Forming a Majority Coalition for Carbon Taxes Under a State-Contingent Updating Rule

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Abstract

Uncertainty and divergent expectations over global warming make it difficult to achieve a majority coalition supporting carbon taxes. We explore a state-contingent approach based on an updating rule that automatically assimilates new information rather than a pre-specified tax path. Agents form expectations which imply the tax sequence correlates with their preferred price trajectory. We show that whereas greater variance in beliefs about future global warming undermines support for a static policy, the state-contingent proposal attracts majority support irrespective of the divergence of views, and even has robustness properties to strategic voting by dishonest agents.

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1 Introduction

When damages due to pollutant emissions are observable and can be traced with certainty to specific emitting activity, use of an emissions tax can yield efficient incentives for abatement activity. But some externalities, such as global warming from greenhouse gas emissions, have complex intertemporal features that make it difficult to identify an optimal shadow price. The emissions (carbon dioxide or CO_2 in the case of global warming) do not directly affect welfare, instead they affect an environmental state variable *s*, normally thought of as some measure of atmospheric temperatures. Changes in *s* then give rise to damages, but *s* is also subject to natural variability, making it difficult to identify the effect due to emissions. Not only is the damage function uncertain, but the function relating emissions to the state variable is also unknown and must be estimated with considerable uncertainty. The effects of current emissions may also operate over a long time lag, the length of which is itself unknown, which also implies that the current state exhibits the effects of historical emissions to an unknown lag. These features lead to at least two major difficulties for devising policy responses.

First, it is effectively impossible to know whether a sequence of future emission tax rates derived from a computer model are optimal or not. In the case of CO_2, the analysis is typically done using Integrated Assessment Models (IAMs) which embed myriad assumptions about the many uncertain parameters describing the climate and economic systems (e.g. William Nordhaus, 2007, Robert Pindyck 2013, IWG 2010). Confidence intervals around key parameters are so wide as to yield an arbitrarily large range of marginal damage calculations. For instance, the IPCC (2007) Synthesis Report stated that peer-reviewed estimates of the Social Cost of Carbon (SCC) ranged from $3 to $95 per ton of CO2 emissions, and other recent surveys show even wider ranges (e.g. Richard Tol 2007; Mikhail Golosov et al., 2014, IWG 2013). These differences trace to divergent assumptions about climate sensitivity, response lags, discount factors etc. Ongoing attempts to tackle the issue through the use of IAMs require imposition of functional forms and parameter values that effectively assume away much of what makes the problem difficult in the first place (Pindyck 2013). Incorporating Bayesian learning into a model may correct the initial parameter values over time. But the learning routine for even two unknown variables can take millennia to reach a 5% critical value, thus making it irrelevant for climate policy (David Kelly and Charles Kolstad, 1999; Andrew Leach, 2007).

Second, the uncertainties about the effects of emissions and marginal damages imply individuals will form divergent preferences over the optimal policy response. If a tax instrument must receive majority support in a voting system, and people can vote against it because they perceive it either to be too high or too low, the formation of a majority coalition to support implementation can be effectively impossible. Illustrations of this are the longstanding failure to implement carbon pricing in the United States despite numerous proposals for doing so since the 1990s, the recent rejection of a carbon tax proposal in Switzerland[1] and the repeal of the Australian

[1] See http://www.wsj.com/articles/swiss-voters-reject-initiative-to-replace-vat-system-with-carbon-tax-1425822327.

carbon tax.[2] The dynamics of the problem interact with the political aspect, since voters know that the starting value will be subject to some form of adjustment over time. Someone who thinks the tax initially too low may nonetheless support it if they expect it to rise, and vice versa. But someone who thinks the initial value acceptable may oppose it if they do not believe it will rise as quickly as it should, or will rise too quickly, in the future.

The purpose of this paper is to examine how a proposed solution to the first problem also addresses the second. Ross McKitrick (2010, herein M10) noted that while the function relating emissions to the climate state may be unknown, the state itself, s, is observable, and contains information that can be used to circumvent some of the major uncertainties in the computation of the optimal tax path. Specifically M10 suggested using observations on s to calibrate a dynamic pricing rule that, under certain assumptions, will closely approximate the unobservable optimal tax path. We extend this reasoning to show why voters would be more likely to support a tax based on this rule than one based on a pre-announced path.

In the M10 set-up, the value of s at time t (i.e. the current global average temperature) is a function of current and past emissions:

$$s_t = s(e_t, e_{t-1}, e_{t-2}, \dots, e_{t-k}) \qquad (1)$$

[2] See http://www.news.com.au/national/australias-carbon-tax-has-been-axed-as-repeal-bills-clear-the-senate/story-fncynjr2-1226991948152.

out to lag length k, where k may be unknown. We assume that there are Q infinitesimally small emitters, so in any period t, total emissions are

$$e_t = \Sigma_{j=1}^{Q} e_t^j.$$

Damages at time t are a function of the state variable, i.e. $D(s_t)$, implying that the current value $V(t)$ of the externality is the discounted present value of damages from the present (time 0) out to the distant future at time T:

$$V(0) = \sum_{m=0}^{T} \beta^j D(s_{t+m}) \quad (2)$$

where β is the discount factor and T is the policy planning horizon. The socially optimal price $\tau^*(t)$ on emissions at time t is the change in the value of the externality as a result of marginal current emissions:

$$\tau^*(t) = \frac{\partial V(t)}{\partial e_t}. \quad (3)$$

A policy plan would consist of an announced sequence of current and future tax rates $\tau(t), \ldots, \tau(t+T)$. Any attempt to derive such a path at time t would run into the computational problems noted above, and any attempt to secure majority agreement to implement such a path would run into the difficulty that most observers would expect the price path to be higher or lower than the one they would prefer based on their beliefs about the severity of the problem. As an alternative approach, M10 proposed a tax path that begins with an announced rate at time zero, then rather than the entire future path being announced at the same time, a rule is announced by which the rate will be updated in real time:

$$\tau_t^s = \gamma s_t \frac{e_t}{\bar{e}_t} \tag{4}$$

where $\bar{e}_t$ is a moving average of past emissions over the regulator's best estimate of k periods and γ is a parameter that must be chosen to determine an initial value of the tax sequence. The state-contingent mechanism is a direct analogue to monetary policy approaches based on committing to updating rules rather than interest rate paths determined long in advance. M10 showed that, over time, the tax path described by Equation (4) will be highly correlated with the unobservable optimal path based on equation (3) that would have been implemented if the planner had enough information to compute it. To implement (4) the regulator only needs to determine a value for γ and then use other information available contemporaneously with the rate revisions, but as a result, agents will not know its future levels, since they will rise or fall in step with s_t.[3] They will therefore have to make decisions based on expectations: those who expect rapid global warming, for instance, will expect τ_t^s to increase rapidly, whereas those who expect little warming will expect it to remain relatively unchanged from its initial value.

[3] Emissions in period t must also be known. As a practical matter the form in which they enter equation (4), as a ratio with the historical moving average could either be replaced with an estimate, or a 1-period lag.

Shi-Ling Hsu (2011) and McKitrick (2011) also proposed supplementing the implementation of (4) with a futures market for certificates dated t, … , $t+T$ defined so that each one exempts the holder from paying the tax on one tonne of CO_2 in the year indicated. In order to price such certificates, market participants would need to form expectations about the future path of s_t, and therefore of τ_t^s. The existence of such a market would allow agents to hedge against future policy costs, thus providing complete pricing certainty, and would also provide a visible indicator of the market's dominant forecast of the path of future temperatures. Experts whose beliefs about global warming deviate from the market consensus could then make investments based on their private information set, depending on how much confidence they have in their views. If their declared deviation from the consensus is merely ideological, for instance if they oppose the emissions tax for political reasons while privately believing the warming will occur, they will have no incentive to bet against the market.

There remains the second problem, namely whether this instrument can obtain majority support for implementation. We present herein a simple model of voting behaviour and show that when agents disagree about the climate issue, a conventional emissions tax based on political compromise will be less likely to get majority support, the higher is the variance of beliefs about the underlying issue. The problem is compounded by the fact that the tax rate is expected to change over time, so even if a majority can agree on a starting value of the tax, as beliefs about future global warming diverge the coalition will tend to break down, affecting the initial adoption decision. We show herein that the state-contingent approach alleviates this problem: if the initial range of beliefs is sufficiently constrained that a starting value of the tax can obtain majority support, the future value of the tax will as well, even if a conventional approach would have failed.

We first show this in a case in which voters are honest, in the sense that they only care about implementing the socially optimal tax rates, but they differ in their beliefs about how the state variable will evolve over time. We then allow voters to be dishonest, such that they declare a preference for low or high tax rates irrespective of their actual beliefs about marginal damages, and we examine the incentives to support or reject the tax mechanism against an alternative in which the regulator implements a compromise tax rate. We find that the state-contingent rule may still obtain majority support, though it is not assured. If there is a combination of (polarized) dishonest as well as honest voters, as long as no one group has an outright majority it will be possible to form a majority coalition in support of the state-contingent tax.

Our voting model has much in common with the standard framework for the Median Voter Theorem (MVT), in particular since the policy is represented as a choice along a single dimension (in this case an emissions tax) and voters have single-peaked preferences determined by a symmetric loss function. However, the MVT assumes that voter preferences are determined by a one-sided inequality, such that a policy parameter deemed acceptable because it exceeds some threshold will remain acceptable no matter how large the parameter gets, so the median voter's preferences determines the outcome of the vote. In our case the policy may be rejected if it deviates too far either way from a preferred value, so the median value may lose support from people with extreme preferences in either direction. This allows us to explore why a policy may be rejected outright even if the parameter value is chosen optimally by a planner who knows everyone's preferences, whereas in the MVT framework there must be always a value of the parameter that would obtain 50 percent support.

The main message of this paper has such clear intuition as to seem almost trivial: voters will be more likely to support a policy if it is structured so that each person expects to get his or her preferred outcome. Our main contribution is the less obvious corollary that in an intertemporal emissions pricing context such an outcome requires a commitment to a specific mechanism for assimilating future information about the severity of marginal damages, an aspect which has largely been ignored both in practice and in the literature on carbon pricing. The policies to be contrasted herein represent polar extremes on this point: in the static option, the price path is fully specified so no role for future information exists, and in the state-contingent option, only the starting price is known when the policy is adopted, along with a mechanism for incorporating new information over time. In practice, climate policies may have aspects of both but they typically resemble the former much more than the latter. International agreements like the Paris Accord and Kyoto Protocol specify long term targets and timetables without subordinating them to future information. Current and future carbon fee schedules, such as those in Canada and the UK, are known and fixed by legislation. Likewise the price paths developed by the US Inter-Agency Working Group (IWG 2010, 2013) were fully spelled out rather than being left blank and made subject to future calculation based on updated information. Notably, while voters and policy makers may assume that future information will be used to guide subsequent refinements, nothing is explicitly stated in the policies as to whether or how this must happen. A key point we make is that policies for long term emission pricing will have a better chance at obtaining voter support if they are more explicit about how future information will be used, and less explicit about how strict future policies will be.

These issues can be illustrated by looking at the fate of the IWG. In 2009 US President Barack Obama ordered the creation of an expert team to work out a time path of SCC estimates for use in US regulatory policy, which was subsequently published in IWG (2010) and implemented in US rulemaking. In that report they committed to periodically updating their estimates (which was done in IWG 2013), but the rule for assimilating new information was not stated and the future price path was fully specified, so it was treated as a static rather than a state-contingent policy plan. In 2017 newly-elected President Trump rescinded the policy and disbanded the IWG. Notably, the Trump administration did not choose to revise the price path based on new information but to reject the price path altogether. The analysis herein proposes that the decision by the IWG to present a static price path without a convincing state-contingent aspect increased the likelihood of its eventual rejection.

Likewise the Kyoto Protocol imposed fixed, perpetual emission reduction requirements with no mechanism for revision in light of future information. The US and Canada both rescinded their prior support for Kyoto following changes in governing parties. Even though an initial coalition existed to support the policy in each country, sequential voting under divergent opinions about the optimal strategy led to subsequent rejection of the treaty.

The key distinction is thus not between one-time decisions and sequential voting, but between static and state-contingent plans. In practice, most policies are subject to sequential voting in the sense that as new information arrives, political parties and voters can change their positions. But what makes a policy state-contingent is whether the future price path is specified in advance or not. If people are presented with a price path but no updating rule, then a sequence of votes is a mere repetition of a static option. If they are presented repeatedly with a current price and a rule for updating it based on future information, then a sequence of votes is merely a repetition of a state-contingent option. The key question is which aspect takes precedence in the voters' minds. Consider a hybrid proposal in which voters are asked to approve a fixed tax path subject to adjustments in light of future information. If the new information will take precedence, the future tax rates need not be specified to fully describe the policy and it is a state-contingent option. But if the tax path is fully described and there is no commitment to use new information in a specific way then it is a static policy, and will be more likely to face voter rejection for the reasons explained herein.

The remainder of the paper is organized as follows. Section 2 briefly discusses earlier studies on voting mechanisms for public goods and externalities. Sections 3 and 4 develop the theoretical structure of our model and provides propositions and their proofs. Lastly, Section 5 presents conclusions.

2 Voting on taxes for externalities and public goods

Numerous authors have examined the way in which voting systems influence the adoption or rejection of proposed taxes. Experimental results of Simon Dresner et al (2006) show that the success of adopting a new tax policy depends on how well the voters understand the proposed policy. For example, some voters may not support a pollution tax because they do not fully understand how it is used to enhance efficiency. Similarly, Peter Clinch et al (2006) conclude that public trust in the government plays a key role in determining the support for new taxes. Several natural field experiments have shown that framing affects voting behavior. For instance, according to Edward McCaffery and Jonathan Baron (2003), some people may react negatively even to the use of the word "tax". On the other hand, Rupert Sausgruber and Jean-Robert Tyran (2005) showed experimentally that some people prefer indirect over direct taxes, an effect they call "fiscal illusion."

An earlier, related literature examined positive externalities such as publicly funded education. John Creedy and Patrick Francois (1990) showed that if education provides a positive externality to the economy by inducing economic growth, and if only certain (high) type of individuals can benefit from education, then under certain conditions a majority of uneducated individuals would be willing to pay taxes to subsidize education for high types in return for (higher) economic growth. Johnson (1984) draws the same conclusion, however, his model does not incorporate opportunity cost of education in terms of forgone wages.

Alberto Alesina and Francesco Passarelli (2013) analyze majority voting outcomes when the government has three environmental policy tools: a rule, which is an instrument that sets an upper limit to the activity; a *quota* that requires a proportional reduction of the activity; and an emissions tax. They show that majority voting may not yield a socially optimal outcome when there are several policy options and voters have divergent preferences. If the group responsible for the externality is in the minority, then the majority will choose a policy that puts the greatest compliance cost burden on the minority group, and vice versa. These results are in line with those of Friedrich Schneider and Juergen Volkert (1999) who show that when the voting community is composed of groups with differentiated interests, the voting outcome may not be socially optimal.

Per Fredriksson and Thomas Sterner (2005) incorporate differences in abatement technologies across firms and show that "clean" firms may lobby for higher tax rates if the revenue is used for rebates. Shinya Kawahara (2011) builds a model with assumptions that voters do not observe politician types and environmental damage. Under this model, a pooling equilibrium results in a sub-optimal tax rate, whereas in the separating equilibrium, pro-environmental politicians choose a tax rate that is too high in order to distinguish themselves from other types. Lastly, Helmuth Cremer et al. (2004) examine revenue recycling and voting outcomes. They show that if environmental tax revenue is used to subsidize income and capital taxes, then the majority will choose an environmental tax that is too low.

Overall, the literature finds that the voting outcome depends not only on preferences of the voters but also on the perceived distribution of expected benefits (and/or costs). Our analysis herein shows similar effects, but the potential popularity of the instrument is increased by replacing a specific future tax proposal with one that correlates with individuals' own expectations of what it ought to be.

3 Voting on a Static Carbon Tax

The voting environment is as follows. There are N voters indexed by $i = \{1,\ldots,N\}$ and one policy maker who proposes an emissions tax path τ_t at time zero. Each voter chooses either to support or oppose the tax policy. The proposal is implemented only if it obtains majority support. In any period, each voter's loss depends on the squared distance between the proposed tax rate and his or her privately-held belief about the ideal tax rate $\tilde{\tau}_{it}$. Throughout this analysis, the tilde always denotes an agent's privately-preferred tax rate. For now we assume that each agent wants the tax to be set at his or her estimate of marginal damages, which we denote $V'_{it} = E(V'_t|\Omega_{i0})$ where Ω_{i0} is person i's information set at the time of the vote. We assume that everyone holds the same beliefs about the form of the damage function D but people have differing beliefs about how emissions will affect the future path of the state variable s_t. As noted in IWG (2010, 2013), the climate sensitivity to greenhouse gas emissions is a key parameter for determining the behaviour of IAMs and hence estimates of the marginal social cost of CO_2 emissions (see also Kevin Dayaratna et al. 2017).

Denote individual i's loss in period t when the proposed tax rate is τ_t as

$$L_{it} = (\tilde{\tau}_{it} - \tau_t)^2 \,. \tag{5}$$

A voter preferring $\tilde{\tau}_{it}$ will support the proposed tax if and only if the loss is less than or equal to a cut-off value d. We assume that d is the same for all agents. The following must therefore hold for a voter who supports the tax:

$$\tilde{\tau}_{it} \in \tau_t \pm \sqrt{d}.$$

A higher value of d thus increases the propensity to vote yes in each period.

The policy maker's objective is to choose a tax path that minimizes the summed losses of voters in each period, $L_t = \Sigma_{i=1}^{N} L_{it}$. We leave aside for now the problem that the regulator does not know the true values of $\tilde{\tau}_i$.[4] The first-best environmental policy requires an emissions charge equal to a term reflecting marginal damages, and if the total damages function is linear in emissions (as is typically the case in a stock pollution problem like climate change) the marginal damage term is constant across the emissions range. Each voters' loss function can then be seen as a reflection of the desire for optimal policy since minimizing net total pollution costs requires marginal damage pricing. The policy maker's objective can thus be seen as deriving from the same motivation with the added condition that the policy must gain enough support to be implemented. The first order condition of the single-period minimization problem implies that the tax should equal the mean of the preferred tax rates:

[4] Under the assumption that voters want the externality priced at marginal damages, this is no different, in principle, than any non-market elicitation problem which would require use of a technique like contingent valuation.

$$\bar{\tau}_{\mathrm{t}} = \frac{1}{N}\, \Sigma \tilde{\tau}_{it} \qquad (6)$$

Total losses will then be

$$L_t = (N-1)\sigma_t^2$$

where σ_t^2 is the variance of preferred tax rates among all voters in at time *t*. It is clear that total losses are increasing in the variance of beliefs. Hence for a given number of voters, when uncertainty grows and the variance of the preferred tax rate rises, we expect the mean loss to go up, implying an increased probability that the median voter will reject the tax.

This can be shown more formally as follows. If a majority consists of 50 percent of voters, we expect the tax will pass in a period if the probability of person *i* voting "No" is less than or equal to 0.5, so $P\left(|\tilde{\tau}_{it} - \bar{\tau}_t| > \sqrt{d}\right) \leq 0.5 \Rightarrow$Expected Majority Yes vote. Note that by Chebychev's inequality (John Rice 1988), as long as the distribution of $\tilde{\tau}_i$ has a finite second moment,

$$P\left(|\tilde{\tau}_{it} - \bar{\tau}_t| > \sqrt{d}\right) \leq \frac{\sigma_t^2}{d}.$$

Hence a sufficient condition for a majority to support the tax is $\sigma_t^2 \leq 0.5d$. For a given value of d, greater variance in the preferred tax rates reduces the likelihood of the vote passing.[5]

The loss function in equation (5) makes a number of influential assumptions that need to be explained. Use of squared deviations allows for tractability and a unique solution in the form of a simple mean, which then supports the distributional results. While squared deviations are familiar, other forms are also possible. Use of absolute, rather than squared, deviations would yield a result less sensitive to outliers, but since the optimization is a linear programming problem there may not be a unique solution nor would it necessarily correspond to $\bar{\tau}_t$.

Another important issue is that the loss function ignores the question of how the revenues will be used. Possibilities include lump-sum refunds or reductions in other tax rates, either of which can affect the voting outcome. Transfers to selected groups of voters could lead to arbitrary outcomes in which a majority coalition can always be found that will vote itself fiscal benefits, without any reference to the externality pricing issue. Transfers and offsetting tax reductions also have large implications in second-best fiscal design models. Since the work of Agnar Sandmo (1975), it has been well-known that when an emissions tax is embedded into a system of pre-existing taxes, general equilibrium considerations strongly influence the optimal form of implementation. Sandmo (1975) showed that, for optimality, the externality tax

[5] If we know that the preferred tax rates are normally distributed we can weaken this condition somewhat, since in that case at least 50% of the distribution will vote yes if $0.68\sqrt{\sigma_t^2} \leq \sqrt{d}$ or $\sigma_t^2 \leq 2.13d$. However, it is unlikely the $\tilde{\tau}_{it}$'s are symmetric and Normally distributed, even if we allow them to take negative values.

should fund reductions in other taxes and needs to be deflated by the marginal cost of public funds. Numerical simulations by Lans Bovenberg and Lawrence Goulder (1996) and Ian Parry et al. (1999) showed that using carbon tax revenues for lump-sum transfers to households rather than reductions in other taxes greatly inflates the welfare cost of the tax, to the extent that any positive emissions fee may be welfare-reducing unless marginal damages are very large; specifically larger than most estimates associated with greenhouse gases. Consequently, transfers to select voters intended to increase overall popular support may instead reduce it. Introducing transfers or offsetting tax cuts into the loss function thus raises a host of issues that, while important, would greatly complicate our analysis and make it intractable. The basic results to be shown herein are robust to the requirement that the emission tax should be deflated by the marginal cost of public funds, since that simply amounts to multiplying γ in equation (4) by a constant.

In sum, for a given value of d, in every period, the higher the variance of preferred tax rates, the less likely it is that a proposed tax rate will be supported by a majority of voters, even if the proposal is the optimal compromise computed by a planner who knows all the privately-preferred tax rate levels. A sufficient condition for a majority to support the tax is that the loss cut-off d is greater than or equal twice the variance of beliefs about the optimal tax.

The parameter d plays an important role in our analysis. Since the policy dimension is measurable (namely in the form of a tax rate) it might be possible to devise an empirical strategy to estimate it. If voter-specific data from a referendum on a carbon tax were available, namely the proposed $\bar{\tau}$ plus individual votes and their judgment on whether the tax was too high or too low, it might be possible to devise a maximum-likelihood estimation akin to a logit regression that would yield an estimate for *d*. However, that topic is left for future research.

In the next section we look at a simple intertemporal version of the problem and contrast the compromise (loss-minimizing) approach with the state-contingent approach, showing that as expectations about the future state diverge the compromise tax may eventually fail to obtain support, but the state-contingent tax is robust to this problem.

3 Two-Period Case Under a State-Contingent Tax

3.1 Pre-Announced Path

Preferences over the optimal tax rate diverge because CO_2 emissions do not cause direct harm but have an indirect effect through an uncertain and potentially long term influence on the climate state, leading to disagreement about the ultimate severity of the externality. The most recent IPCC report (IPCC 2014, Figure SPM.7) shows computer projections of global warming over the coming century spanning half a degree in the current decade, diverging to a span of over 5 degrees by 2100, and of course individuals may privately have an even wider range of expectations. Hence while it might be possible to get a majority to support a compromise emissions tax rate now ($\bar{\tau}_0$), if the policy package also contains a commitment to a specific future values of the tax, the same voters may reject the policy on the grounds that the future rate is too high or too low, because the variance of preferred rates grows over time.

In this section we consider this scenario, showing that the state-contingent approach is robust to the problem.

Dynamics are kept simple by reducing the planning horizon to two-periods. Modifying the notation from before, in period 0, the policymaker proposes a loss-minimizing tax rate $\bar{\tau}_0$ which will change to a preannounced value of $\bar{\tau}_1$ in period 1. Individual *i* has preferred tax rates $\tilde{\tau}_{i0}$ and $\tilde{\tau}_{i1}$ in the two periods, respectively, and the associated variances of preferred rates across *N* voters are denoted σ_0^2 and σ_1^2.

The set of preferred values each period is determined by $\tilde{\tau}_{i0} = V_{i0}' = E(V_0'|\Omega_{i0})$ and $\tilde{\tau}_{i1} = V_{i1}' = E(V_1'|\Omega_{i0})$. M10 shows that a reasonable approximation to the unobservable true value $V_t{}'$ is given by equation (4), hence the state-contingent tax is written as $\tau_t^s = \gamma s_t r_t$ where $r_t = e_t/\bar{e}_t$. This also implies the preferred tax rates at time 0 are (approximately) $\tilde{\tau}_{i0} = \gamma_i s_0 r_0$ where γ_i is agent *i*'s preferred value of the scaling parameter, and the future preferred tax rate is

$$\tilde{\tau}_{i1} = \gamma_i E(s_1 r_1|\Omega_{i0}). \tag{7}$$

M10 shows that γ is fully determined by the parameters of the damage function and the degree of homogeneity of the state function s_t. Since s_0 and r_0 (and all past values) are observable, this implies that γ is, in principle, identifiable even if future expectations of s_t differ across agents. The loss-minimizing solution thus yields $\gamma = s_0 r_0/\bar{\tau}_0$. We assume henceforth that this value of γ is used by all agents. The loss-minimizing method implies that the policy maker should then announce the future tax rate as

$$\bar{\tau}_1 = \gamma \Sigma_i \tilde{\tau}_{i1}/N. \qquad (8)$$

This requires elicitation of the $\tilde{\tau}_{i1}$'s, which are today's estimates of the preferred future tax rates, based on each individual's expectation of, among other things, how s_t will change. We denote the change between the periods in the preferred tax rates as $\Delta\tilde{\tau}_i$ and the change in the proposed tax rates as $\Delta\bar{\tau}$, and denote the difference between these as $\delta_i = \Delta\tilde{\tau}_i - \Delta\bar{\tau}$. Also denote $\varepsilon_{i0} = \tilde{\tau}_{i0} - \bar{\tau}_0$.

The variance of period 1 preferred rates from the perspective of time 0 is:

$$\begin{aligned}
\sigma_1^2 &= \left(\tfrac{1}{N-1}\right)\Sigma_i(\tilde{\tau}_{i1} - \bar{\tau}_1)^2 \\
&= \left(\tfrac{1}{N-1}\right)\Sigma_i(\tilde{\tau}_{i0} + \Delta\tilde{\tau}_i - \bar{\tau}_0 - \Delta\bar{\tau})^2 \\
&= \left(\tfrac{1}{N-1}\right)\Sigma_i(\varepsilon_{i0} + \delta_i)^2 \\
&= \left(\tfrac{1}{N-1}\right)\Sigma_i(\varepsilon_{i0}^2 + 2\varepsilon_{i0}\delta_i + \delta_i^2) \\
&= \sigma_0^2 + \sigma_\delta^2 + 2\Sigma_i(\varepsilon_{i0}\delta_i)/(N-1)
\end{aligned}$$

where $\sigma_\delta^2 = (\Sigma_i\delta_i^2)/(N-1)$. The third term is twice the covariance between $\tilde{\tau}_{i0}$ and $\Delta\tilde{\tau}_i$. It may be zero if people perceive no connection between the current level of marginal damages and the likely growth rate in the future, and it might be positive if those who believe the marginal damages are currently high also anticipate relatively faster growth in the future. But it is unlikely to be negative. We do not expect those who believe marginal damages due to CO_2 to be low at present also tend to believe they will grow rapidly in the future, or vice versa. Hence the last two terms are positive and therefore $\sigma_1^2 > \sigma_0^2$.

In the two-period case we assume that the proposed policy is the pair $(\bar{\tau}_0, \bar{\tau}_1)$. Assume that $\sigma_0^2 < 0.5d$ so the period 0 tax rate on its own would pass a referendum, but that σ_1^2 grows sufficiently large that the period 1 tax $\bar{\tau}_1$ fails to get majority support at time 0, and therefore the entire proposal fails. This is a plausible representation of the climate case, since beliefs about the future path of warming, and thus preferences over preferred carbon tax rates, diverge sharply as the forecast horizon increases. And as we have seen, there are important example where subsequent votes have reversed. Hence if a policy maker is asking voters today to make a one-time commitment to a sequence of policies, the divergence of beliefs about the future optimal values make formation of a stable agreement difficult even when a majority could agree on a compromise policy in the current period. Even if $\bar{\tau}_1$ is the optimal compromise for period 1, the divergence of views implies higher variance of $\tilde{\tau}_{i1}$, eventually making it impossible to hold a majority among voters in period 0.

3.2 State-Contingent Path

The state-contingent mechanism gets around this problem by not specifying $\bar{\tau}_1$ directly. Instead the policy maker announces a rule that will be used to calculate it in period 1, which forces agents to form an expectation about the likely future tax rate and compare it against their preferred future tax rate. Specifically, the policymaker announces that, instead of applying equation (8), the future tax rate will be

$$\tau_1^s = \gamma s_1 r_1 \tag{9}$$

and that the actual rate will only be announced at the start of period 1 when s_1 and r_1 are known (or, for the latter, can be estimated). Each agent thus forms the expectation

$$E_i(\tau_1^s) = \gamma E(s_1 r_1 | \Omega_{i0}). \tag{10}$$

We then obtain the following result:

Proposition 1. If $\sigma_0^2 < 0.5d$ so the state-contingent tax (4) obtains majority support in period 0, it will in period 1 as well, regardless of the divergence of views on the evolution of s_t or the preferred tax rate over time.

Proof. From above we have $\sigma_1^2 = \sigma_0^2 + \sigma_\delta^2 + 2\Sigma_i(\varepsilon_{i0}\delta_i)/(N-1)$ and $\sigma_\delta^2 = (\Sigma_\mathrm{i}\delta_i^2)/(N-1)$, where, in this case, $\delta_i = \Delta\tilde{\tau}_i - E(\Delta\tau^s)$. Using γ in equation (7), $\Delta\tilde{\tau}_i = \gamma(E(s_1 r_1|\Omega_{i0}) - r_0 s_0)$. Also $E(\Delta\tau^s) = \gamma(E(s_1 r_1|\Omega_{i0}) - r_0 s_0)$. Hence $\delta_i = 0$ for all *i*. It immediately follows that $\sigma_1^2 = \sigma_0^2 < 0.5d$ and the policy gets majority support. ∎

Proposition 1 works because everyone expects their preferred tax rate to be implemented in the future. This is a result of the tax rule (4) providing a correlated approximation to the unobservable socially optimal tax rate. So as long as a voter wants to see the socially optimal tax rate implemented at every time *t*, it does not matter whether that voter believes the state variable will increase or not over time. Those who believe in a rapid increase in s_t would both prefer and anticipate a steep increase in the tax rates, while those who believe s_t will not go up would expect and prefer low tax rates.

4. Dishonest Voting on a State-Contingent Tax

We now consider a case in which some voters do not actually care about correctly pricing the externality, but adopt one of two extreme views based on political or other exogenous considerations. There are n_1 voters in the first group who oppose the emissions tax under all circumstances, so we denote this as $\tilde{\tau}_t^1 = 0$. There are n_2 voters in the second group who prefer an emissions tax set to some maximum feasible level w under all circumstances, so we denote this as $\tilde{\tau}_t^2 = w$. If the government chooses a static compromise policy they will set the tax equal to the mean preferred rate, which in this case is:

$$\bar{\tau} = n_2 w / N \tag{11}$$

where $N = n_1 + n_2$. We denote the state-contingent option as $\tau^s = V'$, dropping the time subscripts for convenience but without losing generality.

If the compromise tax is implemented, from equation (5) the total losses for the first group will be $n_1 \bar{\tau}^2$ and the total losses for the second group will be $n_2(\bar{\tau} - w)^2$. Under the state-contingent option the total losses for the first group will be $n_1(V')^2$ and the total losses for the second group will be $n_2(V' - w)^2$.

Suppose the compromise option is currently in place and the policymaker proposes to change to the state-contingent option. The total increase in losses for group 1 will be

$$n_1(V'^2 - \bar{\tau}^2) \tag{12}$$

which may be a negative number. For group 2 the total increase in losses will be

$$\begin{aligned} n_2(V' - w)^2 - n_2(\bar{\tau} - w)^2 &= n_2(V'^2 - \bar{\tau}^2 - 2w(V' - \bar{\tau})) \\ &= n_2[(V' + \bar{\tau})(V' - \bar{\tau}) - 2w(V' - \bar{\tau})] \\ &= n_2(V' - \bar{\tau})(V' + \bar{\tau} - 2w). \end{aligned} \tag{13}$$

Since w is by definition the maximum possible tax rate we have $V' < w$ and $\bar{\tau} < w$, therefore $V' + \bar{\tau} < 2w$ so the second bracketed term is negative. It follows from (12) and (13) therefore that if one group experiences a total net benefit from the policy change, the other group must experience a total net loss, so they will always vote in opposite directions.

If there are only two groups the outcome must be one extreme or the other. If there is a third group n_3 consisting of honest voters who always prefer V', then there is an increased possibility for approval of a non-extreme tax rate. If no group has an outright majority it would not be able to impose its will, which rules out the extremes $(0, w)$. Suppose therefore that the remaining options to be voted on are $\bar{\tau}$ and V'. As long as no group has an outright majority it must be the case that group 3 can combine with either of the other two groups to form a majority (so either $n_1 + n_3 > n_2$ or $n_2 + n_3 > n_1$). Recall that if group 1 prefers V' to $\bar{\tau}$ then group 2 prefers the opposite, and vice versa, so they will never form a coalition. By equation (12) if $\bar{\tau} > V'$ then group 1 will prefer V' and group 3 can combine with it to secure that outcome. If $\bar{\tau} < V'$ then group 2 will prefer V' and group 3 can combine with it to secure that outcome. Hence:

> *[Proposition 2] If $n_1 < 0.5$ and $n_2 < 0.5$ and $n_3 < 0.5$, then a majority coalition can always be formed that yields a tax rate of V'.*

5 Conclusions

This paper has examined voting outcomes when the policy maker proposes an externality pricing instrument that is either based on a static political compromise or on a state-contingent updating rule. We begin with the intuitively obvious idea that policies are more likely to be adopted, the greater the extent to which voters expect to get their preferred outcome. We then apply this idea to the intertemporal carbon pricing problem by tying it to the need to give up specificity about future policy values in favour of explicit mechanisms to assimilate new information as it emerges. We draw upon the specific proposal in McKitrick (2010) and (2011) for making future values of a carbon tax contingent on observations on the climate state and integrate it into a simple two-period voting model. We show that, in the case in which voters prefer the socially optimal price based on their honest expectation of marginal damages, even if a proposed rate is currently acceptable to a majority, a divergence of beliefs about the future severity of the externality implies that the majority coalition will tend to break down if asked to commit today to a future price sequence. But a state-contingent pricing rule can hold on to majority support regardless of the divergence of voters' beliefs about the future. We also show that if some of the voters are dishonest (they prefer either a zero tax or a maximum tax on a priori grounds, irrespective of marginal damages), but no group has an outright majority, then a coalition in favour of the state-contingent tax can still be formed.

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