the green lobby is driven by an extreme form of environmentalism, i.e., μ_G is very high (like in Daubanes and Rochet, 2016). In this case, improvement of the performance thanks to this indirect form of political influence is possible. It requires the minority groups' size be large enough and people awareness be initially low to satisfy (15). From (16), we also note that it is more likely when the stock of pollution is a very persistent one, so

[20]We acknowledge that engaging in political influence is accompanied by a waste of economic resources. This is the well-known rent dissipation induced by lobbying (Tullock, 1967). But, in accordance with the evidence, we consider that this remains a second-order effect when it comes to the analysis of the impact of public persuasion on the aggregate economy.

that δ is low, which fits perfectly with climate cha! nge. In this situation and from that perspective, public persuasion is good for the economy.

On the other hand, when the industrial, or conservative, group displays very aggressive attitude toward the environment (μ_I is very low), one expects that people's concern is nearer that of the environmental group, which implies that $\overline{\mu}_{-P} < \overline{\mu}^0 < \mu_P^0$. In this case, we can conclude that the game for indirect political influence cannot lead the economy to a better situation in the long run.

How is it that public persuasion has so different implications in these two situations? In both cases, there is a first direct (or dynamic) effect that shows up in the evolution of the preferences. Strategic interaction results in a larger gap between the majority's concern and the (initial) average concern of the population: $|\overline{\mu}^0 - \mu_P^0| < |\overline{\mu}^0 - \mu_P^\infty|$. This, other things equal, is bad news for the economy since it tends to bring the economy further away from the efficient outcome. This also means that there must exist a second (indirect) effect that may push in the opposite – or the same – direction as the first one depending on whether $\overline{\mu}_{-P} \gtrless \mu_P^0$. It turns out that this second effect comes from the convexity of the preferences. More precisely, it is relatively easy to show that steady state levels of production and pollution, as defined in Proposition 1, are decreasing and ! convex functions of the awareness parameter. This implies that following a change in μ^k of the same magnitude, the larger the reference point, the lower the impact on y_∞^k or S_∞^k.

This second effect more than offsets the former effect when the initial ranking is $\overline{\mu}_{-P} > \overline{\mu}^0 > \mu_P^0$, whereas it adds up to it when the opposite ranking prevails. Note that the latter effect is, in essence, static and partly comes from our choice of working with quadratic utility functions. But it may hold for other and more general forms of utility functions.[21]

So, the main conclusion drawn from the analysis is the existence of a strong asymmetry in the impact of indirect competition for political influence. In the next Section, we extend the results to the case with different persuasion powers.

[21] For instance, it works for a log (in y), linear (in S) utility function.

4.2 Different lobbying power

We now examine the situation where the heterogeneity among players can also be found in their capacity to influence the people by investing in information campaigns vs disinformation strategies. With $\phi_I \neq 1$, several other outcomes may arise thanks to the interplay between the effects presented following Propositions 2 and 3. Hereafter, we pick up the most interesting results and discuss some of their implications. One can start noticing that by combining $\phi_I < 1$ with $\mu_P^0 < (\overline{\mu}^0) < \overline{\mu}_{-P}$, and $\phi_I > 1$ with $\overline{\mu}_{-P}(< \overline{\mu}^0) < \mu_P^0$, we obtain the same kind of results as the ones stated in Proposition 3. More precisely, better performance due to lobbying is still possible when $\mu_P^0 < \overline{\mu}_{-P}$ goes along with $\phi_I < 1$.[22] With $\mu_P^0 < \overline{\mu}_{-P}$, according to the first effect, people's awareness will rise, other things equal. Strategic interaction thus results in a more favorable situation for the green group. If, on top of that, we add $\phi_I < 1$, then the second effect reinforces the former by putting this group is an even better position to change μ_P. This is still compatible with efficiency gains. In the same vein, when $\phi_I > 1$, the second effect pushes in the same direction as the one channeling through $\overline{\mu}_{-P} < \mu_P^0$. The industrial group faces so good conditions that it wins the game of political influence by substantially lowering μ_P. The strong asymmetry highlighted in Proposition 3 is also valid here: there is nothing to expect from such a parameter configuration.

One may argue that the latter combination gives a proper account of the situation in the US. Conservative groups have been strongly opposed to any environmental regulation since the nineties (very low μ_I). At the same time they were supported by very powerful corporations with stakes in the fossil fuels sector (ϕ_I high, and larger than 1). As mentioned earlier, this period of time coincided with both the rise of the environmentalism ideology and the international acknowledgment that human activities were responsible for global warming (see Oreskes and Conway, 2010). However, the balance of power was clearly in favor of the industrialists. This may explain why they have succeeded in maintaining environmental regulation to a low and not too stringent level from that time up to now. Spreading wrong information to the public[23] and

[22] The necessary condition is the same as (15) whereas the necessary and sufficient condition (16) be! comes weaker or stronger depending on the model parameters (see the Appendix A.2).

[23] About the very existence of warming and the (absence of) causality between burning fossil fuels

keeping people ! environmental concern to a low level, has been part of a successful strategy to prevent any rise in citizens' demand for drastic pollution control. The former combination seems to provide us with a better description of what has been going on in Europe during the same period, where environmental lobbies have grown in visibility and have become more efficient in changing people's mind.

Even more interesting are the two remaining cases where either $\phi_I < 1$ and $\overline{\mu}_{-P} < \mu_P^0$, or $\phi_I > 1$ and $\overline{\mu}_{-P} > \mu_P^0$. These are mixed situations where for instance (second case) the industrialists' lobbying power is weaker than the one of the environmentalists but the latter display very strong preferences for the environment. Denote the critical level of relative lobbying power as $\tilde{\phi}_I$, with $\tilde{\phi}_I = \sqrt{\frac{\mu_G - \mu_P^0}{\mu_P^0 - \mu_I}}$. Then we can show that:

Proposition 4

- *With different lobbying power, the steady state environmental awareness of the people is such that:* $\mu_P^\infty \lesseqgtr \overline{\mu}_{-P} \Leftrightarrow \phi_I \gtreqless 1$.
- *Suppose first that* $\phi_I < 1$ *and* $\overline{\mu}_{-P}(< \overline{\mu}^0) < \mu_P^0$. *If* $\phi_I \in [\tilde{\phi}_I, 1)$, *then people's awareness monotonically decreases as a result of the groups' lobbying efforts. A sufficient condition for the situation to be improving is* $\mu_P^\infty > \overline{\mu}^0$, *which is equivalent to*

$$\mu_P^0 < \frac{\mu_G + \phi_I^2 \mu_I}{1 + \phi_I^2} - 2\rho\overline{\mu}_{-P}. \tag{17}$$

  Else, $\phi_I < \tilde{\phi}_I$, *awareness monotonically increases, and there is no improvement possible of the economic and environmental situation in the long run.*

- *Consider next that* $\phi_I > 1$ *and* $\overline{\mu}_{-P}(> \overline{\mu}^0) > \mu_P^0$. *If* $\phi_I \geq \tilde{\phi}_I$, *people's awareness monotonically decreases; there is nothing to gain from indirect competition for political influence. Else,* $\phi_I \in (1, \tilde{\phi}_I)$, *awareness monotonically increases and a sufficient condition for an improvement induced by public persuasion is* $\mu_P^\infty < \overline{\mu}^0$, *which is the exact opposite of condition (17).*

For a discussion of these mixed situations, it is enough to consider the case reported in the second item of Proposition 4. Here we have $\phi_I < 1$ and $\overline{\mu}_{-P}(< \overline{\mu}^0) < \mu_P^0$.

and climate change.

From the above analysis, $\overline{\mu}_{-P}(< \overline{\mu}^0) < \mu_P^0$ should result in a decrease of the people's awareness thanks to the homogenizing force. Whereas $\phi_I < 1$ pushes in the opposite direction by placing the environmentalists in a better position to change people's mind. It turns out that if $\phi_I < \tilde{\phi}_I$, then the latter effect is very strong and overwhelms the former. So, public persuasion induces an increase in μ_P and pushes the economy further away from the optimum. In the opposite situation, $\phi_I \geq \tilde{\phi}_I$, the industrialists' power is sufficiently high to ensure that the homogenizing force will take over: environmental concern will decrease as a result of indirect political influence. But then the next quest! ion is: will this process lead the economy to a better situation than the one that would prevail in the absence of lobbying eventually? Quite logically, we find that a sufficient condition for the improvement of the economic and environmental performance is ϕ_I be low enough.[24] Indeed in this case, the outcome of the interaction for political influence will be a decrease in μ_P but to a limited extent, implying that μ_P^∞ will remain higher than $\overline{\mu}^0$.

5 Conclusion

This paper aims at studying the impact of strategic interaction between opposing interest groups on environmental and economic performance. Motivated by the history of climate politics in the US over the last decades, it focuses on the specific form of indirect competition for political influence through environmental awareness raising vs disinformation campaigns. In order to change the government's policy in their preferred direction, each – environmental vs industrial – group devotes efforts to bring the majority's concern closer to its view. The impact of strategic interaction between pressure groups on environmental policy stems from the interplay between both a direct and an indirect effect channeling through the preferences. The analysis of the outcome of the game of political influence then shows a strong asymmetry in the results. Strategic interaction may result in a more efficient situation in the long run compared to what would prevail in the absenc! e of lobbying. But this only occurs when the environmental group exhibits a radical ideology and/or people's awareness is initially closer to that of the industrial group. By contrast, economies with very aggressive

[24]It is easy to check that condition (17) holds for ϕ_I close to $\tilde{\phi}_I$.

conservative groups and/or with people originally well aware of environmental problems can never benefit from the outcome of the game of political influence. The latter result is reinforced when one accounts for different lobbying powers and supremacy of industrial groups. This may explain why the US have failed to take action on global warming up to now.

In further works, it would be interesting to determine whether one can get the same qualitative results in the short and medium terms. We may also analyze the impact of the other form of direct lobbying on the economy, and compare the results with the one obtained in the present paper. In another extension of the analysis, one may want to enrich the dynamic structure of the basic model, by adding capital accumulation for instance, in order to investigate more deeply the implications of lobbying on environmental policy and growth prospects.

A Appendix

A.1 Proof of proposition 1

Solving the general problem yields a dynamical system in (y, S), parameterized by μ^k:

$$\begin{cases} \dot{y} = \beta^{-1}[\alpha\mu^k S - (r+\delta)(\theta - \beta y)], \\ \dot{S} = \alpha y - \delta S. \end{cases}$$

Combining these conditions, we obtain a second order differential equation in S:

$$\ddot{S} - r\dot{S} - \beta^{-1}(\alpha^2\mu^k + \beta\delta(r+\delta))S + \beta^{-1}\alpha\theta(r+\delta) = 0.$$

With a constant μ^k, this equation has the following analytical solution (after making use of the transversality condition):

$$\begin{aligned} S^k(t) &= S^k_\infty + (S_0 - S^k_\infty)e^{B^k t} \\ y^k(t) &= \frac{1}{\alpha}\left(\delta S^k_\infty + (\delta + B^k)(S_0 - S^k_\infty)e^{B^k t}\right) \end{aligned} \tag{18}$$

where

$$\begin{aligned} S^k_\infty &= \frac{\alpha\theta(r+\delta)}{\alpha^2\mu^k + \beta\delta(r+\delta)} \\ B^k &= \frac{r - \sqrt{r^2 + 4\beta^{-1}(\alpha^2\mu^k + \beta\delta(r+\delta))}}{2} < 0, \end{aligned}$$

respectively correspond to the long-run equilibrium value of the dynamic process and the speed of convergence to this value. Hereafter we pay attention to monotone trajectories for $S^k(t)$, that is we assume that $S_0 = \max\left\{S^k_\infty\right\}$ only (the analysis can be extended to the other possible cases). From the preliminary results above, we can compare the different solutions obtained when considering a constant awareness parameter. In particular, let us consider the index $k = P, *, -P$ where $k = P$ refers to the MV economy without lobbying, $k = *$ to the efficient solution, and $k = -P$ to the solution reached in an economy following the average preference of the minority groups, $\overline{\mu}_{-P}$. Then one can check that the ranking $\mu^0_P < \overline{\mu}^0 < \overline{\mu}_{-P}$ (or with the notations above $\mu^P < \mu^* < \mu^{-P}$) is equivalent to: $0 < -B^P < -B^* < -B^{-P}$ and $S^{-P}(t) < S^*(t) < S^P(t)$ for all t. The inequalities are reversed for the other o! pposite ranking.

One can finally note that the dynamics in the economy ruled by the median voter but subject to lobbying are given by:

$$\ddot{S} - r\dot{S} - \beta^{-1}(\alpha^2\mu_P(t) + \beta\delta(r+\delta))S + \beta^{-1}\alpha\theta(r+\delta) = 0.$$

Since people's awareness is not constant, it is no longer possible to characterize the explicit solution $(y^\mu(t), S^\mu(t))$, except asymptotically.

A.2 Proof of Propositions 3 and 4

We start with the more general situation where $\phi_I \neq 1$, detail the proof of Proposition 4, and derive the one of Proposition 3 as a particular case. Hereafter we review the four possible cases, which depend on whether $\mu_P^0 \lesseqgtr \overline{\mu}_{-P}$ and $\phi_I \gtreqless 1$.

A.2.1 Ranking in the different cases

• **Case 1:** $\phi_I \leqq 1$ **and** $\mu_P^0 < \overline{\mu}^0 < \overline{\mu}_{-P}$.

From the expressions of steady state output levels (see (7), the analysis is identical when working with the stock of pollution) and given that $\phi_I \leqq 1 \Leftrightarrow \mu_\infty^P \geqq \overline{\mu}_{-P}$, we have $y_\infty^P > y_\infty^* > y_\infty^\mu$.

Now let us define Δ as the gap between μ_∞^P and $\overline{\mu}_{-P}$:

$$\Delta = \mu_\infty^P - \overline{\mu}_{-P} = \frac{(\mu_G - \mu_I)(1-\phi_I^2)}{2(1+\phi_I^2)}, \tag{19}$$

which is non-negative in Case 1 and ultimately related to the gap between minority groups' preferences.

By convention, we say that strategic interaction improves economic (and environmental) performance if and only if it brings the long term equilibrium closer to the benchmark. That is, improvement occurs iff $|y_\infty^\mu - y_\infty^*| < |y_\infty^P - y_\infty^*|$. Then, from straightforward algebra we get that this is equivalent to

$$\alpha^2[2\rho\overline{\mu}_{-P} - (1-2\rho)\mu_P^0] > \beta\delta(r+\delta)(1-4\rho) + \frac{\Delta}{\overline{\mu}_{-P} - \mu_P^0}\left[\beta\delta(r+\delta) - \alpha^2(2\rho\overline{\mu}_{-P} - (1+2\rho)\mu_P^0)\right] \tag{20}$$

Now take $\phi_I = 1 \Leftrightarrow \Delta = 0$, then the condition reduces to

$$\alpha^2[2\rho\overline{\mu}_{-P} - (1-2\rho)\mu_P^0] > \beta\delta(r+\delta)(1-4\rho) \tag{21}$$

As ρ is lower than $\frac{1}{4}$ by definition, the RHS of (21) is positive and the inequality can be satisfied only if $2\rho\overline{\mu}_{-P} - (1-2\rho)\mu_P^0 > 0$, which requires the relative size of minority groups, ρ, be high enough. Then, condition (21) can be rewritten as (16) in Proposition 3.

In the general case with $\phi_I < 1$, the necessary and sufficient condition becomes weaker (resp. stronger) when the term $\beta\delta(r+\delta) - \alpha^2(2\rho\overline{\mu}_{-P} - (1+2\rho)\mu_P^0)$, in the RHS of (20), is negative (resp. positive). Note that imposing this term be negative is equivalent to

$$\mu_P^0 < \frac{2\rho}{1+2\rho}\overline{\mu}_{-P} - \frac{1}{1+2\rho}\frac{\beta\delta(r+\delta)}{\alpha^2},$$

which is similar to – yet different from – (16) in Proposition 3.

• **Case 2:** $\phi_I \geqq 1$ **and** $\mu_P^0 > \overline{\mu}^0 > \overline{\mu}_{-P}$.

Here we know that Δ is non-positive and we necessarily have the opposite ranking for steady state outputs: $y_\infty^P < y_\infty^* < y_\infty^\mu$. Following the same approach as before, we obtain $|y_\infty^\mu - y_\infty^*| < |y_\infty^* - y_\infty^P|$ is equivalent to condition (20) again. Now one can observe that the RHS of (20) is positive for all $\Delta \leqq 0$. But once we observe that the LHS is always negative because ($\rho < \frac{1}{4}$ and) $\mu_P^0 > \overline{\mu}_{-P}$ in Case 2, then we can conclude that there is no improvement possible whether $\phi_I = 1$ or $\phi_I > 1$. This leads to the last statement in Proposition 3.

• **Case 3:** $\phi_I < 1$ **and** $\mu_P^0 > \overline{\mu}^0 > \overline{\mu}_{-P}$.

In this third case, one has $\mu_\infty^P > \overline{\mu}_{-P}$ ($\Delta > 0$) and we have now to determine how μ_∞^P situates w.r.t μ_P^0 and $\overline{\mu}^0$. It requires to look at the equilibrium dynamics of z, given by (14) in Proposition 2. Then, it is easy to check that $z_0 < z_\infty \Leftrightarrow \phi_I > \tilde{\phi}_I$, with $\tilde{\phi}_I = \sqrt{\left(\frac{\mu_G - \mu_P^0}{\mu_P^0 - \mu_I}\right)} \in (0,1)$, in Case 3. If the trajectory is monotone non-increasing ($z_0 \geq z_\infty \leftrightarrow \phi_I \leq \tilde{\phi}_I$), then strategic interaction cannot bring the system closer to the benchmark, i.e., there can't be any improvement of economic performance. Otherwise ($z_0 < z_\infty \leftrightarrow \phi_I \in (\tilde{\phi}_I, 1)$), the trajectory is monotone increasing, which in turn implies that $\mu_P^\infty < \mu_P^0$. Then, it follows that a sufficient condition for an improvement of

economic performance is $\mu_P^{\text{inf!}ty} \geq \overline{\mu}^0$, which is equivalent to

$$\Delta \geq (1-2\rho)(\mu_P^0 - \overline{\mu}_{-P}). \tag{22}$$

This condition involves both the gap between minority groups' awareness and the gap the majority's awareness and the average one of the two minority groups. It can be rewritten as (17) in Proposition 4.

Assume that this condition is not met, which means that μ_P^∞ falls below $\overline{\mu}^0$. Then a gain is still possible if and only if condition (20) holds. Note that, in contrast with Case 2, that shares the same initial ranking in preferences, this condition can indeed be satisfied once we account for specific asymmetry in the lobbying power. This leads to the second statement in Proposition 4.

• **Case 4:** $\phi_I > 1$ **and** $\mu_P^0 < \overline{\mu}^0 < \overline{\mu}_{-P}$.

In the last case, the same logic as in the previous case is at work. This leads to the third item in Proposition 4.

A.2.2 Strong asymmetry in the results when $\phi_I = 1$

The computation of the gap $|y_\infty^\mu - y_\infty^*|$ on one hand, and $|y_\infty^P - y_\infty^*|$ on the other, is simple. In Case 1 for instance, one obtains $y_\infty^P - y_\infty^* > y_\infty^* - y_\infty^\mu \Leftrightarrow$

$$\frac{\overline{\mu}^0 - \mu_P^0}{\alpha^2\mu_P^0 + \beta\delta(r+\delta)} > \frac{\overline{\mu}_{-P} - \overline{\mu}^0}{\alpha^2\overline{\mu}_{-P} + \beta\delta(r+\delta)}.$$

Look at the numerator first. One has $\overline{\mu}^0 - \mu_P^0 = 2\rho(\overline{\mu}_{-P} - \mu_P^0) < (1-2\rho)(\overline{\mu}_{-P} - \mu_P^0) = \overline{\mu}_{-P} - \overline{\mu}^0$: public persuasion results in a larger gap between the majority's concern and the (initial) average concern in the population. Actually, whatever the Case, 1 or 2, it turns out that we end up with the following comparison: $|y_\infty^\mu - y_\infty^*| < |y_\infty^P - y_\infty^*|$ is equivalent to:

$$\frac{2\rho}{\alpha^2\mu_P^0 + \beta\delta(r+\delta)} > \frac{1-2\rho}{\alpha^2\overline{\mu}_{-P} + \beta\delta(r+\delta)}, \tag{23}$$

and, as long as $2\rho < 1-2\rho$, we see that if improvement is possible in Case 1 (where we assume $\mu_P^0 < \overline{\mu}_{-P}$), it is impossible in Case 2 (where $\mu_P^0 > \overline{\mu}_{-P}$). This means that there exists another effect that may offset the former, at least in Case 1. Now we can show that this second effect also plays through the (shape of the) preferences.

Let us work for the time being with general functional forms (except that we assume separability). Recall that group i's payoffs are given by: $u_i = \pi(y) - \mu_i\gamma(S)$. Evaluating the FOCs at the steady state,

$$(r+\delta)\pi'(y) = \alpha\mu^k\gamma'(S),$$
$$\alpha y = \delta S,$$

we obtain

$$(r+\delta)\pi'(y) = \alpha\mu^k\gamma'(\frac{\alpha y}{\delta}).$$

This equation implicitly defines y_∞ as a function of μ^k: $y^k_\infty = y(\mu^k)$ with

$$y'(\mu^k) = \frac{\alpha\gamma'(\frac{\alpha y^k}{\delta})}{(r+\delta)\pi''(y^k) - \frac{\alpha^2}{\delta}\mu^i\gamma''(\frac{\alpha y^k}{\delta})} < 0,$$

under our assumptions. The second derivative can also be computed, which gives:

$$y''(\mu^k) = \frac{\frac{\alpha^2}{\delta}y'(\mu^k)\gamma''(\frac{\alpha y^k}{\delta})((r+\delta)\pi''(y^k) - \frac{\alpha^2}{\delta}\mu^k\gamma''(\frac{\alpha y^k}{\delta}))}{((r+\delta)\pi''(y^k) - \frac{\alpha^2}{\delta}\mu^k\gamma''(\frac{\alpha y^k}{\delta}))^2} -$$
$$\frac{\alpha\gamma'(\frac{\alpha y^k}{\delta})(-\frac{\alpha^2}{\delta}\gamma''(\frac{\alpha y^k}{\delta}) + (r+\delta)\pi'''(y^k)y'(\mu^k) - \frac{\alpha^3}{\delta^2}\mu^k y'(\mu^k)\gamma'''(\frac{\alpha y^k}{\delta}))}{((r+\delta)\pi''(y^k) - \frac{\alpha^2}{\delta}\mu^k\gamma''(\frac{\alpha y^k}{\delta}))^2}$$

For the particular case we consider in the paper, i.e., the linear quadratic problem, this second derivative simplifies to:

$$y''(\mu^k) = \frac{2\alpha^4 y^k}{\delta^2((r+\delta)\pi''(y^k) - \frac{\alpha^2}{\delta}\mu^k\gamma''(\frac{\alpha y^k}{\delta}))^2} > 0.$$

So y^k_∞ decreases at an increasing rate with the preference parameter μ^k.

A.3 Markov Perfect Nash Equilibrium: same lobbying power

In order to solve problem (11) by using MPNE as the equilibrium concept, let us guess a linear quadratic value function $V_i(z) = A_i + B_i z + \frac{C_i}{2}z^2$ and solve the HJB equation for each player

$$rV_i(z) = \min_{x_i}\left\{\rho\left[\frac{(\mu_i - \mu_G + (\mu_G - \mu_I)z)^2}{2} + \frac{\epsilon}{2}\left(\frac{x_i}{\rho}\right)^2\right] + V_i'(z)(x_I - x_G)\right\},$$

it is then possible to characterize the unique stable MPNE with linear feedback strategies.[25] At least for the sake of comparison, we can establish that:

Proposition 5

- *At the MPNE, each group opts for the following strategy:*

$$x_I(z) = -\frac{\rho}{\epsilon}\left\{-\frac{\rho(r+\frac{2\rho C}{\epsilon})(\mu_G-\mu_I)^2}{(r+\frac{3\rho C}{\epsilon})(r+\frac{\rho C}{\epsilon})}+Cz\right\},$$
$$x_G(z) = \frac{\rho}{\epsilon}\left\{\frac{\frac{\rho^2 C}{\epsilon}(\mu_G-\mu_I)^2}{(r+\frac{3\rho C}{\epsilon})(r+\frac{\rho C}{\epsilon})}+Cz\right\},$$
$$\text{with } C = \frac{\epsilon(\sqrt{(}r^2+\frac{12\rho^2(\mu_G-\mu_I)^2}{\epsilon})-r)}{6\rho} > 0.$$

- *The balance of power in the economy at any instant t is given by:*

$$z(t) = z_\infty + (z_0 - z_\infty)e^{-\frac{2\rho C}{\epsilon}t}.$$

  It converges in the long run to the steady state value $z_\infty = \frac{1}{2}$, the convergence being monotonically decreasing iff $z_0 > z_\infty$.

- *In the long run, people's environmental awareness μ_P^∞ converges to the average concern of the minority groups: $\mu_P^\infty = \overline{\mu}_{-P}$. This also corresponds to the average value in the economy: $\overline{\mu}\infty = \overline{\mu}_{-P}$.*

We observe that group I's effort is decreasing in z whereas the larger z, the larger the effort of group G. This is a similar feature as the OLNE. The remainder of the statement of Proposition 5 is exactly the same as the one in Proposition 2 once we set $\phi_I = 1$

[25] Again we refer the reader to Wirl (1994) for more details about the resolution.

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