Political competition within and between parties: an application to environmental policy*

Helmuth Cremer
University of Toulouse
(IDEI and GREMAQ)

Philippe De Donder
University of Toulouse
(IDEI and GREMAQ-CNRS)

Firouz Gahvari
Department of Economics
University of Illinois at Urbana-Champaign

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Abstract

This paper presents a political economy model that explains the low rate of emission taxes in the U.S., as well as the fact that neither Democrats nor Republicans propose to increase them. The voters differ according to their wage and capital incomes which are assumed to have a bivariate lognormal distribution. They vote over the emission tax rate and a budgetary rule that specifies how to redistribute the tax proceeds. The political competition is modeled à la Roemer (2001) where the two parties care for the policies they propose as well as the probability of winning; the equilibrium solution concept is the Party Unanimity Nash Equilibrium (PUNE). We calibrate the model using U.S. data and compute the PUNEs numerically. Two main results emerge. All "viable" PUNEs entail subsidies on emissions (as opposed to taxes). This indicates the importance of distributional concerns in garnering political support for environmental policies. Second, parties always propose an interior value for the budgetary rule even though all citizens prefer extreme values. This illustrates the emergence of political compromise to attract voters.

Key words: Emission taxes, political competition, PUNE, distributional concerns, political compromise.

JEL Classification: H23, D72.

1 Introduction

The U.S. environmental policy is often criticized by the environmentalists, academics and the media for being exceedingly lax on polluters. The criticism has been particularly acute in relation to the greenhouse gases that burning fossil fuels emit. Two facts are often cited to underline this. The first is that gasoline prices are, and have traditionally been, markedly lower in the U.S. than in any other industrial country.[1] The second is the U.S. government's refusal to join the more than 140 countries of the world who have ratified the Kyoto protocol.[2] With no policy change in the offing, one suspects that there must exist strong political pressures pushing the US government to adhere to its current policies. This is all the more likely as the issue is not one of Democrats versus Republicans. Neither party supports higher gasoline taxes, nor ratifying the Kyoto protocol.

This paper presents a political economy model that explains the persistence of the U.S. environmental policy, as well as the fact that *neither* party offers a policy proposal of consequence for changing it. We model the political competition à la Roemer (2001) with the "Party Unanimity Nash Equilibrium" (PUNE) as the equilibrium solution concept. This approach is a more realistic, and historically a more accurate, description of the political process, as compared to the traditional approach which explains every political outcome through the prism of a median voter's preferences. As Roemer (2001) has forcefully argued, the traditional approach suffers from three major shortcomings. First, its Downsian outlook, wherein the political parties (as opposed to voters) have no preferences over policies, accords political parties no role in determining the outcome of the political process within a society. This is plainly counterfactual. Second, the assumption that the distribution of voter types is known for certain, is rather dubious. Third, there is the well-known problem of the generic nonexistence of majority-voting equilibrium when the policy space is multidimensional.

In Roemer's approach, two political parties (here Democrats and Republicans) com-

[1] Currently, a litre of gasoline is taxed about 10 cents in the U.S., compared to 96 cents in France and 1.10 dollar in the UK.

[2] Australia is the only other industrial country not having signed the Kyoto protocol.

pete for votes in an election. Each chooses a policy that it will implement if elected. Parties are composed of two factions: the "opportunists" who aim to maximize the probability of winning the election, and the "militants" who are only interested in policies regardless of their electoral ramifications. *Unanimity* between the two factions is required for a party to accept a *deviation* from its current policy. This unanimity rule determines the preferences (payoffs) of the two parties who simultaneously choose their political platforms. A PUNE is a Nash equilibrium of this game.

This approach often ensures the existence of equilibria even in multidimensional settings. Indeed, the "problem" here is generally one of multiplicity of equilibria. However, unlike many other equilibrium concepts (e.g. uncovered set or top cycle - see De Donder (2000) and Laslier-Picard (2002)), PUNEs are usually quite discriminating in the sense of selecting a small part of the feasible set. Moreover, one can compare two PUNEs and find out how and why they differ. (This is often due to one faction within one party having more bargaining power.)[3] Finally, a compelling feature of PUNEs is that one is able to compute them on the basis of actual data.

We consider a two-dimensional policy comprising a tax (or a subsidy) and a "budgetary rule". The tax (or subsidy) is levied on the consumption of an externality generating (polluting) good; the budgetary rule specifies the way the tax proceeds are redistributed to the polity (or the way the subsidy will have to be financed). Individuals have identical quasi-linear preferences over a (non-polluting) numeraire good and the polluting good. The goods are produced by a linear technology subject to constant returns to scale in a competitive environment. This is essentially the setup we used in our earlier studies; see Cremer *et al.* (2004a, 2004b). However, those studies used a normative and/or traditional Downsian approach[4] and the numerical illustrations were

[3]In certain applications, the model yields robust predictions with all equilibria exhibiting the same characteristics.. Roemer (1999) presents a model that explains why all democracies have progressive income tax systems. He assumes that the set of admissible tax schedules are quadratic in income so that the policy space is two-dimensional when one takes the government's budget constraint into account. He shows that while there exists a continuum of equilibria, in all PUNEs a progressive income tax policy wins with a probability one.

[4]Cremer *et al.* (2004a), following a hybrid normative/positive approach, assumed a unidimensional voting game over emission taxes only. They left the disbursement of the tax revenues to be determined at a "constitutional level," by a "welfare maximizing" government. This led them to assert that the government should be able (under certain conditions) to effect first-best Pigouvian emission taxes. Cre-

not based on actual empirical data.

We calibrate our model using data for the U.S. economy. The voters are US households as represented by the 2001 Panel Study for Income Dynamics Survey, considering the 6,877 households who reported a nonzero income (whether labor *or* asset incomes) for the year 2000. We then fit a bivariate lognormal distribution for labor and asset incomes to this truncated sample (using the same weights that the survey assigns to each household.)

The polluting good is called energy and consists of a weighted sum of energy-related consumption goods (fuel oil, gasoline, natural gas, kerosene, LPG and electricity,) where the weights are the goods' expenditure shares in total expenditures on energy-related consumption goods. We calibrate the demand function on the basis of a -0.30 price elasticity of demand (based on the literature estimates for the price elasticity of consumer demand for energy), and a 0.0555 ratio of average expenditure on energy to average income (found from the Consumer Expenditure Surveys, 2002), with the average income being determined from the 2001 PSID data ($\$59,926$). The quantity of pollution is found according to the carbon content of each, appropriately-weighted, component. Using a value of \$50 for the social marginal cost of a ton of carbon (based on the estimates reported by the EPA), we are able to calculate the marginal social damage of one unit of the polluting good. Finally, we find the weights that the two parties' militants (the Democrats and the Republicans in our setting) assign to different citizens, and the probability that a particular citizen participates in the election, on the basis of Bartels (2002). Both weights (for both parties' militants) and turn out probabilities increase with citizens' total income.

We show that the PUNEs that emerge may be grouped into two different types. Type I PUNEs are characterized by both parties proposing a very huge tax rate (148% to 151%) combined with a budgetary rule which calls for all tax proceeds to be rebated

mer *et al.* (2004a) followed a positive approach throughout but, faced with the non-existence problem, resorted to two sequential voting procedures (with either policy being determined first and the other later), as well as the Shepsle procedure, to arrive at a political equilibrium. They found that (in most cases) the equilibrium corresponded to the preferences of the "median individual". This included the prediction that all tax revenues must be rebated solely through *either* wage subsidies *or* capital income subsidies. Actual policies, of course, never display such a knife-edge property.

solely on the basis of the voters' capital incomes. These tax rates correspond to the most-preferred tax rates of the *militants* in the Democratic and the Republican parties. They are extremely high, considering that the optimal unweighted utilitarian policy calls for a tax of only about 10%, and that the "median voter" most-prefers a *subsidy* of more than 80%. Thus these PUNEs are essentially dictated by the preferences of the militants in the Democratic and the Republican parties, and especially by the fact that militants in both parties put higher weights on richer individuals' preferences.

With both parties proposing to base the taxpayers' rebates solely on the basis of their capital incomes, and with the Democrats proposing a lower tax rate (albeit by a little), it is clear that all individuals who have capital incomes below a threshold level vote Democratic. We thus obtain a society polarized into two groups based only on how much capital income they have. Moreover, the division occurs at a very high level of capital income. This in turn implies that the Democrats have a probability of winning the election that varies from 95% to 95.9% across all possible configurations of the proposed tax rates. Now while each PUNE is, by definition, an equilibrium, one can argue that in the long term the opportunists will stick to a particular party only if that party has a high enough probability to win elections. On the basis of this criterion, it is clear that Type I PUNEs are *not* "viable" equilibria. The 5% probability of winning is too low to keep the Right party's opportunists to stick to their party for long.

Type II PUNEs are the viable equilibrium outcomes of our political economy model, in the sense that each party has a "reasonable" chance of winning and thus not alienating its militants: the Democrats' average probability of winning (among all PUNEs) is 53.8%, and the Republicans' is 46.2%. These PUNEs share the following characteristics. First, both parties offer a subsidy. Specifically, the Democrats offer a subsidy that varies from 1.1% to 73.7% across all PUNEs (with an average of 39.3%), while the Republicans offer a subsidy varying from 1.5% to 74.1% (with an average of 42.8%). That all Type II PUNEs entail subsidies, underscores the importance of distributional concerns in ensuring political support for environmental policies—a factor that the literature on environmental taxation has, with few exceptions, ignored.

Second, both parties offer an interior solution for the budgetary rule despite the fact that all voters have extreme preferences (they want all rebates or taxes to be linked solely either to capital incomes or to wage incomes). This compromise turns out to be a particularly striking feature of the PUNEs; other equilibrium concepts, even when they are not empty in multidimensional choice sets, do not share this feature; see Cremer *et al.* (2004a). It underlines the importance of generating political support for environmental policies (through political compromise)—another aspect that the literature has hitherto paid scant attention to.[5]

Third, with both parties proposing different values for the budgetary rule, it is the individuals' source of income (wage or capital), rather than their aggregate income, that delineates the set of people who vote for one party or the other. Society is polarized between wage earners, who vote for the Democratic party, and capital income earners, who vote for the Republicans.

2 The model

Individuals are identified by the "type parameter" $\theta = (r, w)$, where r is capital income and w is labor income. Let H denote the type space; θ is continuously distributed over H according to the density function, $f(\theta)$. The associated cumulative distribution function is $F(\theta)$. Population size is normalized at one. Total income is $m(\theta) = r + w$. All sources of income are exogenous.

Individuals have identical quasi-linear preferences over a (non-polluting) numeraire good and a polluting good, y. The goods are produced by a linear technology subject to constant returns to scale in a competitive environment. Normalize the producer price of y at one. Let q denote the consumer price of y, $I(\theta)$ the disposable income (net of taxes or transfers) and Y the total consumption of y (across all individuals). The indirect utility function of an individual of type θ is given by:

$$v(q, I, Y) = a(q) + I(\theta) - \varphi(Y), \tag{1}$$

with $a'(q) < 0$, $\varphi'(Y) > 0$, and $\varphi''(Y) > 0$. Total consumption of the polluting good thus creates a negative "atmosphere externality" of $\varphi(Y)$. By Roy's identity, the demand for

[5] Exceptions include Boyer and Laffont (1998), Bös (2000), Brett and Keen (2000), Marsiliani and Renström (2000), and Cremer, De Donder and Gahvari (2004a, 2004b).

y is given by[6]

$$y(q) = -\frac{\partial v}{\partial q} = -a'(q). \tag{2}$$

Note that y is independent of θ. Aggregate consumption of the polluting good is then equal to

$$Y = \int_H y(q) f(\theta) d\theta = \overline{y}(q) = y(q), \tag{3}$$

so that total, average and individual consumption levels are all equal.

Good y is subject to a "pollution tax" levied at the rate of $(q-1)$ per unit of output. The proceeds of the tax are refunded through reductions in labor and capital income taxes. To simplify notation, we do not explicitly include pre-existing income taxes. Consequently, the net of tax income of individual θ is given by

$$I(\theta) = (1 + g_r)r + (1 + g_w)w, \tag{4}$$

where g_r and g_w are the refund rates on capital and wage incomes. The tax $(q - 1)$ is endogenous in our setting and we do not a priori restrict it to be positive. Consequently, negative "refunds" are not ruled out either; they are effectively equivalent to lump-sum taxes.

Let $\overline{r}$, $\overline{w}$ and $\overline{m}$ denote average capital income, average labor income and average income:

$$\overline{r} = \int_H r(\theta) f(\theta) d\theta, \quad \overline{w} = \int_H w(\theta) f(\theta) d\theta, \quad \overline{m} = \int_H m(\theta) f(\theta) d\theta.$$

The tax and refund rates are related through the government's budget constraint

$$R(q) \equiv (q - 1)y(q) = g_r \overline{r} + g_w \overline{w}, \tag{5}$$

where $R(q)$ is the revenue raised from taxing the polluting good (alternatively, the budgetary cost of subsidizing this good). Observe that, in light of (5), the government has only two degrees of freedom in choosing its policy instruments. Once q and, say, g_r

[6]We assume throughout the paper that poor individuals have some exogenous (and non-taxable) wealth, sufficient enough to cover their consumption of the polluting good.

are set, g_w is automatically determined. To represent this in a more symmetric way, and to characterize the refund/funding system through a single parameter, we introduce the concept of a "budgetary rule". This specifies the proportion of tax proceeds, α, that must be refunded on the basis of wage incomes (alternatively, the proportion of the subsidy cost financed by taxing wage incomes). Formally, α is defined such that[7]

$$\alpha = \frac{g_w \overline{w}}{R(q)} = 1 - \frac{g_r \overline{r}}{R(q)}. \tag{6}$$

With this notation, the tax-cum-refund policy is characterized fully by the pollution tax (or the consumer price of y) and by the budgetary rule; i.e. by the two parameters q and α. Assume that $\alpha \in [0, 1]$; this amounts to assuming that g_w and g_r are restricted to be of the same sign.

The determination of q and α through the political process forms the core of our study. The process is one of competition between two parties. However, we depart from the traditional Downsian approach and instead use John Roemer's "Party Unanimity Nash Equilibrium" (PUNE) as our solution concept. We will discuss this solution concept briefly in Section 4 below. The next section examines the voters' preferences over (q, α) and the nature of the "optimal" solution for (q, α). These will provide the other ingredients for our study.

3 Preferences over (q, α) and the optimal policy

A voter's preferences over tax and refund policies may be derived from his utility function (1), by making use of (3)–(6). This yields the following reduced indirect utility function,

$$V(q, \alpha, \theta) = a(q) + m(\theta) + \delta(\theta, \alpha)R(q) - \varphi(y(q)), \tag{7}$$

where

$$\delta(\theta, \alpha) \equiv (1 - \alpha)\frac{r}{\overline{r}} + \alpha\frac{w}{\overline{w}}. \tag{8}$$

Observe that when the polluting good is taxed, $\delta(\theta, \alpha)$ indicates the proportion of θ's tax payment that he will get back in refunds. In the case of a subsidy, $\delta(\theta, \alpha)$ shows the

[7] If $R(q) = 0$, then $g_r = g_w = 0$ as we restrict g_r and g_w to be of the same sign. In this case, $\alpha = [0, 1]$.

ratio of θ's income tax payments to the (price) subsidy he receives from the consumption of the polluting good.[8] It is clear from (7) that the size of $\delta(\theta, \alpha)$ is a crucial determinant of the impact of q on $V(q, \alpha, \theta)$. Additionally, $\delta(\theta, \alpha)$ is the only *direct* channel through which α affects $V(q, \alpha, \theta)$.

3.1 Optimal policy

To characterize the optimal solution for the pair of policy instruments (q, α), we resort to a utilitarian framework. This provides a natural benchmark against which to assess the properties of our political solution. The utilitarian social welfare function can be written, using (7) and (8), as

$$W^F = \int_H V(q, \alpha, \theta) dF(\theta) = a(q) + \overline{m} + R(q) - \varphi(y(q)).$$

Observe that W^F is independent of α so that distributional concerns do not enter in the determination of optimal policy. This is due to the twin assumptions of a utilitarian social welfare function and quasi-linear preferences. Thus, any value for $\alpha \in [0, 1]$ is as good as any other. The tax, on the other hand, does matter. Its optimal level is found by maximizing W^F with respect to q, characterized by

$$q^F - 1 = \varphi'(y(q^F)) > 0.$$

This is the traditional Pigouvian rule, equalizing the tax on the polluting good to its marginal social damage.

3.2 Most-preferred (q, α) for a θ-type voter

As a first-step, consider θ's most-preferred value of α *conditional* on q, $\alpha^*(\theta, q)$, and his most-preferred q *conditional* on α, $q^*(\theta, \alpha)$. Lemma 1 characterizes $\alpha^*(\theta, q)$. It is obtained by differentiating (7) partially with respect to α, making use of (8). Interestingly, it turns out, q affects $\alpha^*(\theta, q)$ only through the sign of $R(q)$. This, in turn, depends on whether the polluting good is taxed ($q > 1$), or subsidized ($q < 1$). We have:

[8] To see this, substitute for α from (6) into (8). This yields

$$\delta(\theta, \alpha) = \frac{g_r r(\theta) + g_w w(\theta)}{R(q)}.$$

Lemma 1 *An individual's most-preferred value of α is given by*

$$\begin{aligned}
\alpha^*(\theta, q) &= 1 \text{ if } \frac{w}{r} > \frac{\bar{w}}{\bar{r}} \text{ and } R(q) > 0, \\
\alpha^*(\theta, q) &= 1 \text{ if } \frac{w}{r} < \frac{\bar{w}}{\bar{r}} \text{ and } R(q) < 0, \\
\alpha^*(\theta, q) &= 0 \text{ if } \frac{w}{r} < \frac{\bar{w}}{\bar{r}} \text{ and } R(q) > 0, \\
\alpha^*(\theta, q) &= 0 \text{ if } \frac{w}{r} > \frac{\bar{w}}{\bar{r}} \text{ and } R(q) < 0, \\
\alpha^*(\theta, q) &= [0, 1] \text{ if } \frac{w}{r} = \frac{\bar{w}}{\bar{r}} \text{ or } R(q) = 0.
\end{aligned}$$

The intuition behind these expressions is straightforward. Recall from (7) that α affects $V(q, \alpha, \theta)$ *directly* through $\delta(\theta, \alpha)$ only. It is then plain that individual θ prefers $\delta(\theta, \alpha)$ to attain its maximum value if $R(q) > 0$, and its minimum value if $R(q) < 0$. Put differently, if the polluting good is taxed and the individual is to receive a refund, he would want the highest possible refund. On the other hand, if the polluting good is subsidized and the individual is to be taxed to finance it, he would want to pay the lowest possible (income) tax.

The first and fourth expressions in Lemma 1 postulate that $w/r > \bar{w}/\bar{r}$. Under this assumption, from (8), $\delta(\theta, \alpha)$ is highest when $\alpha = 1$, and lowest when $\alpha = 0$. That is, if the individual's share of labor income is larger than "average," he would want to link the refunds (if the voters are to get refunds) solely to labor incomes which would get him the highest refunds. And if he were to be taxed (on income), he would want to link the tax solely to capital incomes which would assure him the lowest tax payment.

In contrast, the assumption in the second and third expressions of Lemma 1 is $w/r < \bar{w}/\bar{r}$. Given this, $\delta(\theta, \alpha)$ is highest when $\alpha = 0$, and lowest when $\alpha = 1$. That is, if the individual's share of labor income is smaller than "average," he would want refunds to be based solely on capital income, and tax payments solely to labor incomes. Finally, if $w/r = \bar{w}/\bar{r}$, it will not matter on which income source taxes and refunds are based on. In this case, the individual's utility is independent of α.

Next, Lemma 2 which is proved in the Appendix, characterizes $q^*(\theta, \alpha)$.

Lemma 2 *(i) Let $\widetilde{q}(\delta)$=arg $\max_q[a(q) + \delta R(q) - \varphi(y(q))]$. We have $q^*(\theta, \alpha) = \widetilde{q}(\delta(\theta, \alpha))$ so that q^* depends on θ, as well as on α, only through δ.*

(ii) Assuming V is concave and $R'(q) > 0$, $\widetilde{q}(\delta)$ increases with δ so that $q^*(\theta, \alpha)$ is increasing in r and w (for a given value of α). Furthermore, we have

$$\begin{aligned}
\delta(\theta, \alpha) &= 1 \Rightarrow q^*(\theta, \alpha) = q^F > 1, \\
\delta(\theta, \alpha) &> 1 \Rightarrow q^*(\theta, \alpha) > q^F > 1, \\
\delta(\theta, \alpha) &< 1 \Rightarrow q^*(\theta, \alpha) < q^F \textit{ so that } q^*(\theta, \alpha) \gtrless 1.
\end{aligned}$$

This lemma signifies the importance of δ in determining if an individual θ prefers the polluting good to be taxed or subsidized, and in the case of a tax, whether the tax should exceed of fall short of the Pigouvian tax. If $\delta = 1$, the individual receives a refund precisely equal to his tax payment. With no net monetary costs or benefits, his most-preferred tax will be the Pigouvian one. If $\delta > 1$, taxation of the polluting good confers a net monetary benefit on the individual enticing him to want a tax larger than the Pigouvian tax. Finally, if $\delta < 1$, taxation of the polluting good results in a net monetary loss for the individual. He would then want a lower than Pigouvian tax. Observe that whereas in the first two cases the individual necessarily prefers a tax to a subsidy, in the third case he may prefer either one. In particular, he will prefer a subsidy to tax (i.e., $q^* < 1$), if his net monetary loss exceeds the environmental benefit that results from a positive tax.

Combining these two lemmas, one can provide a full characterization of all individual types' most-preferred policies. The result of this exercise is summarized in Figure 1. The first ingredient in this figure is the line $w/r = \overline{w}/\overline{r}$ which represents the set of types for whom $\partial\delta(\theta, \alpha)/\partial\alpha = 0$. On this ray, w and r move positively together, and, from (8), $\delta(\theta, \alpha) = w/\overline{w} = r/\overline{r}$. Thus, δ, and with it q^* also, increase with w and r. Clearly, this ray passes through the point $\overline{\theta} = (\overline{r}, \overline{w})$ at which we have $\delta(\overline{\theta}, \alpha) = 1$. Consequently, from Lemma 2, the $\overline{\theta}$-type individual's most-preferred tax is positive ($q^*(\overline{\theta}, \alpha) = q^F > 1$). Further observe that the individual with $\theta = (0, 0)$ prefers a negative tax. This is because with quasi-linear preferences the consumption of the polluting good is the same for all.[9] Consequently the individual $(0, 0)$ benefits from the subsidy but does not contribute towards its financing. It then follows by continuity that as one lowers w and r from

[9] See footnote 6.

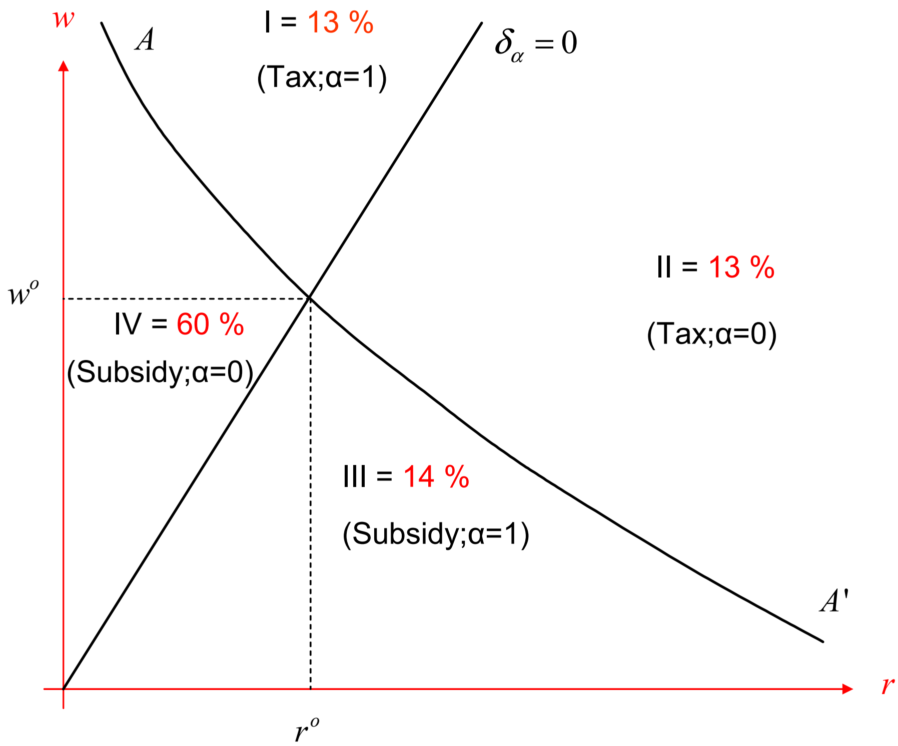

Figure 1: Most preferred levels of q and α: partitioning of the type space.

$(\overline{r}, \overline{w})$ and towards $(0,0)$, along the $w/r = \overline{w}/\overline{r}$ ray, one must pass a point $\theta^0 = (r^0, w^0)$ at which $q^*(\theta^0, \alpha) = 1$. Note also that at $\theta^0 = (r^0, w^0)$, $\alpha^*(\theta^0, q) = [0, 1]$.

The second ingredient in Figure 1 is the curve AA'. It represents the set of all types $\theta = (r, w)$ who are indifferent between their most-preferred policy under $\alpha = 0$ (namely, $(q, \alpha) = (q^*(\theta, 0), 0)$), and their most-preferred policy under $\alpha = 1$ (namely, $(q, \alpha) = (q^*(\theta, 1), 1)$). We prove in the Appendix that:

Lemma 3 *Let AA' be the locus of types $\theta = (r, w)$ for whom*

$$V(q^*(\theta, 0), 0, \theta) = V(q^*(\theta, 1), 1, \theta).$$

We have:

(i) The AA' curve is downward-sloping in (r, w) space;

(ii) q^* is greater than one above the AA' curve and less than one below it;

(iii) there is a discontinuity in q^* whenever one crosses AA', except at (r^0, w^0).

The lines $r = r^0$ and $w = w^0$ that go through (r^0, w^0) define four quadrants. To the *north-east* of (r^0, w^0), $q^* > 1$ so that individuals there prefer a tax to a subsidy. In this quadrant, we have $\alpha^* = 1$ above the $w/\overline{w} = r/\overline{r}$ line, and $\alpha^* = 0$ below it. Now recall, from Lemma 1, that the preferences for α are reversed when $R(q) < 0$ (which is the case when $q < 1$). Thus to the *south-west* of (r^0, w^0), the above results are reversed. We have $q^* < 1$ with $\alpha^* = 1$ below the $w/\overline{w} = r/\overline{r}$ line , and $\alpha^* = 0$ above the line. To the *north-west* as well as the *south-east,* the pattern of solutions is more complex. In the north-west (resp. south-east) quadrant, the individuals compare the most-preferred subsidy under $\alpha = 0$ (resp. $\alpha = 1$) with the most-preferred tax under $\alpha = 1$ (resp. $\alpha = 0$). The dividing line between these two types of solution is the curve AA' defined above.

Summing up, the line $w/\overline{w} = r/\overline{r}$ and the curve AA' partition the space of types into four regions. The first two regions are above the AA' curve where the individuals' most-preferred tax rates are positive ($q^* > 1$). Region I is where one is also above the $w/\overline{w} = r/\overline{r}$ line with $\alpha^* = 1$, and Region II is where one is below the $w/\overline{w} = r/\overline{r}$ line with $\alpha^* = 0$. Individuals in Regions III and IV are below the AA' curve and prefer a subsidy ($q^* < 1$). Region III is located below the $w/\overline{w} = r/\overline{r}$ line with $\alpha^* = 1$, and Region IV is above it with $\alpha^* = 0$. For future reference, Figure 1 also indicates each region's share of total population for our calibrated model studied below.

4 The Political Competition Model: PUNEs

The solution concept we use is John Roemer's "Party Unanimity Nash Equilibrium" (PUNE); see Roemer (2001). To make the paper self contained, we begin by giving a brief sketch of the main features of this equilibrium concept.

Two political parties compete for votes in an election. Each chooses a policy that it will implement if elected, and people vote for the party whose policy they prefer. There are two departures from the classical Downs model. First, there is electoral uncertainty: when choosing their platform, the parties do not know for sure which party will, given the platforms, win the election. Each bases its platform selection, in part, on the probability of winning the election. Second, parties are not interested only in winning the election; they also care about the policies. More precisely, each party is composed of two factions: the "opportunists" and the "militants". These factions are *not* identified with particular types of voters. The opportunists aim to maximize the probability of winning the election; they are uninterested in policies per se. The militants, on the other hand, are only interested in the policies announced regardless of their electoral ramifications. They choose the policy that maximizes their "party's utility" (to be discussed below) without taking the electoral consequences into account.

Each faction has a complete preference order on the set of possible policies. The preference of the party is the intersection of these two orders. Thus, *unanimity* between the two factions is required for a party to accept a *deviation* from its current policy. This unanimity rule determines the preferences (payoffs) of the two parties who simultaneously choose their political platforms. A PUNE is a Nash equilibrium of this game.

To formally define a PUNE, index the parties by $i = L, R$. The objective function of the militants is defined as

$$v_i(q, \alpha) = \int_H \omega_i(\theta) V(q, \alpha, \theta) F(\theta) d\theta, \quad i = L, R, \tag{9}$$

where $\omega_i(\theta)$ is the weight attributed by party i to individuals of type θ. The probability that party i wins the election is denoted by $\pi_i(q_i, \alpha_i, q_j, \alpha_j)$; $i, j = L, R$, $i \neq j$. This probability increases with the share of individuals preferring party i's policy to that of party j. It is determined by assuming that each individual θ participates in the election with some probability $b(\theta)$. Further, assume that when both parties offer the same policy, $\pi_L = \pi_R = 1/2$. The probability of winning the election represents the objective function of the opportunists. We have:[10]

Definition 1 *Let* $T = \mathbb{R}^{+} \times [0,1]$ *be the policy space. A Party Unanimity Nash Equilibrium is a pair of admissible policies* $(q_L, \alpha_L), (q_R, \alpha_R) \in T$ *such that for each* $i, j = L, R,\ i \neq j$; $\nexists (q, \alpha) \in T$ *with the property that, given* (q_j, α_j), $v_i(q, \alpha) \geq v_i(q_i, \alpha_i)$ *and* $\pi_i(q, \alpha, q_j, \alpha_j) \geq \pi_i(q_i, \alpha_i, q_j, \alpha_j)$, *where there is at least one strict inequality.*

Following Roemer (2001), we shall restrict our attention to *regular* PUNEs which are defined as,

Definition 2 *A regular PUNE is a pair of admissible policies* $(q_L, \alpha_L), (q_R, \alpha_R) \in T = \mathbb{R} \times [0,1]$ *that are PUNEs, and additionally satisfy the following conditions:*
(i) for each $i, j = L, R$; $v_i(q_i, \alpha_i) \geq v_i(q_j, \alpha_j)$;
(ii) for each $i, j = L, R$; $0 < \pi_i(q_i, \alpha_i, q_j, \alpha_j) < 1$.

Regularity is thus imposed as an additional requirement which refines the equilibrium concept and (potentially) reduces the set of equilibria. The first condition states that the militants of each party prefer the policy of that party to that of the other party (militants of, say, L prefer (q_L, α_L) to (q_R, α_R)). This requirement, while quite sensible, is *not* automatically satisfied by all PUNEs. The reason is that a switch to the other party's platform could decrease the probability of winning and thus be vetoed by the opportunists. The second condition is essentially a technical requirement which is meant to eliminate some pathological equilibria.

[10] Roemer (2001) considers a third faction, namely the "reformists", who care for the party's expected utility. They choose the electoral platform that maximizes the party's utility, taking into account the probability of winning the election with this platform. The objective of party i's reformists is thus given by

$$\pi_i(q_i, \alpha_i, q_j, \alpha_j) v_i(q_i, \alpha_i) + (1 - \pi_i(q_i, \alpha_i, q_j, \alpha_j))\, v_i(q_j, \alpha_j) \qquad i, j = L, R, i \neq j.$$

This expression shows that the reformists are purely gratuitous in this model: If both opportunists and militants agree to a deviation, reformists will do so as well. This occurs because when both π_i and $v_i(q_i, \alpha_i)$ increase, expected utility also increases.

Since the presence (or the absence) of reformists does not affect the results, we have opted for not introducing them.

5 Data and calibrations

In order to compute the PUNEs, we must know the voters' incomes and preferences. Additionally, we should know the parties' militants' preferences and the probability that a voter of a particular type would participate in the election. We take our voters to be US households as represented by the 2001 Panel Study for Income Dynamics Survey. The survey consists of 7,406 households each of whom is assigned a weight to make the sample representative of the US population in 2000. Naturally, we consider only those who reported a nonzero income for the year 2000 (whether labor *or* asset incomes).[11] These total 6,877 households. We then fit a bivariate lognormal distribution for labor and asset incomes to this truncated sample (while using the same weights that the survey assigns to each household.)[12]

The next task is to calculate numerical values for the parameters of the individuals' utility function. The polluting good is called energy and consists of a weighted sum of energy-related consumption goods (fuel oil, gasoline, natural gas, kerosene, LPG and electricity,) where the weights are the goods' expenditure shares in total expenditures on energy-related consumption goods. Given the quasi-linear specification, we have $-a'(q) = y(q)$. We assume that the demand function, $y(q)$, is linear in price and calculate the two parameters of the linear demand on the basis of a price elasticity of demand equal to -0.30, and a ratio of average expenditure on energy to average income equal to 0.0555, with the average income being $\$59,926$.[13]

[11] Specifically, we calculate labor incomes as the sum of labor income, and labor part of the business income, of the Head of the household and his spouse. To calculate the households' asset incomes, we subtract each family's labor income (as we have calculated it), transfer income, social security income and the Head's farm income, from the family's reported total income.

[12] Recall that our model postulates that voters differ only in two dimensions: labor and asset incomes. The mean, median and standard deviation are \$50,294, \$36,100 and \$64,825 for labor incomes, and \$9,632, \$433, and \$42,838 for asset incomes. The Correlation coefficient between labor and asset incomes is 0.163—a figure which is in line with the numerical calculation of Champernowne and Cowell (1998) who report a correlation coefficient of 0.135 using 1985 PSID data.

[13] The -0.30 figure is based on the literature estimates for the price elasticity of consumer demand for energy. These vary from -0.35 to -0.15; see Branch (1993), Filippini (1999), Gately and Huntington (2001), Hodge (1999), National Institute of Economics and Industry Research (2002), Ninomiya (2002). The 0.0555 figure is found from the Consumer Expenditure Surveys, 2002, which report a value of 0.064 for the ratio of average energy consumption to average annual expenditures; and 0.8667 for the ratio of average net-of-tax to average gross-of-tax income. The $\$59,926$ value for average income comes from the 2001 PSID data. The calculations are also based on the assumption that the price of a "unit" of

Considering the disutility from pollution, we assume that it is increasing and convex in Y, with the specification

$$\varphi(Y) = e^{b+cY}.$$

We take the pollution generated by energy to be the release of carbon dioxide into the atmosphere. The carbon content of the polluting good is found according to the carbon content of each appropriately-weighted component. Using a value of \$50 for the social marginal cost of a ton of carbon,[14] we are able to calculate the marginal social damage of one unit of the polluting good.[15] This leaves one degree of freedom in setting b and c. We use it by choosing the least convex function compatible with a positive value for every household's most-preferred q.

Next, we turn our attention to the militants' preferences. Given the definition of $v_i(\tau)$ in (9), we need to determine the weights that the two parties' militants assign to the preferences of each voter, $\omega_i(\theta)$. These we find from Bartels (2002). He estimates a linear relationship between the ideology (measured on a single dimension) of a senator and the ideology of his constituents, with different constituents being assigned different weights based on their incomes. He runs this regression separately for democratic (L) and republican (R) senators for three consecutive sessions of the Congress, 101–103. The weights (a weighted average of the weights derived for the three sessions of the Congress) are

$$\begin{aligned} \omega_L &= -0.02 + 0.04 * \text{income} \\ \omega_R &= -0.86 + 0.099 * \text{income}. \end{aligned}$$

To apply these to our setting, we modify the weights in two directions. First, the coefficients of incomes are deflated by the variation in the Consumer Price Index between 1990 and 2000. That is, we divide 0.04 and 0.099 in above by 1.278. This is to correct for the fact that Bartels uses incomes expressed in 1990 dollars to calculate the weights,

energy is equal to one.

[14] This is within the range of estimated values of \$5.5 to \$187. See http://www.epa.gov/oppt/epp/guidance/top20faqexterchart.htm on the EPA website.

[15] This translates into a tax rate of about 10% on the polluting good.

but in our calculations we use PSID data for the year 2000. Second, we restrict ω_i to be nonnegative. Thus, for the Democrats, we set the constant part of ω_L at zero (instead of -0.02); and for the Republicans, we use $\max(0, \omega_R)$ rather than ω_R.[16]

Finally, to calculate the probability that a particular voter participates in the election, we continue to rely on Bartels (2002) using his regression of turnout on income. As with the voters' weights, we modify his results (as reported in his Table A6) on the basis of the consumer price indices for 1990 and 2000. Moreover, given the linear specification between turnout and income, there is also a need to cap the very rich individuals' estimated probability of turn out at one. The average turnout in the economy is then 72%, and the "average individual" (a person with average income regardless of the source) participates in the election with a probability of 75.5%.

6 Results

It will be helpful to begin with a study of PUNEs that emerge in a simpler version of our model in which α is fixed. In this case, the political competition is only in terms of q so that the resulting PUNEs are one-dimensional.[17] Then, having studied the properties of the one-dimensional PUNEs, we will examine the two-dimensional PUNEs. This sequential approach helps us identify those underlying features of PUNEs (with respect to the choice of q) which are always at play regardless of the dimension of the policy space. It will also enable us to isolate the additional forces that appear as a result of competition in α as well. Specifically, we will be able to see why certain one-dimensional PUNEs remain as PUNEs in the two-dimensional case, while others do not.

6.1 The one-dimensional choice of q

Assume, for the time being, that α is fixed at some pre-specified value (same for both parties). The political competition problem then reduces to a one-dimensional voting game in q. Since the preferences obtained from our calibrations are single-peaked in

[16] Bartels calculates these weights based on individuals' total incomes, not differentiating between labor and capital incomes. In using them, we thus assume that the weights the two parties assign to an individual are conditioned on his total income $w + r$ independently of the source of the income.

[17] One may justify a pre-determined value for α by assuming that α is determined at the "constitutional level".

Table 1

α	0.000	0.250	0.500	0.750	0.839	1.000
q^M	0.178	0.267	0.348	0.417	0.434	0.439
q^{MV}	0.197	0.320	0.441	0.551	0.578	0.579
q_L^*	2.480	2.451	2.410	2.352	2.324	2.259
q_R^*	2.510	2.485	2.450	2.399	2.374	2.316

Majority-equilibrium, and the Left and the Right parties' militants' most-preferred values of q (for different values of α.)

q, a (classical, Downsian) majority-voting equilibrium exists. This solution serves as a benchmark against which the properties of the one-dimensional PUNEs may be assessed.

6.1.1 The majority-voting equilibrium value of q

Lemma 2 has established that the most-preferred value of q for an individual of type θ, $q^*(\theta,\alpha) \equiv \widetilde{q}(\delta(\theta,\alpha))$, is increasing in δ. This property allows one to rank all $\theta = (w,r)$ individuals on the basis of their preferences for q. Specifically, given any q, define $\delta^*(q) \equiv \widetilde{q}^{-1}(\delta^*)$ (i.e., such that $q = \widetilde{q}(\delta^*)$). This $\delta^*(q)$ specifies a downward-sloping line in (w,r) space

$$(1-\alpha)\frac{r}{\overline{r}} + \alpha\frac{w}{\overline{w}} = \delta^*(q), \tag{10}$$

such that every person who is located on this line will have, from Lemma 2, q as his most-preferred price. Moreover, this line will separate the electorate into two groups. Those who are located above "the δ^* line" and prefer a price higher than q , and those who are located below the δ^* line and prefer a price lower than q. We can then immediately determine the majority-voting equilibrium value of q, denoted by q^M. It defines a δ^M line with 50% of the population being above the line and 50% below it. Table 1 presents the value for q^M corresponding to a number of different values of α. [The case for which $g_w = g_r$, i.e. when taxes or subsidies are proportional to total income regardless of their source, is represented by $\alpha = 0.839$]. Not surprisingly, with the median wage and the median capital income being respectively smaller than the average wage and the average capital income, $q^M < q^{FB}$ for all values of α.

The determination of q^M above is based on the assumption that all citizens participate in the election with the same probability. As we noted in Section 5, however, this is not the case empirically. Instead, turnout probability increases with total income. This suggests that more than 50% of *voters* (as opposed to *citizens*) prefer q to be higher than q^M. We can then determine a second value for the majority-voting equilibrium q which takes the turnout probabilities into account. Denote this equilibrium by q^{MV} and observe that $q^{MV} > q^M$. We report the solutions for q^{MV}, conditional on different values of α, also in Table 1. Note that, as with q^M, for all values of $0 \leqq \alpha \leqq 1$, $q^{MV} < q^{FB}$. This occurs because adjusting for turnout probabilities leaves the ratio of median income to average income, for both wage earners and capital owners, well below one.[18]

6.1.2 The one-dimensional-policy PUNEs

Now turn to the determination of PUNEs in this one-dimensional voting game over q. This requires us to examine the preferences of the militants and the opportunists within each party for q. Consider first the utility of the militants which is a weighted sum of the citizens' utilities. Let q_L^* and q_R^* denote the most-preferred values of q for the militants of the Left and the Right party. Observe that with single-peaked preferences, the utility of militants in party $i = L, R$, increases when their party's proposed q moves closer to their blisspoint q_i^*. Moreover, given that the weights used by both parties' militants are increasing in total income, and that the Right party's militants put a higher weight on the utility of the richer individuals (as compared to the Left party's militants), it follows that $q^{FB} < q_L^* < q_R^*$.[19]

Next, consider the utility of the opportunists. As argued earlier, any proposed tax rate (or the polluting good price q_i) by party $i = L, R$, defines a $\delta^*(q_i)$, and an equation similar to (10), which separates the electorate into those who prefer a q higher than q_i and those who prefer a q lower than q_i. Consequently, in a choice between two proposals

[18] Specifically, the ratio of median income to average income increases from 61% (for median citizen) to 73% (for median voter) in case of wage incomes, and from 22% (median citizen) to 26% (median voter) for capital incomes.

[19] Recall that q^{FB} is the most-preferred value of q under a utilitarian social welfare function that sums the utilities of the entire population (with everyone receiving the same weight). Recall also that persons with higher w and r prefer a higher q.

$q_L < q_R$, the individuals who prefer q_L to q_R, and those who prefer q_R to q_L, will also be separated by a line parallel to that in equation (10) in the (w, r) space (whose slope depends only on α). This line has an associated $\delta = \widehat{\delta}(q_L, q_R)$ which is implicitly defined from $V(q_L, \alpha, \theta) = V(q_R, \alpha, \theta)$, or

$$a(q_L) + \widehat{\delta}R(q_L) - \varphi(y(q_L)) = a(q_R) + \widehat{\delta}R(q_R) - \varphi(y(q_R)). \tag{11}$$

Observe that with single-peaked preferences and $q_L^* < q_R^*$, we have $\delta^*(q_L) < \widehat{\delta}(q_L, q_R) < \delta^*(q_R)$. It then follows from part (ii) of Lemma 2 that people who are above the line associated with $\widehat{\delta}(q_L, q_R)$ prefer the higher price, q_R, while the people below it prefer the lower q_L. Note that when parties vary their q_i's, the slope of this separating line does not change; it will only shift up or down parallel to itself. This property allows us to determine how a change in q_i affects the proportion of the population who prefer one party, or the other, and thus each party's probability of winning the election. Specifically, an increase in q_L results in an upward shift of the separating line and increases the proportion of the electorate who prefer q_L to q_R, thus increasing party L's probability of winning.[20] An increase in q_R will have an opposite effect. To sum, a change in q_i has a predictable impact on the opportunists' utility.[21]

We are now able to show:

Result 1 *If α is fixed at the same level for both parties, the set of one-dimensional PUNEs consists of all (q_L, q_R) given by*

$$q_L^* \leq q_L < q_R \leq q_R^*, \tag{12}$$

and $q_L^* = q_L = q_R < q_R^*$.

[20] To see this, consider a q_L' such that $q_L < q_L' < q_R$. With single-peaked preferences, individuals on the line characterized by $\widehat{\delta}(q_L, q_R)$ strictly prefer q_L' over q_R. Consequently, the line associated with $\widehat{\delta}(q_L', q_R)$ must be above that for $\widehat{\delta}(q_L, q_R)$ and we have $\widehat{\delta}(q_L', q_R) > \widehat{\delta}(q_L, q_R)$.

[21] In order to ascertain the behavior of the opportunists, it is crucial that α takes the same value for both parties. If they differ, the δ line associated with q_L and the δ line associated with q_R will have different slopes. Consequently, the line that separates people who vote for the two parties may be downward- or upward-sloping. More importantly, even if one fixes the values of α_L and α_R, a change in the value of q offered by either party will not only shift this curve, but it will also rotate it. One cannot then a priori determine which party will attract more voters as a result of such a change.

Proof. To prove that any such configuration is a PUNE, one must consider the implications of deviating from it. Observe first that the most-preferred policies of the two parties' militants (q_L^*, q_R^*) constitute, by definition, a PUNE: all deviations from this pair of policy proposals would decrease the utility of the militants in both parties. Now take any (q_L, q_R) such that (12) holds with $q_L^* < q_L$ and consider how the factions in party L react to a decrease in q_L. This would be supported by L's militants as it brings them closer to their blisspoint. On the other hand, the opportunists in party L would oppose this move: It decreases the party's probability of winning by shifting the line that separates the citizens into those who prefer q_L and those who prefer q_R, downward. Similarly, take any (q_L, q_R) such that (12) holds with $q_R < q_R^*$ and consider party R's factions: Militants would like to increase q_R while opportunists would prefer to decrease it.

Observe now that no configuration with $q_L^* < q_L = q_R$ can be a PUNE. Starting from such a configuration, party L can increase both the utility of the militants, and the party's probability of winning, by decreasing q_L (with $q^{MV} < q_L^* < q_L < q_R$, π_L jumps from 1/2 to a strictly higher value). Finally, $q_L^* = q_L = q_R$ is also a PUNE: L's militants oppose any deviation from this point, while R's opportunists block their party's militants' wish to increase q_R (such a change would drop the party's probability of winning from 1/2 discontinuously).

To prove that other configurations are not PUNEs, one must again consider the implications of deviations from all such configurations. As an example, consider $q_L \leq q_L^* < q_R \leq q_R^*$. In this case, both the militants and the opportunists in the Left party want to increase q_L. Similar arguments rule out all other configurations. ■

Observe that with $q^M < q^{MV} < q^{FB} < q_L^* \leq q_L < q_R \leq q_R^*$, the Left party will always have a greater than 50% probability of winning the elections. Moreover, the PUNEs will always entail a higher-than-Pigouvian tax on the polluting good. Table 1 portrays the set of one-dimensional PUNEs for different values of α. These are deduced from the third and the fourth rows which report the Left and the Right parties' militants most-preferred values of q. These numbers, in conjunction with the reported values for q^M and q^{MV}, the unadjusted and the adjusted (for turnout probabilities) majority-voting equilibrium values of q, lead to the following four observations.

First, regardless of the value of α, PUNEs entail a tax while the majority-equilibrium values of q (q^M as well as q^{MV}) call for a subsidy. That PUNEs entail a tax is due to the fact that the militants in both parties put a higher weight on the utility of richer citizens. Observe that the turnout probabilities play no role here; they affect the probability of winning for each PUNE but not the location of the PUNEs. This stays true even if both parties use different turnout probabilities (as long as every voter has a strictly positive turnout probability). That q^M and q^{MV} call for a subsidy is due to the positive skewness of both incomes distributions, with the median incomes for both wage and capital incomes being substantially lower than their respective average incomes.

This observation is particularly important in view of the magnitudes involved. The lowest value of q as a PUNE is 2.259. This entails a massive tax on the polluting good and is markedly higher than the majority-equilibrium value of q (whether q^M or q^{MV}) which calls for a subsidy. The upshot is that the one-dimensional-policy PUNEs are basically dictated by the preferences of the militants of the two parties and are far removed from the preferences of the majority of the electorate.

Our other observations are: Second, both q^M and q^{MV} increase with α. This is the case because wage incomes are less positively skewed than capital incomes so that the gap between median and average is lower for wage income than for capital income. Third, q_L^* and q_R^* decrease with α. The relative skewness of the two income distributions is also responsible for this. Recall that q_L^* and q_R^* correspond to the most-preferred values of q for individuals who are richer than average. Increasing α implies that the wage income, which is less positively skewed than capital income, is receiving a higher weight. This leads to lower levels of most-preferred taxes for both parties' militants. Fourth, q_L^* and q_R^* are relatively close in the values they take (in comparison to the values of q_L^* and q_R^* versus those of q^M, q^{MV}, and the Pigouvian price $q^{FB} = 1.1$). This implies that putting higher weights on the utility of the *very* rich does not matter much. The reason for this is that there are few very rich voters.

We now turn to the two-dimensional-policy PUNEs.

6.2 Two-dimensional-policy PUNEs

With each party proposing a two-dimensional policy, PUNEs can differ along four dimensions: $q_L, \alpha_L; q_R, \alpha_R$. As such, they may be classified in numerous different ways. As far as q_i $(i = L, R)$ is concerned, the most informative distinction is between taxes $(q_i > 1)$ and subsidies $(q_i < 1)$. Specifically, along this dimension, we distinguish between three potential types of results: Both parties propose a tax, both parties propose a subsidy, one party (either Left or Right) proposes a tax and the other party a subsidy.

Regarding α_i, a useful distinction is between corner solutions of $\alpha_i = 1$ or $\alpha_i = 0$, the voters' most-preferred values for α_i, and interior solutions where $0 < \alpha_i < 1$. An interior solution arises when one or both parties decide to offer a "compromise" in order to placate the militants in the party by pushing them closer to their blisspoint(s), and/or the opportunists in an attempt to win more votes in the election. As will be seen below, most regular PUNEs have this feature. We thus categorize the potential solutions into three types along this dimension as well: Both parties propose a corner solution for α_i; one party (either Left or Right) proposes a corner value and the other an interior value for α_i; both the Left and the Right parties propose an interior value for α_i.

With three configurations each for (q_L, q_R) and (α_L, α_R), there will be, potentially, nine different solution categories. To calculate the PUNEs, we draw at random a huge number (in the thousands) of possible vectors $(q_L, \alpha_L; q_R, \alpha_R)$ within each of the nine possible categories, and check whether a particular draw constitutes a PUNE.[22] It turns out that (regular) PUNEs are of two types. In one type (Type I), the parties offer a tax in conjunction with $\alpha_L = \alpha_R = 0$. In the other (Type II), both parties offer a subsidy coupled with an interior value for α. See Figure 2.

[22] Following Roemer(2001), we compute the PUNEs through a local characterization that makes use of Farkas' lemma. This local characterization ensures that no party has an incentive to deviate locally, and nor globally if the program solved were globally convex. It is well known, however, that the probability of winning functions, π_i's, are not in general quasi-concave. We will thus contend ourselves with identifying local PUNEs.

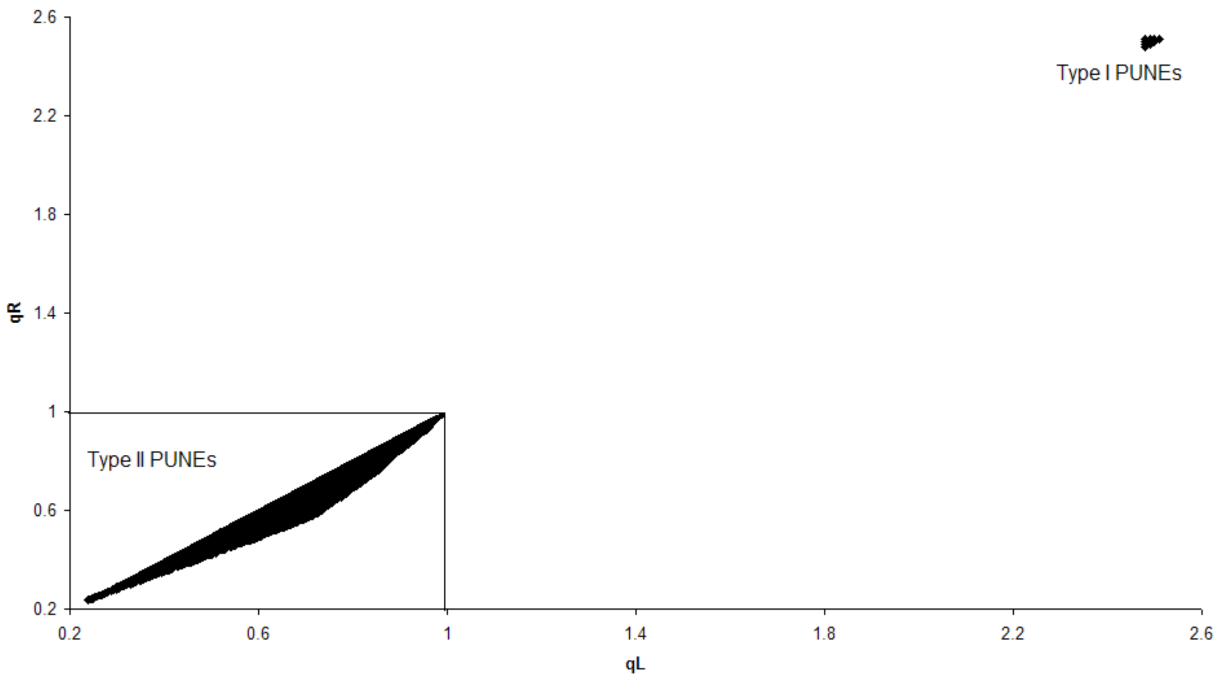

Figure 2: Two dimensional PUNEs

6.2.1 Type I regular PUNEs

Type I (regular) PUNEs consist of all $(q_L, 0)$ and $(q_R, 0)$ combinations such that q_L and q_R lie in the closed interval between each party's militants' most-preferred price conditional on $\alpha = 0$ (one of the voters' two most-preferred values of α). The set of Type I bidimensional PUNEs is thus the same as the set of unidimensional PUNEs when α is fixed at zero for both parties. Specifically, we have $2.48 \leq q_L < q_R \leq 2.51$, where the most-preferred value of q is 2.48 for the Left party and 2.51 for the Right party. Additionally, $q_L = q_R = 2.48$ is also a PUNE. Observe that none of the other one-dimensional-policy PUNEs, namely all those obtained when α is fixed at a positive level, "survive" as a two-dimensional PUNE. This applies to $\alpha = 1$, the other of the voters' two most-preferred values of α.

With nearly three quarters of the electorate preferring $\alpha = 1$ when $q > 1$, one may be rather surprised that the militants of both parties prefer a zero value for α. The explanation lies in the fact that the militants in both parties put a higher weight on the utility of richer citizens. And these individuals prefer $\alpha = 0$ when faced with a tax, because they tend to derive a higher proportion of their incomes from capital.

We have already explained in the previous section why, when α is fixed at zero and the parties can only modify their tax rates, the values of q_L and q_R in $2.48 \leq q_L < q_R \leq 2.51$ form a PUNE. We now further obtain that allowing for simultaneous changes in q and α does not create deviations that simultaneously increase a party's probability of winning and its militants' utility. Intuitively, this result occurs because α is on the boundary of the feasible set (α does not take negative values) which limits the set of admissible deviations.[23] As with one-dimensional-policy PUNEs, Type 1 regular PUNEs are essentially dictated by the preferences of the parties' militants. Observe also that the militants' most-preferred policies are very far from the most-preferred policy of a person with the median wage and the median capital income who, while also preferring $\alpha = 0$, prefer a subsidy of 82.2% ($q = 0.178$).

[23] When $\alpha = 1$, we are again on the boundary of the feasible set. Nevertheless, in this case, even the limited set of admissible deviations (i.e. being able only to reduce α) is sufficient to create possibilities for simultaneously increasing a party's probability of winning and its militants' utility.

Summing up, we have:

Result 2 *Let q_L^* and q_R^* denote the left and the Right parties' militants' most-preferred prices conditional on $\alpha = 0$. Type I (regular) PUNEs are characterized by $\alpha = 0$, and $2.48 = q_L^* \leq q_L < q_R \leq q_R^* = 2.51$, plus $q_L = q_R = q_L^* = 2.48$.*

With both parties proposing the same extreme value of $\alpha = 0$, it is easy to see who will vote for either party. With $\alpha = 0$, only capital income matters, and with $q_L < q_R$, all individuals who have capital incomes below a threshold level vote for party L. We thus obtain a society polarized into two groups based only on how much capital income they have. Moreover, with $q^M < q^{FB} < q_L < q_R$, the division occurs at a very high level of capital income. This in turn implies that the Left party has a probability of winning the election that varies from 95% to 95.9% across all possible configurations of q_L and q_R.

Now while each PUNE is, by definition, an equilibrium, one can argue that in the long term the opportunists will stick to a particular party only if that party has a high enough probability to win elections. On the basis of this criterion, it is clear that Type I PUNEs are not "viable" equilibria. The 5% probability of winning is too low to keep the Right party's opportunists to stick to their party for long.[24]

6.2.2 Type II regular PUNEs

All PUNEs of Type II share the following characteristics: $0 < q_R < q_L < 1$ and $0 < \alpha_L < \alpha_R < 1$. Observe that with both parties offering a subsidy, their policies appeal most to the poor, and the not very rich voters, who belong to Regions III and IV see Figure 1). Observe also that 74% of the electorate belong to these regions and prefer a subsidy to a tax. It is thus apparent that, unlike Type I PUNEs, the opportunists in the two parties play a major role in determining Type II PUNEs. With q_L varying between 0.263 and 0.989 and q_R between 0.259 and 0.985, these PUNEs are closer to

[24]The equilibrium with $q_L = q_R = q_L^*$ is likewise non-viable. R's militants cannot remain happy with their party's proposing the most-preferred policy of the militants of the other party; they will thus quit their party in the long run. Alternatively, one could strengthen the definition of regular PUNEs by requiring that militants strictly prefer their own party's proposal to the other party's.

the most-preferred policy of an individual with the median wage and the median capital income.

To see who votes for which party, recall that this choice is essentially determined by two factors. First, the lower subsidy offered by party L attracts the higher income voters (aggregate income effect). Second, individuals who derive a higher proportion of their income from wages favor party L's proposed budgetary rule while those with high capital incomes prefer party R's (income composition effect). This is the case because with both parties offering a subsidy on the polluting good, whether the Left or the Right party wins, the voters know that they will have to be taxed in order to finance the environmental subsidy. With a high α punishing the high-wage-earners more and a low α punishing the high-capital–income individuals more, the former group will want a low α (α_L) and the latter a high α (α_R).

For certain voters, both factors reinforce each other. Those with a high wage income and low capital income (approximately Region I in Figure 1) prefer party L's policy to party R's, while individuals with low total income but a high share of capital income (Region III) prefer party R's policy. For other voters, the two effects go in opposite directions. In all these cases, however, the income composition effect dominates the aggregate income effect. The set of voters who are indifferent between the two parties' policies is thus given by an *upward-sloping* line in the (w, r) space. All individuals above this line (i.e., relatively more endowed in capital income) prefer party R's policy while individuals below it prefer party L's. Put differently, with Type II PUNEs, it is the electorate's *composition* of wage and capital incomes that polarizes the society. This is in sharp contrast with Type I PUNEs which had the society divided on the basis of the electorate's *level* of capital income.

The end outcome in terms of attracting voters appears to be very close for the two parties, with a small edge to party L. It faces a probability of winning that ranges from 45% to 69.7% (depending on the particular regular PUNE that is selected). Moreover, assuming each PUNE is equiprobable, party L's average probability of winning (among all PUNEs) is 53.8%. Naturally, party R's probability of wining varies from 31.3% to 55% with an average rate of 46.2%. These probabilities are, intuitively, very comforting.

As argued earlier in the discussion of Type I PUNEs, one would expect that in the long term the opportunists will stick to a particular party only if that party has a high enough probability to win elections. This property holds for Type II regular PUNEs we have computed. At 53.8% and 46.2%, the average probabilities of winning for the two parties are rather close. Moreover, the maximum winning probabilities for the two parties over the set of Type II PUNEs exceed, while their minimum winning probabilities fall below, the 50% mark.

Summing up, we have obtained the following main results

Result 3 *Type II PUNEs share the following characteristics:* $0 < \alpha_L < \alpha_R < 1$ *(both parties offer an interior solution) and* $q_R < q_L < 1$ *(both parties offer a subsidy); specifically,* q_L *varies from 0.263 to 0.989 and* q_R *from 0.259 to 0.985. Party L's average probability of winning (among all PUNEs) is 53.8%, and party R's is 46.2%.*

Finally, two interesting and inter-related features of these PUNEs are worth emphasizing. One is the fact that they all entail a subsidy on the environmental good. The subsidies range from 1.1% to 73.7% for q_L (with an average of 39.3%) and from 1.5% to 74.1% for q_R (with an average of 42.8%). These figures underscore the importance of distributional concerns in ensuring political support for environmental policies. The literature on environmental taxation, with few exceptions, has shied away from such considerations.[25] In particular, the burgeoning literature of the past decade has emphasized efficiency issues that arise in second-best settings.[26] In our setup, we have deliberately left second-best non-environmental efficiency considerations out. We have modeled the capital and wage taxes to be non-distortionary in order to exclusively highlight the distributional issues that appear at the center stage, when environmental taxes are set through the political process.

A second interesting feature of Type II PUNEs is that the two parties always compromise in their choices of α, offering an interior solution. Specifically, α_L varies from 0.01 to 0.73 with an average of 0.411 while α_R varies from 0.214 to 0.998 with an average

[25] Cremer, Gahvari and Ladoux (2003) is one exception.

[26] See the many papers that appear in the edited volume by Goulder (2003).

of 0.57. This aspect too underlines the importance of generating political support for environmental policies (through political compromise). The compromise over α turns out to be a particularly striking feature of the PUNEs; other equilibrium concepts, even when they are not empty in multidimensional choice sets, do not share this feature; see Cremer *et al.* (2004a).

6.3 Probabilistic voting

To provide a broader perspective for assessing the properties of the PUNEs, we briefly present here the results one obtains under an alternative, and commonly-used, political modeling framework that also incorporates uncertainty. This is the probabilistic voting equilibrium; see Persson and Tabellini (2000). With probabilistic voting, parties are purely office-motivated. Citizens, on the other hand, care not only for policies per se but also for the political parties that propose the policies. That is, they may strictly prefer one party to another even if the parties propose identical policies. Preferences for a particular party, or what is commonly called "ideological biases," differ in sign and size across individuals. The parties know only the distribution of the bias, with their (prior) information being identical.

In this setting, there will clearly be some degree of uncertainty regarding who votes for which party. Neither party would then know for certain what platform, and offered by which party, can muster the majority of votes. If this uncertainty is "large enough", i.e. if the variance of the bias distribution that causes it is "large enough," an equilibrium exists for a simultaneous and noncooperative game in party platforms between the two parties; see Lindbeck and Weibull (1987). Moreover, this equilibrium will be unique, with both parties converging to the same platform. The platform maximizes a weighted sum of the citizens' utilities, where the weight attributed to a given "citizen type" (the "type" classification is based on the citizens' attributes *excluding* their ideological biases) is proportional to the density of unbiased citizens of this type. The intuition is that with both parties proposing the same policy, only the unbiased swing voters (who are indifferent between voting for either party) matter for the purpose of winning the election. The parties thus court these swing voters. The weight attributed to any citizens' type then depends only on the density of the unbiased swing voters of that type.

The first striking difference between PUNEs and probabilistic voting is the absence of convergence to the same platform in the case of PUNEs. Divergence between equilibrium platforms is a well-documented empirical result; see, for instance, Alesina and Rosenthal (1995) and Poole and Rosenthal (1984a,1984b) for the US, Budge and Hofferbert (1992) for the UK, and Hofferbert and Klingemann (1990) for Germany. Beyond this, capturing other differences requires information on the bias distribution for every citizen type in order to compute the probabilistic voting equilibrium (in our setting one's type is determined by his capital and labor incomes). In the absence of such information, one may follow a shortcut and directly fix the weights attributed by both parties to each citizen type on the basis of some exogenous information. As an example, suppose one believes that the density of unbiased voters is the same at all levels of capital and labor income. This necessitates assigning the same weight to all individual types. In this case, the probabilistic voting equilibrium proposal consists of the Pigouvian tax level coupled with any value for the budgetary rule, α.

Consider now the family of affine weights that are increasing in citizens' total income. The probabilistic voting equilibrium proposal will then be a tax on the polluting good rebated solely through a reduction of capital income taxes ($\alpha = 0$). The reason is that richer people have a preference for a tax, as opposed to a subsidy, and that with the capital income distribution being more positively skewed than the labor income distribution, they prefer a tax rebate based on capital income to one based on labor income. That probabilistic voting equilibria (with linearly increasing weights) *always* lead to a tax in conjunction with a 100% capital income rebate constitutes the second and the third striking differences with the PUNEs (where we had a tax for Type I and a subsidy for Type II PUNEs, with $\alpha = 0$ in the former and α assuming an interior value in the latter equilibria).

Two examples of affine weights are of particular interest in our setting. The first corresponds to the citizens' turn out probabilities based on Bartels (2002). Using these probabilities as weights, results in a probabilistic voting equilibrium characterized by a 51.9% tax ($q = 1.519$ rebated via capital income, $\alpha = 0$). This is a much lower tax rate than the 148% to 151% range we derived for Type I PUNEs. The second example corresponds to the weights attributed to the militants in calculating the PUNEs, also based on Bartels (2002). Using Bartels' weights for party L's militants, leads to a probabilistic voting equilibrium with $q = q_L^* = 2.48$ (and $\alpha = 0$). On the other hand, if we use the weights attributed to party R's militants, the equilibrium will be given by $q = q_R^* = 2.51$ (and $\alpha = 0$). Moreover, using convex combinations of Bartels' weights for Democrats and Republicans, the probabilistic voting equilibria spans precisely the range between q_L^* and q_R^*. This is due to the fact that, as one moves from the Democratic weights to the Republican ones along a convex combination of both, the value of q that maximizes the corresponding weighted sum of utilities increases monotonically from q_L^* to q_R^*. Put differently, any policy played by either party in a Type I PUNE corresponds to a probabilistic voting equilibrium with the density of unbiased voters being some convex combination of the Bartels' weights for Democrats and Republicans.

7 Concluding remarks

This paper has presented a political economy model to explain the low emission taxes in the U.S., and the fact that neither the Republicans and nor the Democrats advocate higher emission tax rates. The paper has two distinctive features and has arrived at two main conclusions. The first feature is its modeling of political competition which has been done à la Roemer (2001). In this setup, each party consists of two factions: one cares about the policies (militants), and the other about the probability of winning the election (opportunists). The equilibrium solution concept is the "Party Unanimity Nash Equilibrium" (PUNE). The second feature is that the model has been calibrated on the basis of the U.S. data. The voters are U.S. households as represented by the 2001 PSID survey, and the parameters of their utility function are calculated using U.S. studies.

The first main result of the paper is that the two parties always compromise in their choices of a budgetary rule, offering an interior solution (while voters prefer the two extreme values). This underlines the importance of generating political support for environmental policies through political compromise. The second major result of the paper is that both parties offer not a tax but a subsidy on the polluting good. This underscores the importance of distributional concerns in ensuring political support for environmental policies.

It will be interesting to undertake the same calibration exercise for other countries, especially those in the West, to test the robustness of our conclusions. This, however, requires quite a bit of care. The two-party political competition approach adopted here is more suited to the US, and less to the majority of European countries. Another extension of this analysis, would make the militants' utility endogenous by assuming that they maximize the average utility of citizens who vote for their party at equilibrium. These avenues are left for future research.

Appendix

Proof of Lemma 2

The first-order condition for the most preferred level of q is given by

$$\frac{\partial V(q,\alpha,\theta)}{\partial q} = [\delta(\theta,\alpha)-1]\,R'(q) - \left[\varphi' - (q-1)\right] y'(q) = 0. \tag{A1}$$

Observe that θ and α enter this expression only through δ. Differentiating with respect to δ and q yields:

$$\frac{d\widetilde{q}}{d\delta} = -\frac{R'(q)}{\partial^2 V(q,\alpha,\theta)/\partial q^2} > 0,$$

where $\partial^2 V(q,\alpha,\theta)/\partial q^2 < 0$ by the concavity assumption (second-order condition). Consequently, $\widetilde{q}$ increases with δ, which also implies that q^* increases with r and w (for a given value of α). To complete the proof it is then sufficient to note that when $\delta = 1$ (A1) reduces to

$$\left[\varphi' - (q-1)\right] y'(q) = 0$$

which yields $q^* = q^F$.

Proof of Lemma 3

Take any $\theta = (r,w) \in AA'$, i.e. with

$$V(q^*(\theta,0),0,\theta) = V(q^*(\theta,1),1,\theta).$$

We first show that all types belonging to AA' other than θ° are indifferent between their most preferred subsidy and their most preferred tax, i.e. either $q^*(\theta,1) < 1 < q^*(\theta,0)$ or $q^*(\theta,1) > 1 > q^*(\theta,0)$. From (A1), observe that θ influences $q^*(\theta,\alpha)$ only through $\delta(\theta,\alpha)$. For $\theta = (r^\circ,w^\circ)$, we have that $\delta(\theta^\circ,\alpha) = \delta^\circ$ for any $\alpha \in [0,1]$, so that $q^*(\theta^\circ,0) = q^*(\theta^\circ,1) = 1$. For any $\theta = (r,w) \in AA'$ with $w > w^\circ$ and $r < r^\circ$ (i.e. θ belongs to the north-west quadrant in Figure 1), we have that $\delta(\theta,0) < \delta^\circ < \delta(\theta,1)$ so that $q^*(\theta,0) < 1 < q^*(\theta,1)$. We obtain symmetrically that $q^*(\theta,1) < 1 < q^*(\theta,0)$ for any $\theta = (r,w) \in AA'$ with $w < w^\circ$ and $r > r^\circ$.

(i) Using the implicit function theorem, we have, for any $\theta \in AA', \theta \neq \theta^\circ$,

$$\begin{aligned}\frac{dw}{dr} &= -\frac{\partial V(q^*(\theta,0),0,\theta)/\partial r - \partial V(q^*(\theta,1),1,\theta)/\partial r}{\partial V(q^*(\theta,0),0,\theta)/\partial w - \partial V(q^*(\theta,1),1,\theta)/\partial w} \\ &= \frac{\bar{w}}{\bar{r}}\frac{R(q^*(\theta,0))}{R(q^*(\theta,1))} < 0,\end{aligned}$$

where the last inequality comes from the fact that $\text{sign}(q^*(\theta,1)-1) = -\text{sign}(q^*(\theta,0)-1)$ as established above.

(iii) We then show that there is a discontinuity in the most preferred q as one crosses AA', except for θ°.

Take any $\theta = (r, w) \in AA'$and look at the impact of increasing, say r, on the utility levels reached with the two bundles this type is indifferent between:

$$\frac{\partial V(q^*(\theta,0),0,\theta)}{\partial r} - \frac{\partial V(q^*(\theta,1),1,\theta)}{\partial r} = \frac{R(q^*(\theta,0))}{\bar{r}}.$$

Observe that $R(q^*(\theta,0)) > 0$ iff $q^*(\theta,0) > 1$. This means that, as one increases r from any point along AA', individuals most prefer $q^*(\theta,0)$ if $q^*(\theta,0) > 1 > q^*(\theta,1)$ or $q^*(\theta,1)$ if $q^*(\theta,1) > 1 > q^*(\theta,0)$. In other words, as one crosses AA' from left to right, the most preferred value of q of individuals jumps discontinuously from $\min(q^*(\theta,0), q^*(\theta,1)) < 1$ to $\max(q^*(\theta,0), q^*(\theta,1)) > 1$ (except for θ° for which $q^*(\theta^\circ,0) = 1 = q^*(\theta^\circ,0)$, so that q^* increases continuously from 1 as we increase r).

(ii) The proof of (iii) has shown that individuals below (above) AA' most prefer $q^* < 1$ ($q^* > 1$) in the north-west and south-east quadrants of Figure 1. We now show that the same result holds for the other two quadrants. Take $\theta = (r, w)$ with $r > r^\circ$ and $w > w^\circ$ (i.e θ belongs to the north-east quadrant). Then $\delta(\theta, \alpha) > \delta^\circ$ for any $\alpha \in [0, 1]$ so that $q^*(\theta,0) > 1$ and $q^*(\theta,1) > 1$: whatever the most preferred value of α, we have $q^* > 1$. The same analysis holds mutatis mutandis for the south-west quadrant.

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