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Rational Skeptics: On the Strategic Communication of Scientific Data

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Abstract

I show that a credibility gap is created between the scientist and the government if the preference of the scientist is not perfectly aligned with that of the government. I find a remarkable result that the credibility gap is eliminated and the *ex-ante* social welfare is maximized if and only if the scientist's preference is perfectly aligned with that of the government, not with that of the median voter. This is endogenously achieved when the government is allowed to appoint its optimal scientist without election concerns. In the case where the government has election concerns, if the median voter perceives an alarming message from the climate scientist, then even a "right-wing" government must choose an aggressive climate change policy to avoid losing the election. Accordingly, it will prefer to appoint a climate scientist who is unlikely to send an alarming message. Thus the government deliberately creates a credibility gap which may cause a distorted climate change policy in a democracy.

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1 Introduction

Climate scientists express strong consensus on anthropogenic climate change. Although science is based on "hard facts" and assumed unbiased, there have been cases where scientists have been found to misrepresent data, or to hide relevant facts,[1] and where politicians "cherry picks" results (or scientists that show those results) to match their ideology.[2] Since politicians in general have no scientific background and they often suspect that scientific data could be misrepresented or manipulated,[3] it is worthwhile to study the strategic interaction between a climate scientist and a politician who suspects the scientist may be manipulating the data. The fundamental reason for this distrust must be different preferences: the politician may care more about economic growth, while the scientist cares more about the environment. This raises the following issue: Suppose the politician cares less about the environment than the the median voter (average citizen) does. How does the welfare of the median voter depend on the scientist's preferences? I study this issue in a game-theoretic model developed by Crawford and Sobel (1982), where politician is not sufficiently educated to verify the scientific evidence, but is forced to rely on the scientist's judgment of the risk of climate change. I find a remarkable result: Social welfare is maximized when the scientist's preferences agree with the politician's, even if these do not represent the median voter. Intuitively, it may seem the scientist's preferences ought to be aligned with the median voter's; after all, it would mean that the scientist internalizes the true preferences of the society when she communicates the results of the scientific study to the politician. However, there is the counter balancing effect: when the scientist's preferences differ from the politician, there may be a lack of trust, which is the "crying wolf" problem. In one of Aesop's fables, "The Boy Who Cried Wolf", since

[1]Editorial. Beautification and fraud. *Nature Cell Biol.* 8, 101-102 (2006).

[2]For example, Martin Luther King Jr in the 1960s hired Samuel Bowles and Herbert Gintis (two economists that had research showing the inefficiencies associated with inequality) to write papers for his policy positions. It is not that Bowles and Gintis were biased scientists, its just at their data had results that matched the ideology of the politician.

[3]For a specific example, see the prepared statement of Mr. Markey of the Hearing on the Administration's View on the State of Climate Science from the 111th Congress, which Mr. Markey complains of "systematic suppression of dissenting opinion," "intimidation," "manipulation of data and models, possible criminal activity," and more.

the boy cried wolf too often, nobody believed him when a wolf actually came.

The main contribution of my study is to model a communication game with the median voter (the third agent) to examine how the welfare of the median voter depends on the scientist's preferences. In other words, I consider how communication between the sender and receiver determines the welfare of the third party. Moreover, via election concerns, the third party can influence the cheap-talk game, both by influencing how the receiver responds to messages, and by causing the receiver to deliberately create a credibility gap (by strategic selection of a sender). Thus, my research also relates to the literature of political decision-making in a democracy (see Downs (1957), Congleton (1992), Schultz (1995, 1996), List and Sturm (2006), and more). Congleton (1992) provides a simple model to show how different political institutions affect the enactment of environmental regulations. He finds empirical evidence that political institutions play a significant role to the pollution control policies. Fredriksson and Neumayer (2013) study the relationship between countries' democratic capital stocks and climate change policies. They show that larger democratic capital stocks are associated with more stringent climate change polices. List and Sturm (2006) provided a game-theoretical model that predicts politicians manipulate environmental policy to attract voters; and they find empirical evidence that shows there are strong effects of electoral incentives. In my study, I present a game-theoretical model that shows how a government deliberately creates a credibility gap which may cause a distorted climate change policy in a democracy.

Both the causes of and the solutions to climate change involve intrinsic global externalities, which led many governments to the negotiations table for international cooperations against climate change. There is a deep literature in international environmental agreements, which provides important implications for designing climate change agreements (see Hoel (1992), Carraro and Siniscalco (1993), Barrett (1994), and Battaglini and Harstad (2012) and more). Decisions to participate in international climate change agreements should be a part of, and based on, the domestic political decisions about climate change. Therefore, domestic political decisions about climate change should be considered first before stepping up to the negotiations table for international cooperations against climate change. I examine the socio-economic political context of climate change by examining the domestic political decision-making framework for climate change policies, which involves a government (policymaker or politician), a climate scientist, a median voter.

I work out the implications of having a government with “right-wing bias”. My basic model shows that a credibility gap between the climate scientist and the government is created if the climate scientist’s preference for what policy to enact is not perfectly aligned with the government. Specifically, if the climate scientist is more favorable toward renewable energy than the government, the credibility gap can result in too much burning of fossil fuels. The “left-wing” climate scientist sends an alarming message about climate change too often. As a result, a “right-wing” policymaker may feel that the “left-wing” climate scientist is sending an alarming message about climate change too often. The policymaker may then discount the alarming message, assuming that it is just exaggeration from the left wing. This may be indeed the case when the state is not bad. However, when the state *is* truly bad, the scientist cannot credibly communicate the danger. This results in a shortfall of renewable energy, which is very costly to society. To illustrate the credibility gap, we can turn to one of Aesop’s fables, “The Boy Who Cried Wolf.” Since the boy cried wolf too often, nobody believed him when a wolf actually came. If the preferences of the climate scientist and the government could be better aligned, this problem could be mitigated.

The credibility gap is eliminated and the *ex-ante* social welfare is maximized if and only if the climate scientist’s preference is perfectly aligned with the government. If the government is allowed to appoint its climate scientist, then it would select one whose preference agrees with its own preference. Therefore, we can endogenously eliminate the credibility gap and maximize the *ex-ante* social welfare. This is a striking result. One might think that if the government is “right-wing biased” compared to the median voter, then the voter would not want the government to appoint a scientist that shares its preferences, because doing so could lead to bad climate change policies. However, I show that the opposite is true: When a right-wing government appoints its favorite scientist, the *ex-ante* social welfare is maximized. The intuition here is that, when the government appoints a scientist, it appoints someone that it trusts not to "cry wolf" too often. This improves information transmission: In a truly dangerous state, the government will trust the alarming message and implement climate change policies accordingly. Thus it is socially optimal for the government to appoint a scientist who it feels comfortable with.

Finally, I introduce election concerns. Under this constraint, if the median voter perceives an alarming message from the climate scientist, then even a right-wing government will be forced to choose an aggressive climate change policy to avoid losing the election. This deviation from its unconstrained optimum (without election concerns) is costly to the government, so it prefers to appoint a climate scientist who is unlikely to send an alarming message, i.e., one with more right-wing views.[4] Intuitively, the right-wing government has a political incentive to distort the communication with the scientific community, because it knows that it will have to respond to an alarming message with stronger climate change policies than it would like. Thus, a government with election concerns deliberately creates a credibility gap by appointing a scientist whose preferences differ from its own. Some anecdotal evidence regarding climate change may be found from the case where George W. Bush, former president of the U.S., appointed Dr. John Marburger as the head of the White House Office of Science and Technology Policy. Dr. Marburger served as the presidential science adviser for Bush's entire time in office, and defended Bush administration policies which were often criticized by most scientists. There is a series of evidence that the Bush administration has deliberately distorted the communication with the scientific community. [5]

This is in sharp contrast to the case where the government has no election concerns and

[4]In the opposite case when a left-wing government is in power, the climate change policy distortion causes the government to commit to a more left-wing climate scientist, which means that it is more likely to receive an alarming message.

[5]See The *Union of Concerned Scientists* 2004 Scientist Statement on *Restoring Scientific Integrity to Federal Policy Making* for further details.

therefore can choose its unconstrained optimal response to the scientist's message. In the unconstrained case it prefers to minimize the credibility gap by appointing a scientist with the same preference as itself. Thus, I have a surprising result: Election concerns may be the cause of a credibility gap in a democratic society, and this leads to distorted climate change policies. Despite this surprising result, I show that there will be more renewable energy when the government has election concerns than when it does not. Thus, from my model, I obtain a theoretical prediction that countries with more democratic political institutions will have climate change policies more targeted towards renewable energy.

The basic model is presented in Section 2. The equilibrium without election concerns and with election concerns are discussed in Section 3 and 4, respectively. I conclude in Section 5.

2 Basic Model

I consider a cheap-talk game among a government (policymaker), a climate scientist, and a median voter. I show how a credibility gap is created between the scientific community and the political arena. I note that the messages from climate scientists, which are scientific reports on climate change, are not verifiable by governments. Therefore, the messages themselves are talk-costless, nonbinding, and nonverifiable claims, which make the game a cheap-talk game. I note that the policymaker's preference is critical when he or she implements climate change policies.

A government (country) produces GHGs by consuming fossil fuels, and I denote the government's quantity of GHG emissions per capita as G. I assume that consuming fossil fuels produces the same quantity of GHGs. Thus we may interpret G as either GHG emissions per capita or fossil fuel consumption per capita. The quantity of energy consumption per capita generated by renewable energy sources (clean energy), which do not emit GHGs, is denoted by R. We can also interpret R as the level of clean technology that a country uses to mitigate its GHG emissions. The quantity of total energy consumption per capita is denoted by y, which I assume is fixed. I assume that each country has two sources of energy: energy from fossil fuels (G) and energy from renewable energy sources (R). If a country increases its quantity of renewable energy (R) when the total quantity of energy (y) is fixed, then it would decrease its consumption of fossil fuels and thereby its GHG emissions (G) would fall. Therefore, we have the following relationship:

$$G = y - R. \tag{1}$$

If we interpret R as the level of clean technology employed to mitigate GHGs, then G is interpreted as the quantity of GHGs mitigated by the clean technology (R). There is a one-to-one relationship between G and R: reducing one unit of GHGs or fossil fuels (G) is equal to increasing one unit of renewable energy (R).

I normalize G and R in (1) to be fractions:

$$g = 1 - r, \tag{2}$$

where $g = G/y$ and $r = R/y$. Since I assume that the total quantity of energy (y) is fixed, choosing the proportion of total energy due to fossil fuel (or equivalently renewable energy) is what the government cares about in our model. I denote the proportion of total energy due to fossil fuel and the proportion due to renewable energy g and r, respectively.

When choosing its optimal energy policy, a government considers not only the benefit of consuming fossil fuels (g) but also the adverse effects from excessive consumption of fossil fuels. Thus I assume that a government's utility of consuming fossil fuels, $u(g)$, is represented by a quadratic and concave function of the proportion of total energy due to fossil fuel:[6]

$$u(g) \quad = \quad -g^2 + \bar{\beta} g. \tag{3}$$

[6] I follow Battaglini and Harstad (2012) among many others.

$\bar{\beta} \in [0, 2]$ is a parameter that represents the general preference for clean environment of a government. It is assumed to be smaller (closer to 0) as countries naturally prefer cleaner environments. Notice that $u'(g) = 0$ when $g = \bar{\beta}/2$. If a government does not have any preference for a clean environment (i.e., $\bar{\beta} = 2$), then all of its total energy consumption comes from burning fossil fuels (i.e., $g = 1$). Alternatively, we can interpret that there is no clean technology mitigating GHGs if $\bar{\beta} = 2$, and thereby $g = 1$.

We can express the utility function (3) as a function of r (the proportion of total energy due to renewable energy or the level of clean technology) by using the one-to-one relationship between g and r:

$$u(r) = -1 + \bar{\beta} + (2 - \bar{\beta})r - r^2. \tag{4}$$

2.1 The State of the World

I assume that there are two possible states of the world, *Good State* and *Bad State*. In the *Good State*, there is no possibility that climate change results in disaster, so each government can conduct its business as usual. In the *Bad State*, it is certain that climate change will result in disaster, so each government must take precautionary actions against climate change. The government does not know the true state of the world, and it cannot observe the probability of the *Bad State*. But it has a prior distribution F with a continuous density f over the probability of the *Bad State*, $\theta \in [0, 1] \equiv \Theta$. The climate scientist can observe the probability of the *Bad State*, θ. The utility function of the climate scientist is

$$U^S(r, \theta) = \theta \underbrace{[-1 + \beta_S + (2 - \beta_S)r - r^2]}_{\text{Payoff in } \textit{Bad State}} + (1 - \theta) \underbrace{[-1 + \bar{\beta} + (2 - \bar{\beta})r - r^2]}_{\text{Payoff in } \textit{Good State}}. \tag{5}$$

The government's utility function is

$$U^G(r, \theta) = \theta \underbrace{[-1 + \beta_G + (2 - \beta_G)r - r^2]}_{\text{Payoff in } \textit{Bad State}} + (1 - \theta) \underbrace{[-1 + \bar{\beta} + (2 - \bar{\beta})r - r^2]}_{\text{Payoff in } \textit{Good State}}. \tag{6}$$

Notice that the payoff in the *Good State* is the same as (4).

I have a few criteria to define the preferences for energy policies in the *Bad State*, i.e., climate change policies. First, the government's preference may be different from the climate scientist's. Note that the government and the climate scientist each have a parameter, β_G and $\beta_S \in [0, 2]$, respectively, when they are in the *Bad State*. They measure how the government and the climate scientist weigh the importance of renewable energy when they are in the *Bad State*. If β_G and β_S are closer to 0, then the government and the climate scientist prefer higher levels of renewable energy (r) when he or she is in the *Bad State*. Second, I assume that both the government and the climate scientist put a greater weight on renewable energy when they are in the *Bad State* than when they are in the *Good State*. Thus we have the following assumption.

Assumption 1. $0 \leq \beta_G < \bar{\beta} \leq 2$ *and* $0 \leq \beta_S < \bar{\beta} \leq 2$.

Notice that the payoff in the *Bad State* has a higher benefit from consuming renewable energy than that in the *Good State*.

We may interpret β_G and β_S as the ideological positions of the government and the climate scientist, respectively. Recall that we consider two dimensions of economic policy, growth and the environment. If $\beta_S < \beta_G$, then it may be the case where the climate scientist is more biased toward the environment, while the government is more biased toward growth.

3 Information Transmission without Election Concerns

First, I consider the case where the government does not have any election concerns regarding climate change policies. We can think of this case as an authoritarian state with regard to climate change policies. Therefore in this variation of the model, I consider only two players, a government (G) and a climate scientist (S).

I assume that β_S is exogenously given. I consider the message space of the climate scientist, $M \equiv \{m_L, m_H\}$, where m_L indicates a message of *Low* probability of the *Bad State* (a comforting message) and m_H indicates a message of *High* probability of the *Bad State* (an alarming message). The timing of the game is as follows:

Stage 1. The climate scientist privately observes the probability of the *Bad State*, $\theta \in \Theta$, and then sends a message $m \in M$ to the government.

Stage 2. The government observes the climate scientist's message m (but not θ) and then chooses $r^*(m)$, its optimal climate change policy.

I define a perfect Bayesian equilibrium, which consists of signaling rules $q(m|\theta)$ for S, optimal climate change policies $r^*(m)$ for G, and the G's posterior belief $\rho(\theta|m)$ such that

(C1) for each $m \in \{m_L, m_H\}$, $r^*(m)$ solves

$$\max_{r \in \mathbb{R}_+} \int_0^1 U^G(r, \theta)\rho(\theta|m)d\theta \tag{7}$$

where $\rho(\theta|m)$ is the government's posterior belief after observing the climate scientist's message m by applying Bayes' rule whenever possible; and

(C2) for each $\theta \in [0, 1]$ and $m^* \in M$, if $q(m^*|\theta) > 0$, m^* solves

$$\max_{m \in M} U^S(r^*(m), \theta). \tag{8}$$

I derive a partially separating equilibrium with a two-step by assuming that f is a uniform distribution over $\Theta = [0, 1]$. As I assume that there exist only two possible messages $m \in \{m_L, m_H\}$, there must exist a cut-off point $x \in \Theta$ such that the climate scientist sends $m(\theta) = m_L$ if $\theta < x$, and $m(\theta) = m_H$ if $\theta \geq x$.

Suppose that the government will update its belief that θ is uniformly distributed over $[0, x)$ if it receives the comforting message m_L; likewise, it will update its belief that θ is uniformly distributed over $[x, 1]$ when it receives the alarming message m_H. That is,

$$\rho(\theta|m) = \frac{q(m|\theta)f(\theta)}{q(m)},$$

where

$$q(m) = \int_0^1 q(m|t)f(t)dt.$$

Lemma 1. *The proportion of renewable energy is higher when the government receives the alarming message m_H (High probability of the Bad State) than when it receives the comforting message m_L (Low probability of the Bad State). That is,*

$$r^*(m_L; x) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - \beta_G), \tag{9}$$

$$\leq r^*(m_H; x) = 1 - \frac{\bar{\beta}}{2} + \frac{x+1}{4}(\bar{\beta} - \beta_G). \tag{10}$$

Proof. See Appendix. □

Notice that $r^*(m_L)$ is the government's optimal climate change policy if it receives the comforting message m_L and that $r^*(m_H)$ is its optimal climate change policy if it receives the alarming message m_H. The government responds to the alarming message with higher proportion of renewable energy.

Since the climate scientist's utility function is in a quadratic form and thus is symmetric around her optimal climate change policy $r^S(\theta)$ where

$$r^S(\theta) = arg \max_r U^S(r, \theta) = 1 - \frac{\bar{\beta}}{2} + \frac{\theta}{2}(\bar{\beta} - \beta_S), \tag{11}$$

the climate scientist prefers $r^*(m_L)$ to $r^*(m_H)$ if the midpoint between $r^*(m_L)$ and $r^*(m_H)$ is higher than its optimal energy policy $r^S(\theta)$. However, she prefers $r^*(m_H)$ to $r^*(m_L)$ if $r^S(\theta)$ is higher than the midpoint. Therefore, for the existence of a partially separating equilibrium with a two-step, the cut-off point $x \in \Theta$ must be the point where $r^S(\theta)$ is exactly equal to the midpoint between $r^*(m_L)$ and $r^*(m_H)$.

Proposition 1. *If $\beta_S \leq \bar{\beta}/4 + 3\beta_G/4$, there exists a partially separating equilibrium with a two-step, where the cut-off point is given by*

$$x = \frac{\frac{1}{2}(\bar{\beta} - \beta_G)}{\bar{\beta} + \beta_G - 2\beta_S} \in \Theta. \tag{12}$$

Proof. See Appendix. □

3.1 Credibility Gap

Recall that I assumed the climate scientist's ideological position is exogenously given. If the climate scientist's ideological position is perfectly aligned with that of the government, i.e., $\beta_S = \beta_G$, then the cut-off point $x \in \Theta$ becomes $1/2$.

Definition 1. *A credibility gap is the difference between the government's cut-off point x and $1/2$.*

If a government receives a message from a more left-wing climate scientist, i.e., $\beta_{S'} < \beta_G$, then the cut-off point $x \in \Theta$ becomes smaller than $1/2$. That is, a credibility gap is created by the left-wing scientist. Figure 4 illustrates a credibility gap created by the left-wing scientist. To illustrate, suppose that the exogenous climate scientist has an identical ideological position to a left-wing party, and the right-wing government's ideological position is different from that, i.e., $\beta_S = \beta_{LW} < \beta_{RW}$. Then the right-wing government's cut-off point x is smaller than $1/2$. The climate scientist and the left-wing party views being close together creates a credibility gap about the scientist for the right-wing government, and therefore the right-wing government is doubtful about the truthfulness of the scientist's message. The existence of a credibility gap means that a government is less likely to trust that the information being transmitted is unbiased, and thus is doubtful about the veracity of the message sent by the scientist.

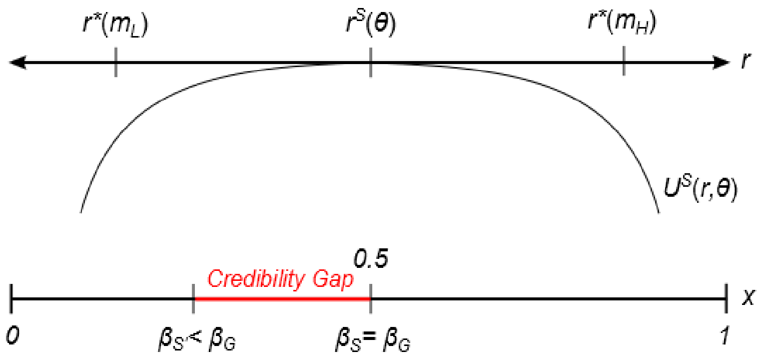

Figure 1: A credibility gap

Some episodic observations seem to support our theoretical results. For example, many right-wing politicians in the U.S. seem to be skeptical about human-caused climate change, which is strongly supported by climate scientists. As they have gained greater scientific confidence in human-caused climate change, climate scientists' political views on climate change policies have become much closer to those of the left wing. Thus right-wing politicians have become more doubtful about human-caused climate change as investigated by the scientific community.[7] Figure 2 shows the percentage of U.S. citizens who believe that effects of global warming are already occurring, by major political party.[8] Republican view on climate change is certainly different from that of Democrats, and as is clear, the belief gap between the two parties has been increasing since 1998. The percentage of Republicans who believe in climate change has decreased since then, even though the scientific community has gained greater scientific confidence in human-caused climate change over the same period of time.[9]

When the climate scientist is more left wing than the government, the climate scientist

[7]Meet the Republicans in Congress who don't believe climate change is real, *The Guardian*, Nov 17th 2014.

[8]This graph shows responses to the following question from the Gallop Poll: Which of the following statements reflects your view of when the effects of global warming will begin to happen – [*they have already begun to happen; they will start happening within a few years; they will start happening within your lifetime; they will not happen within your lifetime; but they will affect future generations; (or) they will never happen*]?

[9]The Scientific Consensus on Climate Change, *Science*, 2004.

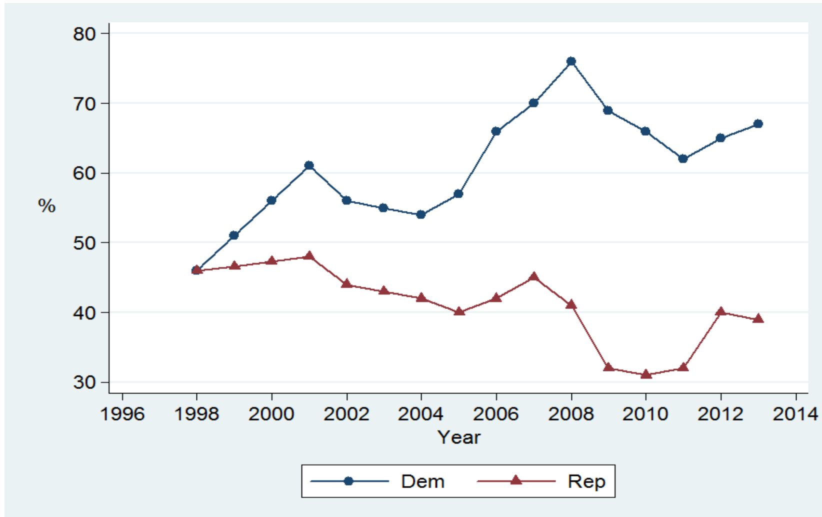

Figure 2: % of U.S. citizens who believe that effects of global warming are already occurring, by major U.S. political party, *Gallop Poll conducted March 7-10, 2013*

becomes more "alarmist": he becomes more likely to send the alarming message m_H as $x < 1/2$. To illustrate, suppose that the climate scientist's ideological position is constant but the ruling party of the government changes from the left wing to the right wing. Then, we would expect that the scientific reports to become more alarming. We may turn to one of Aesop's fables, "The Boy Who Cried Wolf," to illustrate the credibility gap created by the left-wing scientist. Since the boy cried wolf too often, nobody believed him when a wolf actually came.

3.2 Social Welfare

Let us consider a social welfare function to examine the optimal ideological position of the climate scientist. I assume a purely utilitarian social welfare function of citizens of a society. I consider the median voter's utility function as follows:

$$U^V(r, \theta) = \theta[-1 + \beta_V + (2 - \beta_V)r - r^2] + (1 - \theta)[-1 + \bar{\beta} + (2 - \bar{\beta})r - r^2], \qquad (13)$$

where β_V is the ideological position that measures how the median voter weighs the importance on renewable energy in the *Bad State*.

Assumption 2. $\beta_V \in [0, \frac{\bar{\beta}+\beta_G}{2})$.

The *ex-ante* social welfare function is the summation of all the median voters' *ex-ante* utility function.[10] Assuming that the number of the median voters is given by N, the *ex-ante* social welfare function is the following.

$$W\{E_\theta U^V[r^*(m(\theta)),\theta]\} = N \cdot E_\theta U^V[r^*(m(\theta)),\theta], \tag{14}$$

where

$$\begin{aligned} E_\theta U^V[r^*(m(\theta)),\theta] =& q(m_L)\int_0^x U^V(r^*(m_L),\theta)\rho(\theta|m_L)d\theta \\ &+ q(m_H)\int_x^1 U^V(r^*(m_H),\theta)\rho(\theta|m_H)d\theta. \end{aligned}$$

I present the optimal ideological position of the climate scientist which maximizes the *ex-ante* social welfare in the following theorem.

Theorem 1. *The ex-ante social welfare is maximized with respect to β_S when $\beta_S = \beta_G$, i.e., when there is no credibility gap.*

Proof. See Appendix. □

This is a striking result: the *ex-ante* social welfare is maximized if the climate scientist's ideological position is aligned with the government's, not the median voter's. This striking result is due to the fact that a credibility gap reduces the *ex-ante* social welfare. If the climate scientist is to the left of the government, a credibility gap is created, and this reduces the *ex-ante* social welfare. As the credibility gap is created by the left-wing climate scientist, the alarming message is sent "too often". As a result, a "right-wing" policymaker may feel that the "left-wing" climate scientist is sending an alarming message about climate change too often. The policymaker may then discount the alarming message, assuming that it is

[10]In the real-world, the number of the median voters outweighs the number of climate scientists and policymakers.

just exaggeration from the left wing. This may be indeed the case when the state is not bad, i.e., $x \leq \theta < 1/2$. However, when the state *is* truly bad, i.e., $\theta > 1/2$, the scientist cannot credibly communicate the danger. This results in a shortfall of renewable energy, which is very costly to society.

If the ideological positions of the climate scientist and the government could be better aligned, the problem would be mitigated. Indeed, even if the government's ideological position on the environment deviates from the median voter's position, the *ex-ante* social welfare is maximized as long as the climate scientist's position is aligned with the government's, not with the median voter's.

3.3 Endogenous Selection of Scientist

I allow the government to choose its climate scientist in the very first stage of the game (Stage 0). I show how the government selects its optimal climate scientist (b_s) when it does not have any election concerns with regard to its climate change policy. The timing of the game is as follows:

Stage 0. The government chooses a climate scientist with β_S.
Stage 1. The climate scientist privately observes the probability of the *Bad State*, $\theta \in \Theta$, and then sends a message $m \in M$ to the government.
Stage 2. The government observes the climate scientist's message m (but not θ) and then chooses $r^*(m)$, its optimal climate change policy.

I define a perfect Bayesian equilibrium, which consists of signaling rules $q(m|\theta)$ for S, the optimal climate scientist β_S^* and optimal climate change policies $r^*(m)$ for G, and the G's posterior belief $\rho(\theta|m)$ such that satisfies **(C1)**, **(C2)**, and
(C3) β_S^* solves

$$\max_{\beta_S \in [0,2]} E_\theta U^G[r^*(m(\theta)), \theta]. \tag{15}$$

Proposition 2. *If the climate scientist is endogenously chosen by the government, the government selects a climate scientist whose ideological position is perfectly aligned with its own position, i.e.,* $\beta_S^* = \beta_G$.

Proof. See Appendix. □

We can derive an important implication from Proposition 2. The maximized *ex-ante* social welfare is achieved endogenously if we allow the government to choose its climate scientist. Then it will select a climate scientist whose ideological position agrees with its own position, so the credibility gap will be eliminated.

Corollary 1. *The ex-ante social welfare is endogenously maximized if the government can select a climate scientist perfectly aligned with its own ideological position.*

Proof. Follow from Theorem 1 and Proposition 2. □

This is another striking result. The social welfare is maximized when the government appoints its favorite scientist. The intuition is that when the government appoints a climate scientist, it appoints someone that it trusts not to "cry wolf" too often. This indeed improves the information transmission; in the truly dangerous state, the government will trust the alarming message and implement enough renewable energy. So it is socially optimal for the government to appoint a climate scientist who it feels comfortable with.

4 Information Transmission with Election Concerns

I consider a case where the government has election concerns with regard to climate change policies. I assume that the political system is a full democracy (where the median voters have the power to replace the regime). I consider two political parties, a left wing (LW) and a right wing (RW). I assume that the left-wing party puts higher weight on renewable energy than the right-wing party in the *Bad State*. Thus I have the following assumption.

Assumption 3. $\beta_{LW} < \beta_V < \beta_{RW}$.

I assume that the median voter cannot observe the probability of the *Bad State* (θ). However, they can observe the message from the climate scientist, $m \in M$, as well as the government's optimal climate change policies, $r_G(m_L)$ and $r_G(m_H)$ for all $G = \{LW, RW\}$.

Recall that I focus on the case where the government is more right wing than the median voter. Thus I shall suppose that the right-wing party is in power at the beginning of the game. In Stage 0, the right-wing government selects its optimal climate scientist while it considers the following voter constraints (VC).

(VC) β_S^* solves

$$\max_{\beta_S} E_\theta U^{RW}[\hat{r}_{RW}(m(\theta)), \theta]$$

$$\text{s.t.}$$

$$\int_0^x U^V(\hat{r}_{RW}(m_L), \theta)\rho(\theta|m_L)d\theta \geq \int_0^x U^V(r^*_{LW}(m_L), \theta)\rho(\theta|m_L)d\theta \tag{16}$$

$$\int_x^1 U^V(\hat{r}_{RW}(m_H), \theta)\rho(\theta|m_H)d\theta \geq \int_x^1 U^V(r^*_{LW}(m_H), \theta)\rho(\theta|m_H)d\theta \tag{17}$$

Note that $\hat{r}_{RW}(m_L)$ and $\hat{r}_{RW}(m_H)$ are the constrained optimum when the government has election concerns. It is a commitment of climate change policy to prevent the alternative party from winning the election. The left-hand sides of the voter constraints (16) and (17) are the median voter's expected utility levels from the climate change policies of the current government (the right wing), $\hat{r}_{RW}(m)$, conditional on the message $m \in \{m_L, m_H\}$. So, conditional on the message, the expected utility of the current policy has to be greater than the expected utility from the alternative party's policies, $r^*_{LW}(m_L)$ and $r^*_{LW}(m_H)$, which are the unconstrained optimum specified in Lemma 1. The median voter will choose the alternative party in the next election if he expects strictly higher utility from the climate change policy of the alternative party than that of the current government. Therefore, in

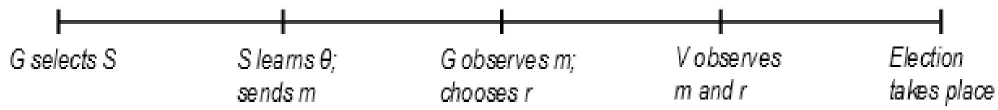

Figure 3: Timing of the game

order for the current government to maintain its regime, the median voter's expected utility from the current government's climate change policy must be higher or at least equal to the expected utility from the alternative party.

The timing of the game is as follows:

Stage 0. The government chooses a climate scientist with β_S.

Stage 1. The climate scientist privately observes the probability of the *Bad State*, $\theta \in \Theta$, and then sends a message $m \in M$ to the government.

Stage 2. The government observes the climate scientist's message m (but not θ) and then announces $\hat{r}_G(m)$, its optimal climate change policy.

Stage 3. The median voter observes both the climate scientist's message m and the government's optimal climate change policy $\hat{r}_G(m)$.

Stage 4. The election takes place. The median voter can either choose the current ruling party; or choose the alternative party if the constraints are not satisfied. If the alternative party takes power, it will choose its optimal climate change policy given m. That is, the new government cannot change the climate scientist and must take the message given.

Note that, in Stage 4, I assume that the new government cannot change the climate scientist (appointed by the current government) and must take the message given. This assumption makes sense because, once climate change is investigated by the climate scientist appointed by the current government, it would be hard for a new scientist to send a different message from the current scientist. As all the data of climate change is already organized and presented by the current scientist, there would be little chance to reveal completely new data in the scientific community.[11][12]

I define a perfect Bayesian equilibrium, which consists of signaling rules $q(m|\theta)$ for S, the optimal climate scientist β_S^* and optimal climate change policies $r^*(m)$ for G, and the G's posterior belief $\rho(\theta|m)$ that satisfy **C1**, **C2**, and **VC**.

I first examine partially separating equilibria where the election concerns do not distort the selection of scientist. I consider two cases. First, if the median voter's ideological position (β_V) is closer to the ruling party than the alternative party, then the voter constraints (16) and (17) are not active. Therefore, the government appoints a scientist whose ideological position agrees with the ruling party, and then announces the unconstrained climate change policy, $r_G^*(m)$, derived in Lemma 1. Second, suppose that the median voter's position is equidistant from both parties. Namely, $\beta_V = (\beta_{LW} + \beta_{RW})/2$. Then, the median voter is indifferent between the two parties because their policies are equally far away from its optimum. Let us assume that he votes for the ruling party when he is indifferent. Then the voter constraints are not active, and thus the ruling party can disregard the election concerns. Therefore, the government appoints a scientist whose ideological position agrees with the government, and then announces the unconstrained climate change policy, $r_G^*(m)$, derived in Lemma 1. Notice that we can eliminate the credibility gap in both cases, i.e., $x = 1/2$.

Proposition 3. *The government (the ruling party) appoints a scientist whose ideological position agrees with its own position, i.e.,* $\beta_S^* = \beta_G$*, and thereby no credibility gap, i.e.,* $x = 1/2$*, in the following two cases:*
(i) the median voter's position is closer to the ruling party; and
(ii) the median voter's position is equidistant between the two parties, i.e., $\beta_V = (\beta_{LW} + \beta_{RW})/2$.

[11] Even if the alternative party can select its optimal scientist, the climate change data provided the previous scientist cannot be changeable. Namely, the new scientist cannot observe θ.

[12] One may extend our model as follows: in Stage 4, the alternative party can select its optimal climate scientist who can observe θ and send a new message $m \in \{m_L, m_H\} \equiv \tilde{M}$.

Proof. See Appendix. □

4.1 Deliberately Created Credibility Gap

I now examine partially separating equilibria where the ideological position of the median voter is closer to the alternative party. In this case, the government (the ruling party) has fears of losing power at Stage 0 when it chooses its optimal climate scientist. That is, the voter constraints (16) and (17) are strictly binding. In order for the government (the ruling party) to win the election at Stage 4, the government announces the constrained optimum policy, $\hat{r}_G(m_L)$ and $\hat{r}_G(m_H)$, which are stronger than the unconstrained policies derived in Lemma 1, i.e., more aggressive renewable energy policies.[13] The fears of losing power cause a distortion of the government's optimal climate change policy.

The policy distortion causes another distortion in Stage 0. That is, the government does not appoint a scientist whose ideological position agrees with its own position. As a result, a credibility gap is created between the government and the climate scientist. Recall that we focus on the case where the government is more right-wing than the median voter. In Stage 0, the right-wing government knows that it must announce the constrained optimum policy, which is stronger than its unconstrained policy in Stage 2. The distortion of climate change policies causes the right-wing government to appoint a more right-wing climate scientist than itself at Stage 0, i.e., $\beta_S^* > \beta_{RW}$. Intuitively, the right-wing government has a political incentive to distort the communication with the scientific community, because it knows that it will have to respond to an alarming message with stronger climate change policies than it would like. Thus, the government's election concerns cause it to deliberately create a credibility gap by appointing a scientist whose ideological position differ from its own. This is in sharp contrast to the case where the government has no election concerns and therefore can choose its unconstrained optimal response to the scientists message – in the unconstrained case it prefers to minimize the credibility gap by appointing a scientist with

[13]The constrained optimum climate change policies are weaker than the unconstrained policies, i.e., less aggressive renewable energy policies, when the left wing is the ruling party of the government.

the same ideological position as itself. Thus, we have a surprising result: election concerns may be the cause of a credibility gap in a democratic society, and this leads to distorted climate change policies.

Proposition 4. *If the ideological position of the median voter is closer to that of the alternative party,*
(i) the right-wing government appoints a more right-wing climate scientist, $\beta_S^* > \beta_{RW}$*;*
(ii) the right-wing government commits to higher proportions of renewable energy than the unconstrained policies derived in Lemma 1. That is, the constrained policies are

$$\hat{r}_{RW}(m_L; x) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - 2\beta_V + \beta_{LW});$$
$$\hat{r}_{RW}(m_H; x) = 1 - \frac{\bar{\beta}}{2} + \frac{x+1}{4}(\bar{\beta} - 2\beta_V + \beta_{LW}).$$

Proof. See Appendix. □

The right-wing government commits to a climate scientist more inclined to the right wing, i.e., $\beta_S^* > \beta_{RW}$, because it knows that it will have to commit to higher levels of renewable energy (the constrained optimum policies); and it becomes less likely to receive the alarming message as $x > 1/2$. In Stage 3, it commits to higher levels of renewable energy than those derived in Lemma 1. The commitment of higher renewable energy is due to the fact that the right-wing government has fears of losing power. The median voter and the left-wing party being close together raises fears of losing power in the next election at Stage 4. The fears of losing power lead the government to commit to higher levels of renewable energy (see Figure 4), which will make it win the next election at Stage 4. That is, the right-wing party's commitment of climate change policies must be at least as good as the alternative party's policy.[14]

These results are interesting. The fears of losing power, which arises from the fact that

[14]In the case where the left wing is in power at the beginning of the game and the median voter is closer to the right wing, the results are the reverse of the Proposition 4: the government appoints a more left-wing climate scientist, i.e., $\beta_S^* < \beta_{LW}$; and the government commits to lower levels of renewable energy than the

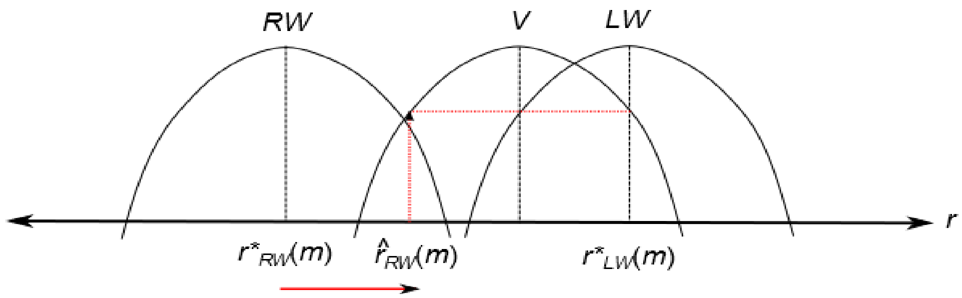

Figure 4: Distortion of climate change policies due to fears of losing power

the ideological position of the median voter is closer to the alternative party, are the cause of a credibility gap in a democratic country (see Figure 5). Although we cannot achieve the maximized *ex-ante* social welfare if the government has the fears of losing power, we can achieve more moderate climate change polices compared to the case without the fears.

We may find anecdotal evidence of Proposition 4 in the Bush administration. George W. Bush, former president of the U.S., appointed Dr. John Marburger as the head of the White House Office of Science and Technology Policy. Dr. Marburger served as the presidential science adviser for Bush's entire time in office, and defended Bush administration policies which were often criticized by most scientists. Dr. Marburger was widely criticized for defending these policies on climate change, particularly his defense against an assertion by the National Academy of Sciences that political influence was contaminating the scientific research in government agencies. He defended the Bush Administration from accusation that the Bush administration had distorted scientific information that would conflict with its policy preferences, especially on climate change policy research. In 2004, a number of leading scientists released a statement in which they charged the Bush administration with

unconstrained policies specified in Lemma 1. That is, the constrained policies are

$$\hat{r}_{LW}(m_L) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - 2\beta_V + \beta_{RW});$$
$$\hat{r}_{LW}(m_H) = 1 - \frac{\bar{\beta}}{2} + \frac{x+1}{4}(\bar{\beta} - 2\beta_V + \beta_{RW}).$$

Proof. See Appendix □

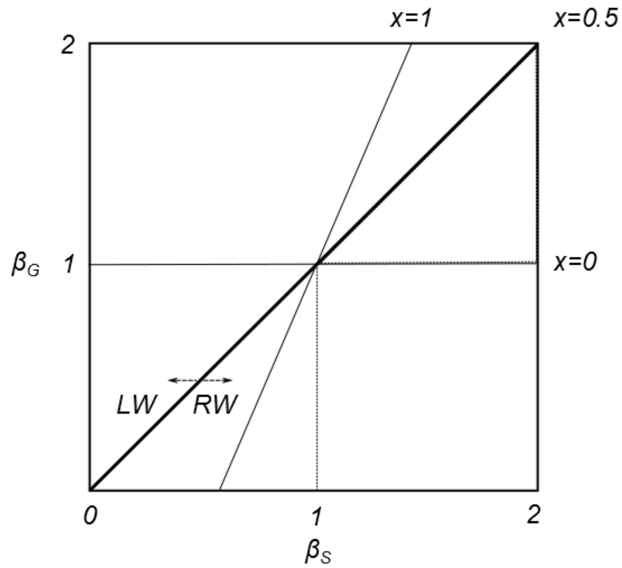

Figure 5: A credibility gap created by distortion in selection of scientist (when $\bar{\beta} = 1$)

widespread and unprecedented "manipulation of the process through which science enters into its decisions." [15]

4.2 Uninformed Voters

The public perception of climate change is also a critical factor in determining climate change policies. Even in a democratic society, an unconcerned public can cause policymakers neglect climate change warnings from the scientific community if policymakers' ideological position is different from the climate scientists.

I consider the case where the median voter observes the government's optimal climate change policy $\hat{r}_G(m)$, but do not observe the climate scientist's message m in Stage 4. In this case, the median voter can infer from the government's optimal climate change policy $\hat{r}_G(m_H)$ (or $\hat{r}_G(m_L)$) that the probability of the *Bad State* is high (or low). However, they do not directly observe which message was sent from the climate scientist. Thus the government

[15] The *New York Times* Obituary, July 29, 2011; John H. Marburger, Bush Science Advisor, Dies at 70
The *Union of Concerned Scientists* Scientific Integrity in Policy Making, An Investigation of the Bush Administration's Misuse of Science, March 2004; Further Investigation, July 2004
The *Union of Concerned Scientists* 2004 Scientist Statement on *Restoring Scientific Integrity to Federal Policy Making*

can deviate from the optimal policy that it should choose in accordance with the message from the climate scientist, if it is profitable for the government. Note that I do not solve for an equilibrium here; however, I show that the government can deviate to out of the equilibrium path if the median voter does not observe the climate scientist's message.

Proposition 5. *We cannot achieve climate change policies accordant with the climate scientist when the median voter is uninformed. The right-wing government deviates from* $\hat{r}_{RW}(m_H)$ *to* $\hat{r}_{RW}(m_L)$ *but not in the opposite direction.*[16]

Proof. See Appendix. □

As in Schultz's 1995 model in which voters do not directly observe the true state of the world, the government's optimal climate change policy may not reflect the true probability of the *Bad State* if the voters do not directly observe the message from the climate scientist. This is the cost of a society in which voters do not monitor research on climate change: climate change policy may not be aligned with the true state of climate change. In order to achieve a climate change policy in accordance with climate scientists, the public must be aware of the true state of climate change investigated by those scientists, and they should take the government's climate change policy into consideration when they vote.

5 Conclusion

The subject of climate change is by nature complex and full of uncertainties, and these complications often result in discordant climate change policies. I incorporate some of them into our game-theoretic model to examine why climate change policies are sometimes discordant, and suggest a solution to achieve accordant climate change policies.

I develop a game-theoretic model of the three parties associated with climate change: the government, the climate scientist, and the median voter. The climate scientist tells the

[16] The left-wing government deviates from $\hat{r}_{LW}(m_L)$ to $\hat{r}_{LW}(m_H)$ but not in the opposite direction.

government about the state of climate change. Since the governments cannot verify the truthfulness of scientific reports, the scientist's message is considered "cheap talk".

In the basic model, where all preferences are exogenous and the government has no election concerns, I show that a credibility gap between a climate scientist and a government is created if their preference for what policy to enact is not perfectly aligned with the government. If the government is allowed to select its climate scientist, then it would select a climate scientist whose preference agrees with its own preference. Then we can eliminate the credibility gap and maximize the *ex-ante* social welfare. I show a striking result: the *ex-ante* social welfare is maximized if and only if the preference of the scientist is perfectly aligned with the government, not the median voter. This is due to the fact that a credibility gap reduces the *ex-ante* social welfare.

I show that election concerns may be the cause of the credibility gap in a democratic society. The right-wing government has a political incentive to distort the communication with the scientific community, because it knows that it will have to respond to an alarming message with stronger climate change policies than it would like when it has binding election concerns. My contribution from our research to this literature is that I theoretically showed that climate change denial can be a rational behavior in a democratic society.

From my model, I obtain a theoretical prediction that countries with more democratic political institutions will implement climate change policies more targeted towards renewable energy. If the government's preference for climate policy is not high as compared to that of its alternative party and the median voters, the preference of the median voters being closer to the alternative party raises fears of losing power for the government. The fears of losing power lead the government to implement much stronger climate change policy to win the election. This democratic procedure of implementing climate policy will be more likely to occur in countries with higher level of democracy.

My research presents a theoretical model that shows how a climate scientist affects domestic political decisions on climate change policies. One may argue that climate change policies are inherently related with international positive externalities, so one should include another player in the model to see how a scientist affects a climate game between two different players. I leave that for the future research.

Appendix

Proof of Lemma 1. In Stage 2, the government solves

$$\max_{r\in\mathbb{R}_+}\int_0^1 U^G(r,\theta)\rho(\theta|m)d\theta = -\int_0^1 \theta(\beta_G-\bar{\beta}-(\beta_G-\bar{\beta})r)\rho(\theta|m)d\theta-(1-\bar{\beta})+(2-\bar{\beta})r-r^2,$$
$$\text{where}\int_0^1 \theta\rho(\theta|m)d\theta = \begin{cases} x/2, & \text{if } m(\theta)=m_L \\ (x+1)/2, & \text{if } m(\theta)=m_H. \end{cases}$$

Note that there is a unique interior solution to this maximization problem due to the strict concavity of $U^G(r,\theta)$ in r. From the first-order condition, we obtain

$$r^*(m_L;x) = 1-\frac{\bar{\beta}}{2}+\frac{x}{4}(\bar{\beta}-\beta_G), \tag{18}$$
$$r^*(m_H;x) = 1-\frac{\bar{\beta}}{2}+\frac{x+1}{4}(\bar{\beta}-\beta_G). \tag{19}$$

Thus, $r^*(m_L;x)<r^*(m_H;x)$ if $\bar{\beta}>\beta_G$ and $x>0$.■

Proof of Proposition 1. In Stage 1, the climate scientist solves

$$\max_{m\in\Omega} U^S(r^*(m),\theta) = \theta[\beta_S-\bar{\beta}-(\beta_S-\bar{\beta})r^*(m)]-1+\bar{\beta}+(2-\bar{\beta})r^*(m)-r^*(m)^2$$
$$\text{s.t.}\quad r^*(m) = \begin{cases} r^*(m_L), & \text{if } m(\theta)=m_L \\ r^*(m_H), & \text{if } m(\theta)=m_H. \end{cases}$$

Note that the climate scientist faces a binary decision in Stage 1. She can choose either

m_L or m_H. Due to the quadratic form of $U^S(r^*(m), \theta)$ in r,

$$U^S(r^*(m_L), \theta) \leq U^S(r^*(m_H), \theta), \quad \text{if} \quad r^S(\theta) \geq \frac{r^*(m_L) + r^*(m_H)}{2}$$
$$U^S(r^*(m_L), \theta) \geq U^S(r^*(m_H), \theta), \quad \text{if} \quad r^S(\theta) \leq \frac{r^*(m_L) + r^*(m_H)}{2}.$$

Thus, in order for a partially separating equilibrium with a two-step to exist, x must be the point where

$$r^S(x) = \frac{r^*(m_L) + r^*(m_H)}{2}, \tag{20}$$

which is equivalent to

$$1 - \frac{\bar{\beta}}{2} + \frac{x}{2}(\bar{\beta} - \beta_S) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - \beta_G) + \frac{1}{8}(\bar{\beta} - \beta_G).$$

Solving for x, we obtain

$$x = \frac{\frac{1}{2}(\bar{\beta} - \beta_G)}{\bar{\beta} + \beta_G - 2\beta_S}. \tag{21}$$

Since $\beta_G < \bar{\beta}$ by Assumption 1, and x must be strictly positive,

$$\beta_S < \frac{\bar{\beta} + \beta_G}{2}.$$

Furthermore, it must be that $x \leq 1$. Thus

$$\beta_S \leq \frac{\bar{\beta} + 3\beta_G}{4}. \tag{22}$$

■

Proof of Theorem 1. The social planner solves

$$\max_{b_s} W\left\{E_\theta U^V[r^*(m(\theta)),\theta]\right\} = N \cdot E_\theta U^V[r^*(m(\theta)),\theta],$$

where

$$E_\theta U^V[r^*(m(\theta)),\theta] = q(m_L)\int_0^x U^V(r^*(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^V(r^*(m_H),\theta)\rho(\theta|m_H)d\theta$$
$$r^*(m_L) = 1-\frac{\bar\beta}{2}+\frac{x}{4}(\bar\beta-\beta_G),$$
$$r^*(m_H) = 1-\frac{\bar\beta}{2}+\frac{x+1}{4}(\bar\beta-\beta_G),$$
$$x = \frac{\frac{1}{2}(\bar\beta-\beta_G)}{\bar\beta+\beta_G-2\beta_S}.$$

Note that

$$\begin{aligned}E_\theta U^V[r^*(m(\theta)),\theta] &= q(m_L)\int_0^x U^V(r^*(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^V(r^*(m_H),\theta)\rho(\theta|m_H)d\theta\\ &= x\{\frac{x}{2}[\beta_V-\bar\beta-(\beta_V-\bar\beta)r^*(m_L)]-1+\bar\beta+(2-\bar\beta)r^*(m_L)-r^*(m_L)^2\}\\ &+(1-x)\{\frac{x+1}{2}[\beta_V-\bar\beta-(\beta_V-\bar\beta)r^*(m_H)]-1+\bar\beta+(2-\bar\beta)r^*(m_H)-r^*(m_H)^2\}.\end{aligned}$$

From the first-order condition with respect to β_S,

$$-(1-\frac{\bar\beta}{2})x'+\frac{1}{4}(4-\frac{3}{2}\bar\beta-\frac{\beta_V}{2})x'+\frac{x}{2}(\frac{\beta_V}{2}-\frac{\bar\beta}{2})x'=0,$$

where $x' = \frac{dx}{d\beta_S} = \frac{\bar\beta-\beta_G}{(\bar\beta+\beta_G-2\beta_S)^2} > 0$.

Thus we obtain

$$x = \frac{\frac{1}{2}(\bar\beta-\beta_V)}{\bar\beta-\beta_V} = \frac{1}{2}. \tag{23}$$

Since $x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}+\beta_G-2\beta_S}$,

$$x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}+\beta_G-2\beta_S^*} = \frac{1}{2}.$$

Thus $\beta_S^* = \beta_G$. ■

Proof of Proposition 2. In Stage 0, the government solves

$$\begin{aligned}
&\max_{\beta_S \in [0,2]} q(m_L) \int_0^x U^G(r^*(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H) \int_x^1 U^G(r^*(m_H),\theta)\rho(\theta|m_H)d\theta \\
&\quad = x\{\frac{x}{2}[\beta_G - \bar{\beta} - (\beta_G - \bar{\beta})r^*(m_L)] - 1 + \bar{\beta} + (2-\bar{\beta})r^*(m_L) - r^*(m_L)^2\} \\
&\quad + (1-x)\{\frac{x+1}{2}[\beta_G - \bar{\beta} - (\beta_G - \bar{\beta})r^*(m_H)] - 1 + \bar{\beta} + (2-\bar{\beta})r^*(m_H) - r^*(m_H)^2\} \\
\text{where} \quad & r^*(m_L) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - \beta_G), \\
&r^*(m_H) = 1 - \frac{\bar{\beta}}{2} + \frac{x+1}{4}(\bar{\beta} - \beta_G), \\
&x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}+\beta_G-2\beta_S}.
\end{aligned}$$

From the first-order condition with respect to β_S,

$$-(1-\frac{\bar{\beta}}{2})x' + \frac{1}{4}(4 - \frac{3}{2}\bar{\beta} - \frac{\beta_G}{2})x' + \frac{x}{2}(\frac{\beta_G}{2} - \frac{\bar{\beta}}{2})x' = 0,$$

where $x' = \frac{dx}{d\beta_S} = \frac{\bar{\beta}-\beta_G}{(\bar{\beta}+\beta_G-2\beta_S)^2} > 0$.

Thus we obtain

$$x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}-\beta_G} = \frac{1}{2}. \tag{24}$$

Since $x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}+\beta_G-2\beta_S}$,

$$x = \frac{\frac{1}{2}(\bar{\beta}-\beta_G)}{\bar{\beta}+\beta_G-2\beta_S^*} = \frac{1}{2}.$$

Thus $\beta_S^* = \beta_G$. ■

Proof of Proposition 3. Suppose that the right wing is the ruling party of the government. If the voter constraint (16) is non-binding or weakly binding,

$$[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_L)-r^*_{LW}(m_L)]-[r^*_{RW}(m_L)^2-r^*_{LW}(m_L)^2]\geq 0. \tag{25}$$

The above constraint (25) becomes

$$2-\bar{\beta}+\frac{x}{2}(\bar{\beta}-\frac{\beta_{LW}+\beta_{RW}}{2})\geq 2-\bar{\beta}+\frac{x}{2}(\bar{\beta}-\beta_V). \tag{26}$$

Thus $\beta_V \geq \frac{\beta_{LW}+\beta_{RW}}{2}$.

If the voter constraint (17) is non-binding or weakly binding,

$$[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_H)-r^*_{LW}(m_H)]-[r^*_{RW}(m_H)^2-r^*_{LW}(m_H)^2]\geq 0. \tag{27}$$

The above constraint (27) becomes

$$2-\bar{\beta}+\frac{x+1}{2}(\bar{\beta}-\frac{\beta_{LW}+\beta_{RW}}{2})\geq 2-\bar{\beta}+\frac{x+1}{2}(\bar{\beta}-\beta_V). \tag{28}$$

Thus $\beta_V \geq \frac{\beta_{LW}+\beta_{RW}}{2}$.

In Stage 0, the right wing government solves the following constrained maximization problem:

$$\begin{aligned}
\max_{\beta_S\in[0,2]} q(m_L)&\int_0^x U^{RW}(\hat{r}_{RW}(m_L),\theta)\rho(\theta|m_L)d\theta+q(m_H)\int_x^1 U^{RW}(\hat{r}_{RW}(m_H),\theta)\rho(\theta|m_H)d\theta\\
&=x\{\frac{x}{2}[\beta_{RW}-\bar{\beta}-(\beta_{RW}-\bar{\beta})\hat{r}_{RW}(m_L)]-1+\bar{\beta}+(2-\bar{\beta})\hat{r}_{RW}(m_L)-r^*_{RW}(m_L)^2\}\\
&+(1-x)\{\frac{x+1}{2}[\beta_{RW}-\bar{\beta}-(\beta_{RW}-\bar{\beta})\hat{r}_{RW}(m_H)]-1+\bar{\beta}+(2-\bar{\beta})\hat{r}_{RW}(m_H)-\hat{r}_{RW}(m_H)^2\}\\
\text{s.t.}\quad &[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_L)-\hat{r}_{RW}(m_L)]-[r^*_{LW}(m_L)^2-\hat{r}_{RW}(m_L)^2]\leq 0\\
&[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_H)-\hat{r}_{RW}(m_H)]-[r^*_{LW}(m_H)^2-\hat{r}_{RW}(m_H)^2]\leq 0.
\end{aligned}$$

Form the Lagrangian function:

$$\mathcal{L} = q(m_L)\int_0^x U^{RW}(\hat{r}_{RW}(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^{RW}(\hat{r}_{RW}(m_H),\theta)\rho(\theta|m_H)d\theta$$
$$-\lambda_1\{[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_L)-\hat{r}_{RW}(m_L)]-[r^*_{LW}(m_L)^2-\hat{r}_{RW}(m_L)^2]\}$$
$$-\lambda_2\{[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_H)-\hat{r}_{RW}(m_H)]-[r^*_{LW}(m_H)^2-\hat{r}_{RW}(m_H)^2]\}. \quad (29)$$

Note that the voter constraints (16) and (17) are not active. Therefore, from the first-order condition, we obtain: $\lambda_1 = 0$ and $\lambda_2 = 0$: $\beta^*_S = \beta_{RW}$.

Likewise, $\beta^*_S = \beta_{LW}$ in the case where the left wing is the ruling party and $\beta_V \leq \frac{\beta_{LW}+\beta_{RW}}{2}$ (the constraints (16) and (17) are non-binding or weakly binding). ■

Proof of Proposition 4. Suppose that the right wing is in power at the beginning of the game. Note that the constraints (16) and (17) are strictly binding if $\beta_V < \frac{\beta_{LW}+\beta_{RW}}{2}$.

At the constrained optimum $\hat{r}_{RW}(m_L)$ and $\hat{r}_{RW}(m_H)$, it must be that

$$[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_L)-\hat{r}_{RW}(m_L)]-[r^*_{LW}(m_L)^2-\hat{r}_{RW}(m_L)^2]=0 \quad (30)$$
$$[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{LW}(m_H)-\hat{r}_{RW}(m_H)]-[r^*_{LW}(m_H)^2-\hat{r}_{RW}(m_H)^2]=0, \quad (31)$$

where $r^*_{LW}(m_L)$ and $r^*_{LW}(m_H)$ are the unconstrained optimum specified in Lemma 1.

Solving (30) and (31) for $\hat{r}_{RW}(m_L)$ and $\hat{r}_{RW}(m_H)$, respectively, yields

$$\hat{r}_{RW}(m_L) = 1-\frac{\bar{\beta}}{2}+\frac{x}{4}(\bar{\beta}-2\beta_V+\beta_{LW}); \quad (32)$$
$$\hat{r}_{RW}(m_H) = 1-\frac{\bar{\beta}}{2}+\frac{x+1}{4}(\bar{\beta}-2\beta_V+\beta_{LW}). \quad (33)$$

In Stage 0, the right wing government solves the following constrained maximization problem:

$$
\begin{aligned}
\max_{\beta_S\in[0,2]} q(m_L) & \int_0^x U^{RW}(\hat{r}_{RW}(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^{RW}(\hat{r}_{RW}(m_H),\theta)\rho(\theta|m_H)d\theta \\
&= x\{\frac{x}{2}[\beta_{RW}-\bar{\beta}-(\beta_{RW}-\bar{\beta})\hat{r}_{RW}(m_L)] - 1 + \bar{\beta} + (2-\bar{\beta})\hat{r}_{RW}(m_L) - \hat{r}_{RW}(m_L)^2\} \\
&+ (1-x)\{\frac{x+1}{2}[\beta_{RW}-\bar{\beta}-(\beta_{RW}-\bar{\beta})\hat{r}_{RW}(m_H)] - 1 + \bar{\beta} + (2-\bar{\beta})\hat{r}_{RW}(m_H) - \hat{r}_{RW}(m_H)^2\} \\
\text{s.t.} \quad & [\frac{x}{2}(\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_L) - \hat{r}_{RW}(m_L)] - [r^*_{LW}(m_L)^2 - \hat{r}_{RW}(m_L)^2] \le 0 \\
& [\frac{x+1}{2}(\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_H) - \hat{r}_{RW}(m_H)] - [r^*_{LW}(m_H)^2 - \hat{r}_{RW}(m_H)^2] \le 0.
\end{aligned}
$$

Form the Lagrangian function:

$$
\begin{aligned}
\mathcal{L} = q(m_L) & \int_0^x U^{RW}(\hat{r}_{RW}(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^{RW}(\hat{r}_{RW}(m_H),\theta)\rho(\theta|m_H)d\theta \\
& - \lambda_1\{[\frac{x}{2}(\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_L) - \hat{r}_{RW}(m_L)] - [r^*_{LW}(m_L)^2 - \hat{r}_{RW}(m_L)^2]\} \\
- \lambda_2\{[\frac{x+1}{2} & (\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_H) - \hat{r}_{RW}(m_H)] - [r^*_{LW}(m_H)^2 - \hat{r}_{RW}(m_H)^2]\}. \quad (34)
\end{aligned}
$$

From the first-order condition, we obtain the following solution β_S^*, λ_1^*, and λ_2^* such that

(i)

$$
\begin{aligned}
& [\frac{x}{2}(\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_L) - \hat{r}_{RW}(m_L)] - [r^*_{LW}(m_L)^2 - \hat{r}_{RW}(m_L)^2] = 0 \\
& [\frac{x+1}{2}(\bar{\beta}-\beta_V) + (2-\bar{\beta})][r^*_{LW}(m_H) - \hat{r}_{RW}(m_H)] - [r^*_{LW}(m_H)^2 - \hat{r}_{RW}(m_H)^2] = 0,
\end{aligned}
$$

where $x = \frac{\frac{1}{2}(\bar{\beta}-\beta_{RW})}{\bar{\beta}+\beta_{RW}-2\beta_S^*}$ and $\hat{r}_{RW}(m_L)$ and $\hat{r}_{RW}(m_H)$ are the constrained maximum.

(ii) $\lambda_1^* = \frac{(\bar{\beta}-\beta_{RW})^2(x-\frac{1}{2})}{(\beta_{RW}-\beta_{LW})xx'(\bar{\beta}-\beta_V)(1-x)} > 0$. Note that it must be that $\beta_S^* > \beta_{RW}$ (equivalently, $x > \frac{1}{2}$) since the denominator of λ_1^* is always strictly positive.

(iii) $\lambda_2^* = \frac{(\bar{\beta}-\beta_{RW})^2(x-\frac{1}{2})}{(\beta_{RW}-\beta_{LW})x'[\frac{3}{2}(\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})x^2+\frac{1}{2}(2-\frac{\beta_V}{2}-\frac{\bar{\beta}}{2})x-1+\frac{\beta_V}{2}]} > 0$.

Note that $\lambda_2^* > 0$ if $x > \frac{1}{2}$ and

$$\frac{1}{2} \leq \frac{-\frac{1}{2}(2 - \frac{\bar{\beta}}{2} - \frac{\beta_V}{2}) + \sqrt{\frac{1}{4}(2 - \frac{\bar{\beta}}{2} - \frac{\beta_V}{2})^2 + 6(1 - \frac{\beta_V}{2})(\frac{\bar{\beta}}{2} - \frac{\beta_V}{2})}}{3(2 - \frac{\bar{\beta}}{2} - \frac{\beta_V}{2})} < x. \tag{35}$$

Notice that the numerator of λ_2^* is positive only if $x > \frac{1}{2}$, and the denominator of λ_2^* is positive only if the condition (35) is satisfied.

In sum, it must be that $\beta_S^* > \beta_{RW}$ (equivalently, $x > \frac{1}{2}$). ■

Suppose that the left wing is the ruling party of the government. Note that the voter constraints (16) and (17) are strictly binding if $\beta_V > \frac{\beta_{LW}+\beta_{RW}}{2}$.

At the constrained optimum $\hat{r}_{LW}(m_L)$ and $\hat{r}_{LW}(m_H)$, it must be that

$$[\frac{x}{2}(\bar{\beta} - \beta_V) + (2 - \bar{\beta})][r_{RW}^*(m_L) - \hat{r}_{LW}(m_L)] - [r_{RW}^*(m_L)^2 - \hat{r}_{LW}(m_L)^2] = 0 \tag{36}$$

$$[\frac{x+1}{2}(\bar{\beta} - \beta_V) + (2 - \bar{\beta})][r_{RW}^*(m_H) - \hat{r}_{LW}(m_H)] - [r_{RW}^*(m_H)^2 - \hat{r}_{LW}(m_H)^2] = 0, \tag{37}$$

where $r_{RW}^*(m_L)$ and $r_{RW}^*(m_H)$ are the unconstrained optimum specified in Lemma 1.

Solving (36) and (37) for $\hat{r}_{LW}(m_L)$ and $\hat{r}_{LW}$, yields

$$\hat{r}_{LW}(m_L) = 1 - \frac{\bar{\beta}}{2} + \frac{x}{4}(\bar{\beta} - 2\beta_V + \beta_{RW}); \tag{38}$$

$$\hat{r}_{LW}(m_H) = 1 - \frac{\bar{\beta}}{2} + \frac{x+1}{4}(\bar{\beta} - 2\beta_V + \beta_{RW}). \tag{39}$$

In Stage 0, the left wing government solves the following constrained maximization problem:

$$\begin{aligned}
\max_{\beta_S\in[0,2]} q(m_L)&\int_0^x U^{LW}(\hat{r}_{LW}(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^{LW}(\hat{r}_{LW}(m_H),\theta)\rho(\theta|m_H)d\theta \\
&= x\{\frac{x}{2}[\beta_{LW}-\bar{\beta}-(\beta_{LW}-\bar{\beta})\hat{r}_{LW}(m_L)]-1+\bar{\beta}+(2-\bar{\beta})\hat{r}_{LW}(m_L)-\hat{r}_{LW}(m_L)^2\} \\
&+(1-x)\{\frac{x+1}{2}[\beta_{LW}-\bar{\beta}-(\beta_{LW}-\bar{\beta})\hat{r}_{LW}(m_H)]-1+\bar{\beta}+(2-\bar{\beta})\hat{r}_{LW}(m_H)-\hat{r}_{LW}(m_H)^2\} \\
\text{s.t.}\quad &[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_L)-\hat{r}_{LW}(m_L)]-[r^*_{RW}(m_L)^2-\hat{r}_{LW}(m_L)^2]\le 0 \\
&[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_H)-\hat{r}_{LW}(m_H)]-[r^*_{RW}(m_H)^2-\hat{r}_{LW}(m_H)^2]\le 0.
\end{aligned}$$

Form the Lagrangian function:

$$\begin{aligned}
\mathcal{L} = q(m_L)&\int_0^x U^{LW}(\hat{r}_{LW}(m_L),\theta)\rho(\theta|m_L)d\theta + q(m_H)\int_x^1 U^{LW}(\hat{r}_{LW}(m_H),\theta)\rho(\theta|m_H)d\theta \\
&-\lambda_1\{[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_L)-\hat{r}_{LW}(m_L)]-[r^*_{RW}(m_L)^2-\hat{r}_{LW}(m_L)^2]\} \\
-\lambda_2\{[&\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_H)-\hat{r}_{LW}(m_H)]-[r^*_{RW}(m_H)^2-\hat{r}_{LW}(m_H)^2]\}. \quad (40)
\end{aligned}$$

From the first-order condition, we obtain the following solution β_S^*, λ_1^*, and λ_2^* such that

(i)

$$\begin{aligned}
&[\frac{x}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_L)-\hat{r}_{LW}(m_L)]-[r^*_{RW}(m_L)^2-\hat{r}_{LW}(m_L)^2]=0 \\
&[\frac{x+1}{2}(\bar{\beta}-\beta_V)+(2-\bar{\beta})][r^*_{RW}(m_H)-\hat{r}_{LW}(m_H)]-[r^*_{RW}(m_H)^2-\hat{r}_{LW}(m_H)^2]=0,
\end{aligned}$$

where $x=\frac{\frac{1}{2}(\bar{\beta}-\beta_{LW})}{\bar{\beta}+\beta_{LW}-2\beta_S^*}$ and $\hat{r}_{LW}(m_L)$ and $\hat{r}_{LW}(m_H)$ are the constrained maximum.

(ii) $\lambda_1^*=\frac{(\bar{\beta}-\beta_{LW})^2(x-\frac{1}{2})}{(\beta_{LW}-\beta_{RW})xx'(\bar{\beta}-\beta_V)(1-x)}>0$. Note that it must be that $\beta_S^*<\beta_{LW}$ (equivalently, $x<\frac{1}{2}$) since the denominator of λ_1^* is always strictly negative.

(iii) $\lambda_2^*=\frac{(\bar{\beta}-\beta_{LW})^2(x-\frac{1}{2})}{(\beta_{LW}-\beta_{RW})x'[\frac{3}{2}(\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})x^2+\frac{1}{2}(2-\frac{\beta_V}{2}-\frac{\bar{\beta}}{2})x-1+\frac{\beta_V}{2}]}>0$.

Note that $\lambda_2^* > 0$ if $x < \frac{1}{2}$ and

$$\frac{-\frac{1}{2}(2-\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})+\sqrt{\frac{1}{4}(2-\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})^2+6(1-\frac{\beta_V}{2})(\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})}}{3(2-\frac{\bar{\beta}}{2}-\frac{\beta_V}{2})} < x < \frac{1}{2}. \tag{41}$$

Notice that the numerator of λ_2^* is negative only if $x < \frac{1}{2}$, and the denominator of λ_2^* is negative only if the condition (41) is satisfied.

In sum, it must be that $\beta_S^* < \beta_{LW}$ (equivalently, $x < \frac{1}{2}$). ■

Proof of Proposition 5. The maximizer of the government's *ex-ante* utility function $E_\theta U^G[r^*(m(\theta)),\theta]$ is

$$\begin{aligned} arg\max_r E_\theta U^G[r^*(m(\theta)),\theta] = q(m_L)\int_0^x U^G(r^*(m_L),\theta)\rho(\theta|m_L)d\theta \\ + q(m_H)\int_x^1 U^G(r^*(m_H),\theta)\rho(\theta|m_H)d\theta = 1-\frac{\beta_G+\bar{\beta}}{4}. \end{aligned} \tag{42}$$

In the case where the constraints are non-binding or weakly binding, notice that

$$\begin{aligned} r^*(m_L) &= 1-\frac{\bar{\beta}}{2}+\frac{x}{4}(\bar{\beta}-\beta_G) \leq 1-\frac{\beta_G+\bar{\beta}}{4}, \\ r^*(m_H) &= 1-\frac{\bar{\beta}}{2}+\frac{x+1}{4}(\bar{\beta}-\beta_G) \geq 1-\frac{\beta_G+\bar{\beta}}{4}. \end{aligned}$$

Since $E_\theta U^G[r^*(m(\theta)),\theta]$ is in a quadratic form and the government prefers $r^*(m_L)$ to $r^*(m_H)$ if

$$1-\frac{\beta_G+\bar{\beta}}{4}-r^*(m_L) = \frac{1-x}{4}(\bar{\beta}-\beta_G) \leq \frac{x}{4}(\bar{\beta}-\beta_G) = r^*(m_H)-1+\frac{\beta_G+\bar{\beta}}{4}, \tag{43}$$

which is equivalent to $x \geq \frac{1}{2}$. That is, the government prefers $r^*(m_L)$ to $r^*(m_H)$ if $x \geq \frac{1}{2}$ and vice versa. Note that $x = \frac{1}{2}$ when the constraints (16) and (17) are non-binding or weakly binding. Thus the government does not have any incentive to deviate from the given message. ■

In the case where the right wing is in power at the beginning of the game, and the constraints (16) and (17) are strictly binding (equivalently, $\beta_V < \frac{\beta_{LW}+\beta_{RW}}{2}$), the government deviates from $\hat{r}_{RW}(m_H)$ to $\hat{r}_{RW}(m_L)$ at Stage 3 since

$$\hat{r}_{RW}(m_H) - 1 + \frac{\beta_{RW} + \bar{\beta}}{4} - 1 + \frac{\beta_{RW} + \bar{\beta}}{4} - \hat{r}_{RW}(m_L) = -\beta_V + \frac{\beta_{LW} + \beta_{RW}}{2} > 0.$$

In the case where the left wing is in power at the beginning of the game, and the constraints (16) and (17) are strictly binding (equivalently, $\beta_V > \frac{\beta_{LW}+\beta_{RW}}{2}$), the government deviates from $\hat{r}_{LW}(m_L)$ to $\hat{r}_{LW}(m_H)$ at Stage 3 since

$$\hat{r}_{LW}(m_H) - 1 + \frac{\beta_{LW} + \bar{\beta}}{4} - 1 + \frac{\beta_{LW} + \bar{\beta}}{4} - \hat{r}_{LW}(m_L) = -\beta_V + \frac{\beta_{LW} + \beta_{RW}}{2} < 0.$$

■

References

Anderegg, William R. L., and James W. Prall, eds. 2010. Expert credibility in climate change. *Proceedings of the National Academy of Sciences* 107 (27): 12107-12109.

Austen-Smith, David. 1990. Information transmission in debate. *American Journal of Political Science* 34 (1): 124-152.

Barrett, Scott. 1994. Self-enforcing international environmental agreements. *Oxford Economic Papers* 46: 878-894.

Battaglini, Marco, and Bard Harstad. 2016. Participation and duration of environmental agreements. *Journal of Political Economy* 124 (1): 160-204.

Carraro, Carlo, and Domenico Siniscalco. 1993. Strategies for the international protection of the environment. *Journal of Public Economics* 52 (3): 309-328.

Cho, In-Koo, and David M. Kreps. 1987. Signaling games and stable equilibria. *Quarterly Journal of Economics* 102 (2): 179-222.

Cho, In-Koo, and Joel Sobel. Strategic stability and uniqueness in signaling games. *Journal of Economic Theory* 50 (2): 381-413.

Congleton, Roger D. 1992. Political institutions and pollution control. *Review of Economics and Statistics* 74 (3): 412-421.

Crawford, Vincent P., and Joel Sobel. 1982. Strategic information transmission. *Econometrica* 50 (6): 1431-1451.

Downs, Anthony. 1957. An economic theory of political action in a democracy. *Journal of Political Economy* 65 (2): 135-150.

Dunlap, Riley E., and Aaron M. McCright. 2011. Organized climate change denial. *The Oxford Handbook of Climate Change and Society* 144-160.

Fredriksson, Per G., and Eric Neumayer, eds. 2005. Environmentalism, democracy, and pollution control. *Journal of Environmental Economics and Management* 49 (2): 343-365.

Fredriksson, Per G., and Eric Neumayer. 2013. Democracy and climate change policies: Is history important?", *Ecological Economics* 95: 11-19.

Fudenberg, Drew, and Jean Tirole. 1990. Perfect Bayesian equilibrium and sequential equilibrium. *Journal of Economic Theory* 53 (2): 236-260.

Gibbons, Robert. 1992. *Game Theory for Applied Economists*. Princeton: Princeton University Press.

Harstad, Bard. Climate contracts: A game of emissions, investments, negotiations, and renegotiations. *Review of Economic Studies* 79 (4): 1527-1557.

Hassler, John., and Per Krussel. 2012. Economics and climate change: Integrated assessment in a multi-region world", *Journal of the European Economic Association* 10 (5): 974-1000.

Hoel, Micheal. 1992. International environment conventions: The case of uniform reductions of emissions. *Environmental and Resource Economics* 2 (2): 141-159.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate change 2014: Mitigation of climate change, Working group III, Fifth assessment report https://www.ipcc.ch/report/ar5/wg3/

Leiserowitz, Anthony. 2006. Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climate Change* 77 (1): 45-72.

List, John A., and Daniel M. Sturm. 2006. How elections matter: Theory and evidence from environmental policy. *Quarterly Journal of Economics* 121 (4): 1249-1281.

National Research Council of the National Academies. 2012. Climate change, evidence, impacts, and choices.

Oreskes, Naomi. 2004. The scientific consensus on climate change. *Science* 306 (5702): 1686.

Schultz, Christian. 1995. The politics of persuasion when voters are rational. *Scandinavian Journal of Economics* 97 (3): 357-368.

Schultz, Christian. 1996. Polarization and inefficient policies. *Review of Economic Studies* 63 (2): 331-344.

The *Union of Concerned Scientists*. 2004. Scientific integrity in policy making, an investigation of the Bush Administration's misuse of science.

The *Union of Concerned Scientists*. 2004. Scientific integrity in policy making, further investigation of the Bush Administration's misuse of science.