TYING GOVERNMENTS HANDS: WHY HARMONISATION OF ENVIRONMENTAL POLICIES MAY BE DESIRABLE

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ABSTRACT

We consider environmental policy in a federal system where states face purely domestic environmental problems. It is normally argued that in this context, environmental policy is best set at the state level, perhaps because of better local information. To provide a rationale for federal involvement, we use a simple strategic trade model in which if states act non-cooperatively they set laxer environmental policies than if they acted cooperatively ("environmental dumping"). While this provides a possible role for a federal government to co-ordinate environmental policies, it is sometimes argued that a federal government should impose uniform environmental policies across states (harmonisation). It is well known that harmonisation would be inefficient if states differ in important respects, such as environmental damage costs. We showed elsewhere that even if there is asymmetric information, so that damage costs in a state is private information to that state's government, it is better to set environmental policy at the federal level, and that while environmental policies for states with different damages costs will differ less than would be the case with symmetric information, this does not justify harmonisation.

Our earlier work assumed welfare maximising governments. In this paper we assume that governments at state and federal level can be influenced by pressure groups. In our model we assume there are two such groups - environmentalists and industrialists. Depending on which group's interests are represented by the government in power a government may give too high or too low a weight to environmental damages relative to its weight in social welfare. As in our earlier work, the true value of environmental damage costs in each state is private information to the state government which comes into power. There is then a choice between allowing governments to set environmental policy using the information they acquire about damage costs, but giving these costs too high or too low a weight (*political discretion*), or tying governments hands by prescribing policies which maximise welfare, but based on the expected value of damage costs (*social pooling*). In our model social pooling implies harmonisation. We show that with both political discretion and social pooling it is better to set environmental policy at the federal level. For a wide set of parameter values it will be desirable to tie governments' hands if policy is set at the federal level, but not to do so if it is set at the state level. This may provide an explanation why calls for harmonisation of environmental policies arise when policies are considered at the federal level, but not when they are considered at the state level.

Keywords: Environmental policy co-ordination, harmonisation, asymmetric information, political economy, federal/state relations.

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1. Introduction

It is widely accepted that there is a need for international co-ordination of environmental policies of nation states to tackle transboundary or global pollution problems. But in recent debates on trade liberalisation, some environmentalists and business interests have called for co-ordination and even harmonisation of the environmental policies of nation states to deal with purely domestic environmental problems. One rationale given by environmentalists for harmonisation is the fear that in a more competitive trade regime, governments of nation states acting independently will compete by setting weak environmental regulations ('environmental dumping'), triggering a 'race-to-the bottom'[1]. The rationale given by industrialists for harmonisation is a wish to preserve a 'level playing field' for international trade. There are many definitions of harmonisation of environmental policies[2], but in this paper we shall take the strictest definition, namely that nation states should set identical environmental standards (e.g. the same emission tax or the same emission standard).

Conventional economic analysis provides little support for harmonisation or even co-ordination of purely domestic environmental policies. Globally efficient allocations of resources are supported by free trade with national governments setting the usual first-best environmental policies[3]. If countries differ in terms of endowments of environmental resources, tastes for a clean environment or abatement technology, then in general efficient allocations will have countries setting different environmental policies. Moreover, in a small country with no other distortions a welfare maximising government would wish to pursue free trade and first-best environmental policies, no matter what policies were pursued in other countries, so there would be no incentive for 'environmental dumping'. A welfare maximising government in a large country prevented from setting trade taxes might wish to set environmental policies which differed from the first-best, but, for pollution related to production, this would involve net exporters setting environmental policies tougher than first-best, net importers setting policies weaker than first-best, so again there is no presumption of environmental dumping by all states[4].

As Krugman(1997) notes there are two possible routes by which one might try to make sense of environmentalists' concern about environmental dumping and their call for harmonisation[5] - strategic trade considerations and political economy models.

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[1] Bhagwati (1996) gives an elegant survey of a number of philosophical, political and economic arguments advanced to support calls for harmonisation of environmental, labour and other policies.

[2] See Leebron (1996) for an excellent discussion.

[3] By first-best environmental policies we mean policies which ensure that marginal abatement costs are equalised for all polluters and are equal to marginal environmental damage costs.

[4] See Bhagwati and Srinivasan (1996) and Ulph (1997a) for surveys of the literature on trade and environment where these standard results are presented. Verbruggen and Kuik (1997) also summarise the main welfare economic principles linking trade and environment in their report on the failure of the first Ministerial WTO Conference in Singapore in December 1996 to tackle trade and environment issues, in part because of the tension between calls for harmonisation of environmental policies as opposed to preserving environmental diversity.

[5] Karp, Zhao and Sacheti (1997) use a second-best argument to provide a justification for harmonisation of purely domestic environmental policies; but this does not explain why distortions arise in the first

It is straightforward to construct models of imperfectly competitive trade where welfare maximising governments who cannot use trade instruments engage in environmental dumping[6]. As is well known from the literature on strategic trade, these results are not at all robust[7], and it is also difficult to find any empirical support that differences in environmental policies between countries have significant effects on trade or FDI[8]. However even if there was a significant problem of national governments setting weak environmental policies, what would the policy implications be? By the second definition of environmental dumping, it is possible to choose a set of 'cooperative policies' which make all the states which engage in environmental dumping better off than when they act non-cooperatively. If countries differ with respect to the environment in the ways noted above, then both harmonisation of environmental policies and the imposition of minimum environmental standards may fail to deliver even a Pareto improvement over the non-cooperative equilibrium[9].

This raises the question of how a cooperative set of policies might be implemented. In the context of regulatory competition it seems natural to consider a federal/state structure in which the setting of environmental policies at the state level corresponds to a non-cooperative equilibrium, while if environmental policies are set at the federal level this implies the choice of a cooperative policy[10]. Then, if imperfectly competitive trade leads to significant environmental dumping when domestic environmental policies are set at the state level, the solution is to have such policies set at the federal level. This raises the natural question of whether the federal government may be less well informed about domestic environmental problems than state governments, and some authors simply assume that such an asymmetry of information implies that when policy is set at the federal level it must be uniform across states[11]. A more sophisticated analysis would analyse how the asymmetry of information affected the design of federal policy. Ulph (1997b, c) showed that when each state has private information about its own environmental damage costs, then environmental policies for states with different damage costs will be more similar than would be the case if there was full information, but this falls far short of

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place, and, as with most second-best arguments, it requires a rather special model to justify harmonisation, rather than just co-ordination, of domestic environmental policies.

[6] Note that the literature employs two distinct definitions of environmental dumping: (a) national governments set environmental policies which are weaker than the first-best environmental policies described earlier; (b) national governments acting non-cooperatively set environmental policies which are weaker than they would set if they acted cooperatively.

[7] Thus it is also possible to produce models in which there is a 'race-to the-top', e.g. NIMBYISM. Results depend upon the form of market competition (e.g. Bertrand or Cournot), whether producers are also able to make strategic investments in capital, R&D or location, the level of environmental damage costs, general equilibrium effects amongst others. See Wilson (1996 Rauscher (1997) Chapter 6 and Ulph (1997a) for surveys of the available results.

[8] See, for example, Levinson (1996), van Beers and van der Bergh (1997).

[9] See Kanbur, Keen and van Wijnbergen (1995), Ulph (1997b, c).

[10] i.e. a policy which maximises a federal welfare function, which is a non-decreasing function of the welfares of each state, subject to the condition that no state is worse off than in the non-cooperative equilibrium.

[11] See for example Emeny, Frederikson and Gaston (1997) who analyse the impact of political lobbying at state and federal level. Although there is no explicit analysis of asymmetric information, they explicitly assume that the federal government must set a uniform policy (rather than this being the equilibrium outcome when states are identical), and it is this inefficiency in federal policy which drives the difference between state and federal outcomes in their model.

harmonisation of environmental policies[12]. In short, the first route for trying to rationalise environmentalists' concern that governments may impose weak environmental policies can provide a basis for such a concern, though it is neither theoretically nor empirically compelling, and while this could justify a need to co-ordinate domestic environmental policies of states, it cannot justify harmonisation of these policies.

We now turn to the second route for rationalising environmentalists' concerns - political economy models. There is now a small literature applying political economy models of electoral competition or political influence to trade and environment[13]. As with strategic trade arguments, these models can explain why, even in a small country, a government may not implement first-best environmental policies, or pursue free trade, but deviations from first-best could involve either too lax or too tough environmental policies depending on relative strengths of lobby groups. This literature also explains why environmentalists may support protectionist groups. However, this literature does not provide any support for a policy of harmonisation, for two reasons. First, even if it is true that environmental policies in some states are not first-best, that does not provide a reason to co-ordinate reforms of environmental policies; there have to be other reasons, such as those provided by strategic trade literature, for co-ordinating environmental policies. Second, the literature is entirely positive, and does not address the issue of whether or how to limit political influence on environmental policies.

Boyer and Laffont (1996) address the second concern by analysing whether it might be desirable to limit political influence over the setting of environmental policy. They consider a single government regulating a single polluter whose abatement costs are private information. Environmental policy must be designed to take account of this asymmetry of information, and this leaves the polluter with an information rent. Because there is a social cost to raising funds, leaving this rent with the firm is costly. The social cost of funds is unknown to voters, and becomes known only to a government when it comes into power. The government may be elected either by a party which represents the interests of shareholders in the regulated firm, and who attach too little weight to the social cost of the information rent (relative to its weight in a social welfare function), or by non-shareholders who attach too much weight to the social cost of the information rent[14]. At a prior constitutional stage, society can choose two ways to organise government. Society can opt for *political discretion*, i.e. the government in power can implement an environmental policy based on the true social cost of funds, but applying a weight to the information rent which may be too high or too low. Or society can select *social pooling*, in which the voters 'tie the government's hands' to implement an environmental policy which maximises welfare,

[12] The rationale is that in a full information cooperative equilibrium where states have different damage costs, it is efficient to have a lot of production take place in states with lower damage costs. To provide states with high damage costs with an incentive to truthfully reveal this information, they must be given a larger market share, and hence their environmental policies must move closer to those in states with lower damage costs.

[13] See Hillman and Ursprung (1992, 1994), Frederikson (1997a, 1997b), Rauscher (1997); Ulph (1997d) provides an overview.

[14] Paradoxically this will mean the 'shareholder government' will impose a tougher environmental policy than the 'non-shareholder government'.

but based only on the expected value of the social cost of funds. The choice between these two regimes is based on expected welfare, and Boyer and Laffont show that social pooling will be preferred when there is a relatively low variance of true social cost of funds, and a relatively high variance on the weight different parties attach to the social cost of funds.[15]

In this paper we address both the limitations of the existing literature identified above, by combining the strategic trade analysis of Ulph (1997b,c) with the Boyer and Laffont (1996) analysis of whether to tie governments hands. As in Ulph (1997b, c) environmental damage costs in each state are unknown *a priori*, and are learned only by the state government once it gets into power. However, each government (at the state and federal level) is no longer assumed to maximise welfare, but to maximise a utility function which puts too high or too low a weight on environmental damage costs depending on whether they are a 'green' or an 'industrial' government. As in Boyer and Laffont, there is a constitutional choice between *political discretion* (allowing a government to set environmental policy knowing the true environmental damage cost, but attaching too high or too low a weight to environmental damages) or *social pooling*, where a government is constrained to act to maximise welfare, but based on the expected value of environmental damages. In the simple model presented here, countries are *ex ante* identical, so that pursuing social pooling implies harmonisation of environmental policies across countries which, *ex post*, may have very different damage costs. There is a fourfold constitutional choice to be made: for each level at which environmental policy may be set, there is a choice between political discretion and social pooling; for each choice of social pooling or political discretion there is a choice between policy being set at the state or federal level. We show that, with social pooling, it is better to have policy set at the federal level. This is also true with political discretion, calculating expected welfare across all configurations of government types at state and federal level. However, for particular configurations of government types it may be better to have environmental policy set at the state level.. At both the state and federal level, the choice between social pooling and political discrimination depends on the variances of damage costs and government types. For plausible parameter values we show that for a large range of values of these variances society would choose to tie the governments hands if policy is made at the federal level, but not if it is set at the state level. This might provide some rationale for why a perceived need for greater co-ordination of environmental policies seems to be linked to calls for harmonisation of these policies.

[15] Grossman and Maggi (1998) consider the issue of "rules versus discretion" in relation to strategic trade policy. Firms use investment in capital and knowledge as a signal to influence their governments' choice of subsidy in an asymmetric information setting. Since firms' private benefits from these investments exceed the social loss, there is a tendency to over-invest. In such a scenario they argue it may be better to undertake free trade even if potential strategic benefits are possible.

2. The Model.

As in Ulph (1997b, c) we take the simplest model which generates environmental dumping (in the sense of both the definitions provided in footnote 6.). We begin by describing the basic model with welfare maximising governments and full information.

2.1 The Basic Model.

Consider a partial equilibrium model of an industry with two identical firms each located in a different state. These two states form a federation. The two firms produce a good which is sold entirely outside the federation. The production of the good causes emissions of a pollutant, although these emissions can be abated, at a cost. The only instrument available to control pollution in each state is an emission limit. Each firm takes as given its emission limit and the output of the other firm and chooses its own output level and abatement to maximise profits (net of abatement costs). Assuming that both emission limits bite, the resulting equilibrium profit function for firm i = 1, 2 is denoted $\Pi(e_i, e_j)$ where e_i is the emission limit set by country i. Under standard assumptions it can be shown (Ulph 1997b) that the equilibrium profit function has the properties $\Pi_1 > 0,\ \Pi_2 < 0,\ \Pi_{12} < 0,\ \Pi_{22} > 0.$ We assume that $\Pi_{11} < \Pi_{12} < 0$ and $\Pi_{11} + \Pi_{22} < \Pi_{12} + \Pi_{21}$.

Unabated pollution causes environmental damage, but only in the state in which the firm is located. The damage cost function in state i is denoted $\delta_i D(e_i)$ where δ_i is a parameter and D is a strictly convex function. Welfare in state i is thus given by $W(e_i, e_j, \delta_i) \equiv \Pi(e_i, e_j) - \delta_i D(e_i)$; it follows from the above that $W_2 < 0;\ W_{11} < W_{12} < 0;\ \ W_{13} < 0;\ \ W_{22} > 0$ and we shall assume that $W_{11} + W_{22} < W_{12} + W_{21}$.

If environmental policy is set at the state level, then emission limits are determined by a Nash equilibrium in which the government of each state takes as given the emission limit of the other state and chooses its own emission limit to maximise state welfare. If environmental policy is set at the federal level, then emission limits are set as a cooperative equilibrium in which the federal government chooses emission limits in both states to maximise the sum of the welfares in both countries, subject to the constraint that welfare in each country is no less than if policy were set at the state level. In both cases emission limits in each country will depend on the damage cost parameters in both countries. It is straightforward to show that emission limits are lower and welfare higher in both states when policy is set at the federal rather than the state level (Ulph (1997b, c)).

2.2 Asymmetric Information

We now suppose that the damage cost parameter in each state is known only to the state government in power[16]. To keep things simple, we suppose that in state i =1, 2, δ_i can take one of only two values, δ_L and δ_H, $\delta_L < \delta_H$, with probabilities p and 1-p respectively. Note that this implies that, *ex ante*, both states are identical. We denote the expected value of damage costs and the variance of damage costs respectively by $\bar{\delta} \equiv p\delta_L + (1-p)\delta_H, \quad V(\delta) \equiv 2p(1-p)(\delta_H - \delta_L)^2$

If environmental policy is set at the state level, emission limits are set as the outcome of a Bayesian-Nash non-cooperative equilibrium. Let $\hat{e}_{iL}$ ($\hat{e}_{iH}$)be the emission limit set by state i = *1, 2* if it has a low (high) damage cost parameter. It is chosen to maximise: $pW(\hat{e}_{iL}, \hat{e}_{jL}, \delta_L) + (1-p)W(\hat{e}_{iL}, \hat{e}_{jH}, \delta_L)$. In equilibrium, because of *ex ante* symmetry, $\hat{e}_{iL} = \hat{e}_{jL} = \hat{e}_L, \hat{e}_{iH} = \hat{e}_{jH} = \hat{e}_H$. Let $\hat{W}_L$ ($\hat{W}_H$) be the expected welfare of a state with low (high) damage cost parameter.

If environmental policy is set at the federal level, then the federal government has to solve a mechanism design problem. The federal government asks states to declare their damage costs, and depending on what they announce sets emission limits and financial transfers. Emission limits and financial transfers are chosen to maximise the expected sum of welfares in the two states less the social cost of funding the financial transfers, subject to incentive compatibility constraints and the participation constraints that a state must be no worse off than if policy were set at the state level. Formally, the federal government chooses emission limits $\tilde{e}_{LL}, \tilde{e}_{LH}, \tilde{e}_{HL}\ \tilde{e}_{HH}$ and financial transfers M_L, M_H to maximise its welfare function defined by:

$$W^F(\tilde{e}_{LL}, \tilde{e}_{LH}, \tilde{e}_{HL}, \tilde{e}_{HH}, M_L, M_H) \equiv p^2\{2[W(\tilde{e}_{LL}, \tilde{e}_{LL}, \delta_L) + M_L]\}$$
$$+2p(1-p)\{[W(\tilde{e}_{LH}, \tilde{e}_{HL}, \delta_L) + M_L] + [W(\tilde{e}_{HL}, \tilde{e}_{LH}, \delta_H) + M_H]\}$$
$$+(1-p)^2\{2[W(\tilde{e}_{HH}, \tilde{e}_{HH}, \delta_H) + M_H]\}$$
$$-(1+\sigma)\{2p^2 M_L + 2p(1-p)(M_L + M_H) + 2(1-p)^2 M_H\}$$

subject to:

[16] It may be that in some cases it would be inappropriate to assume that the federal government is less well informed than the state government about damage costs even for purely local environmental problems. However even if that is true, there remains the issue of whether the information could be made verifiable in court, and if not then the federal government will still need to design its environmental policy to be self-enforcing. While this would change the formulation of the problem we don't believe this would change the basic results of this paper. We are grateful to Joe Swierbinski for this point.

$$pW(\tilde{e}_{LL},\tilde{e}_{LL},\delta_L)+(1-p)W(\tilde{e}_{LH},\tilde{e}_{HL},\delta_L)+M_L \geq$$
$$pW(\tilde{e}_{HL},\tilde{e}_{LH},\delta_L)+(1-p)W(\tilde{e}_{HH},\tilde{e}_{HH},\delta_L)+M_H \quad (1)$$

$$pW(\tilde{e}_{HL},\tilde{e}_{LH},\delta_H)+(1-p)W(\tilde{e}_{HH},\tilde{e}_{HH},\delta_H)+M_H \geq$$
$$pW(\tilde{e}_{LL},\tilde{e}_{LL},\delta_H)+(1-p)W(\tilde{e}_{LH},\tilde{e}_{HL},\delta_H)+M_L \quad (2)$$

$$pW(\tilde{e}_{LL},\tilde{e}_{LL},\delta_L)+(1-p)W(\tilde{e}_{LH},\tilde{e}_{HL},\delta_L)+M_L \geq \hat{W}_L \quad (3)$$

$$pW(\tilde{e}_{HL},\tilde{e}_{LH},\delta_H)+(1-p)W(\tilde{e}_{HH},\tilde{e}_{HH},\delta_H)+M_H \geq \hat{W}_H \quad (4)$$

In the federal government's welfare function the term $(1+\sigma)$ represents the social cost of raising one unit of funds to pay the financial transfers. Constraints (1) and (2) are the incentive compatibility constraints to ensure that governments of states with low and high damage cost parameters respectively correctly reveal their damage costs. Constraints (3) and (4) are the individual rationality constraints which ensure that governments of states with low and high damage cost parameters are at least as well off as they would have been if environmental policy had been set at the state level. Ulph (1997b, c) showed that there are three possible solutions to this problem. If there is a large difference between high and low damage costs, then it is possible to implement the same emission limits as if the federal government had full information. If $\sigma = 0$, so the federal government can costlessly raise funds, then it is again possible to implement the full information set of emission limits using only financial transfers to induce state governments to correctly reveal their damage costs. In all other cases (the most likely cases) it will not be possible to implement the full information emission limits; if one state has low damage costs and the other high damage costs, then the difference between their emission limits $(\tilde{e}_{LH}-\tilde{e}_{HL})$ will be smaller than when the federal government has full information.

2.3 Political Competition

We now drop the assumption that governments seek to maximise welfare. We follow Boyer and Laffont (1996) in using a very simple model to motivate our analysis. Thus, consider a state in which profits are Π and environmental damage costs are *D*. Suppose that the population in this state has two groups: shareholders and non-shareholders in proportions α and $1-\alpha$, where $0 < \alpha < 1$. The government taxes profits at a rate τ, $0 < \tau < 1$, and distributes these taxes in a lump-sum fashion to all members of society. Environmental damage costs are also experienced equally by all members of society. Normalising the total population to 1, a typical non-shareholder and shareholder have utilities respectively given by:

$$u^N \equiv \tau\Pi - D = \tau(\Pi - \frac{D}{\tau}) = \tau(\Pi - \gamma_H D) \qquad (5)$$

$$u^S \equiv \tau\Pi + \frac{(1-\tau)\Pi}{\alpha} - D = \frac{[\alpha\tau + (1-\tau)]}{\alpha}[\Pi - \gamma_L D] \qquad (6)$$

where $\gamma_H \equiv 1/\tau > 1, \quad \gamma_L = \dfrac{\alpha}{\alpha\tau + (1-\tau)} < 1$

Welfare in this state is given by: $W = \alpha u^S + (1-\alpha)u^N = \Pi - D$. Political parties are formed to represent the interests of the two groups, and elections are held in which the party which represents the largest group wins. We call the parties representing shareholders and shareholders Industry and Green parties respectively. With probability *q*, $\alpha > 0.5$, and so the elected government represents the interests of shareholders. The Industry government uses a utility function, which, ignoring the multiplicative constant in (6), can be written as $\Pi - \gamma_L D, \quad \gamma_L < 1$, i.e. the Industry government gives too little weight to environmental damages relative to social welfare. With probability *1 - q*, $\alpha < 0.5$ and so the Green government is elected and uses a utility function, which again ignoring the multiplicative constant in (5), can be written as $\Pi - \gamma_H D, \quad \gamma_H > 1$, i.e. the Green government gives too much weight to environmental damage costs relative to social welfare.

Combining this with our previous model, we now suppose that in state $i = 1, 2$, the state government uses a utility function: $U(e_i, e_j, \delta_i, \gamma_i) \equiv \Pi(e_i, e_j) - \gamma_i \delta_i D(e_i)$. As before, with probabilities *p* and *1-p* respectively, the damage cost parameter δ_i can take values δ_L and δ_H. With probabilities *q* and *1-q* respectively the political weight attached to environmental damage costs, γ_i can take values γ_L and γ_H, $\gamma_L < 1 < \gamma_H$. We assume that expected value of the political weight is equal to 1, and denote the variance by $V(\gamma) = 2q(1-q)(\gamma_H - \gamma_L)^2$. The random process which determines the damage cost parameter in state *i* is independent of the random process which determines the value of the political weight attached to environmental damage costs, and both these processes are also independent of the processes operating in state *j*. We also suppose that the federal government attaches its own political weight, γ_F, to environmental damage costs in the two states. We shall not spell out the political process which links the federal government to the state governments, but simply assume that there is an identical, but independent, random process for determining γ_F, i.e. with probabilities *q* and *1-q* γ_F can take the values γ_L and γ_H. An alternative treatment which would have provided a stronger link between the two levels of government would have been to assume that if both state governments were of the same type, then the federal government had to also be of that type. If, however, the two state governments were of different types then there was an equal probability of the federal government being of one type or the other.

The final point to emphasise is that while it is public knowledge what type of government is in power in both states and at the federal level, we retain the assumption that it is only the state government in power that learns the true value of environmental damage costs in that state. This point is crucial for the question arises in all political economy models why voters allow governments to be captured by special interest groups rather than pursuing policies which maximise welfare. For this

to happen there must be an element of voter ignorance, and in our simple model this is captured by assuming that voters will not learn the true value of environmental damage costs. Green governments can defend the implementation of tough environmental policies by claiming that their scientific advisers tell them that environmental damage costs are high, while industrial governments can make the opposite claim[17]. If voters are to 'tie the government's hands' to force them to implement policies which maximise welfare they must do so by giving up the ability to condition environmental policies on the true value of environmental damage costs. The analysis of this choice is contained in the next section.

2.4 Social Pooling and Political Discretion.

We assume that there is a prior constitutional stage at which society has to decide how to allow governments to operate with respect to environmental policy. There are two kinds of choices society must make. The first is the standard question in a federal system of which level of government should be allowed to set environmental policy. Whatever level is chosen, there is a second choice, which is how to deal with the problem of governments being captured by interest groups, and for this choice we follow Boyer and Laffont (1996).

The constitutional stage occurs prior to the outcome of the random processes which determine which governments will be elected in each state and at the federal level, and prior to the random processes which determine what the value of environmental damage costs will be in the two states. Society recognises that the political process is imperfect in that it allows governments to be captured by special interest groups. We suppose that in principle it would be possible to constitutionally bind governments to implement policies which maximise welfare. Since at this stage the value of damage costs are unknown, this would involve devising a set of policies which maximise welfare for each possible value of damage costs. The problem is that the voters will never learn what the true value of damage costs is, and so cannot punish governments which do not implement the welfare maximising policy contingent on the true value of damage costs. Thus the second choice facing society at the prior constitutional stage is between what Boyer and Laffont call *social pooling* and *political discretion*. By social pooling we mean that society will bind governments to implement policies which maximise welfare, but can only do so based on the expected value of environmental damage costs. By political discretion we mean that society allows the governments which come in to power to implement policies which maximise their utility functions, but those policies will be based on the true value of environmental damage costs. If it has been decided that policy should be determined at the federal level, then of course the federal government will need to devise a mechanism design to get the state governments to reveal the information they have learned.

Thus the timing of events is as follows. At the first stage society chooses the level of government at which environmental policy should be set and whether to use social pooling or political discretion; so there are four combinations which society can choose. Then nature determines which type of government will be elected in each

[17] See Austen-Smith (1997) for a nice model of political competition in terms of scientific advice.

state and at the federal level, and also what the true value of damage costs will be in each state. Governments then come into power and the state governments learn the true value of damage costs. Governments then set policies according to the choice made by society at the first stage. These are described in detail below. Thus for each choice made at stage one, society can calculate the policies that will be chosen by governments for each configuration of government types and each configuration of damage costs, and hence calculate the resulting welfare level. Society chooses one of the four combinations at stage one based on expected total welfare across the two states. Since at the prior constitutional stage the two states are *ex ante* identical the choice based on expected total welfare is the same as the choice based on expected welfare in either state.

We now make the above discussion more precise by setting out in detail what happens for each choice society makes at stage one.

2.4.1 Social Pooling - Policy Set at State Level.

Governments in each state are constrained to maximise welfare based on the expected value of damage costs. Thus the government in state i = 1, 2 takes as given the emission limit set the other state, $\bar{e}_j$ and sets its own emission limit $\bar{e}_i$ to maximise $U(\bar{e}_i, \bar{e}_j, \bar{\delta}, 1)$. In the resulting Nash equilibrium it is clear that since the two states are *ex ante* identical, the equilibrium emission limits will be equal, $\bar{e}_i = \bar{e}_j = \bar{e}$. Expected social welfare for each state from this stage one choice is simply $\overline{W} \equiv U(\bar{e}, \bar{e}, \bar{\delta}, 1)$.

2.4.2 Social Pooling - Policy Set at Federal Level.

The federal government is constrained to maximise total welfare based on the expected value of damage costs, and subject to the condition that each state is no worse off than if policy had been set at the state level. Thus the federal government chooses e^*_1, e^*_2 to maximise $U(e^*_1, e^*_2, \bar{\delta}, 1) + U(e^*_2, e^*_1, \bar{\delta}, 1)$ subject to $U(e^*_i, e^*_j, \bar{\delta}, 1) \geq \overline{W}$, *i, j* = 1, 2, $i \neq j$. Again it is clear that since the two states are identical *ex ante,* the solution must require $e^*_1 = e^*_2 = e^*$. Expected social welfare for each state from this stage one choice is simply $W^* \equiv U(e^*, e^*, \bar{\delta}, 1)$.

If we compare the two social choices involving social pooling, it is clear that since this is a special case of the general model set out in section 2.1, $e^* < \bar{e}, \quad W^* > \overline{W}$, so that if social pooling is chosen at the constitutional stage, then it always be better to have environmental policy set at the federal level. Note the important point that social pooling implies that environmental policies will be *harmonised* across the two states, no matter what the *ex post* level of damage costs turns out to be in the two states.

2.4.3 Political Discretion - Policy Set at the State Level.

There are four possible configurations of government types in the two states. For any configuration (γ_1, γ_2) the emission limits in the two states are set as the equilibrium of a Bayesian-Nash game in which each state government knows its own damage costs but not those of its rival. Thus there are four equilibrium emission limits to be determined: $\hat{e}_1(\gamma_1, \gamma_2, \delta_L)$, $\hat{e}_1(\gamma_1, \gamma_2, \delta_H)$, $\hat{e}_2(\gamma_1, \gamma_2, \delta_L)$, $\hat{e}_2(\gamma_1, \gamma_2, \delta_H)$, and four first-order conditions to determine them. For example, if state 1 has low damage costs, it will take as given the low damage cost and high damage cost emission limits of state 2 and choose $\hat{e}_1(\gamma_1, \gamma_2, \delta_L)$ to maximise expected utility:
$pU[\hat{e}_1(\gamma_1, \gamma_2, \delta_L), \hat{e}_2(\gamma_1, \gamma_2, \delta_L), \delta_L, \gamma_1] + (1-p)U[\hat{e}_1(\gamma_1, \gamma_2, \delta_L), \hat{e}_2(\gamma_1, \gamma_2, \delta_H), \delta_L, \gamma_1]$

Denote the resulting maximised expected utility by $\hat{U}_1(\gamma_1, \gamma_2, \delta_L)$. In a similar fashion we can define the equilibrium expected utilities for each state for each configuration of government types and each level of damage costs:
$\hat{U}_1(\gamma_1, \gamma_2, \delta_L)$, $\hat{U}_1(\gamma_1, \gamma_2, \delta_H)$, $\hat{U}_2(\gamma_1, \gamma_2, \delta_L)$, $\hat{U}_2(\gamma_1, \gamma_2, \delta_H)$.

For each configuration of government types we define expected utility for each state *i* in the Bayesian Nash equilibrium: $\hat{U}_i(\gamma_1, \gamma_2) = p\hat{U}_i(\gamma_1, \gamma_2, \delta_L) + (1-p)\hat{U}_i(\gamma_1, \gamma_2, \delta_H)$. By using the same equilibrium emission limits but replacing the term γ_i by 1 in state *i*'s utility function we can also evaluate expected welfare for state *i* : $\hat{W}_i(\gamma_1, \gamma_2)$.

Finally, we can evaluate expected utility and welfare for each state over the four possible configurations of government types in the two states:

$$\hat{U} = q^2\hat{U}(\gamma_L, \gamma_L) + q(1-q)[\hat{U}(\gamma_L, \gamma_H) + \hat{U}(\gamma_H, \gamma_L)] + (1-q)^2\hat{U}(\gamma_H, \gamma_H)$$
$$\hat{W} = q^2\hat{W}(\gamma_L, \gamma_L) + q(1-q)[\hat{W}(\gamma_L, \gamma_H) + \hat{W}(\gamma_H, {}_L)] + (1-q)^2\hat{W}(\gamma_H, \gamma_H)$$

Note that since the two states are identical *ex ante* expected utility and welfare must be the same for the two states, so we drop the subscript identifying the state.

2.4.4 Political Discretion - Policy Set at the Federal Level.

There are eight possible configurations of government types at the state and federal levels, and to save notation we denote a given configuration by $\Gamma = (\gamma_1, \gamma_2, \gamma_F)$. For any given Γ, the federal government has to solve a mechanism design problem in which it sets emission limits and financial transfers for each state contingent on the announced damage costs of both states so as to maximise expected utility of the federal government less the social cost of funding the financial transfers subject to incentive compatibility constraints and the constraints that no state government with its given political weight and damage cost parameter would be worse off than in the case where environmental policy was set at the state level. Note that in the federal government's utility function it is the federal government's political weight for environmental damage costs that will be used, but the in the incentive compatibility constraints and the individual rationality constraints the federal government must take account of the political weights in the individual states' utility functions.

Formally, the federal government must choose the set of policy instruments[18]: $\tilde{e}^1_{LL}, \tilde{e}^1_{LH}, \tilde{e}^1_{HL}, \tilde{e}^1_{HH}, \tilde{e}^2_{LL}, \tilde{e}^2_{LH}, \tilde{e}^2_{HL}, \tilde{e}^2_{HH}, M^1_L, M^1_H, M^2_L, M^2_H$ to maximise:

$$
\begin{aligned}
&p^2\{[U(\tilde{e}^1_{LL}, \tilde{e}^2_{LL}, \delta_L, \gamma_F) + M^1_L] + [U(\tilde{e}^2_{LL}, \tilde{e}^1_{LL}, \delta_L, \gamma_F) + M^2_L]\} \\
&+p(1-p)\{[U(\tilde{e}^1_{LH}, \tilde{e}^2_{HL}, \delta_L, \gamma_F) + M^1_L] + [U(\tilde{e}^2_{HL}, \tilde{e}^1_{LH}, \delta_H, \gamma_F) + M^2_H]\} \\
&+p(1-p)\{[U(\tilde{e}^1_{HL}, \tilde{e}^2_{LH}, \delta_H, \gamma_F) + M^1_H] + [U(\tilde{e}^2_{LH}, \tilde{e}^1_{HL}, \delta_L, \gamma_F) + M^2_L]\} \\
&+(1-p)^2\{[U(\tilde{e}^1_{HH}, \tilde{e}^2_{HH}, \delta_H, \gamma_F) + M^1_H] + [U(\tilde{e}^2_{HH}, \tilde{e}^1_{HH}, \delta_H, \gamma_F) + M^2_H]\} \\
&-(1+\sigma)\{pM^1_L + (1-p)M^1_H + pM^2_L + (1-p)M^2_H\}
\end{aligned}
$$

subject to the incentive compatibility constraints:

$$
\begin{aligned}
&pU(\tilde{e}^1_{LL}, \tilde{e}^2_{LL}, \delta_L, \gamma_1) + (1-p)U(\tilde{e}^1_{LH}, \tilde{e}^2_{HL}, \delta_L, \gamma_1) + M^1_L \geq \\
&pU(\tilde{e}^1_{HL}, \tilde{e}^2_{LH}, \delta_L, \gamma_1) + (1-p)U(\tilde{e}^1_{HH}, \tilde{e}^2_{HH}, \delta_L, \gamma_1) + M^1_H
\end{aligned} \qquad (7)
$$

$$
\begin{aligned}
&pU(\tilde{e}^1_{HL}, \tilde{e}^2_{LH}, \delta_H, \gamma_1) + (1-p)U(\tilde{e}^1_{HH}, \tilde{e}^2_{HH}, \delta_H, \gamma_1) + M^1_H \geq \\
&pU(\tilde{e}^1_{LL}, \tilde{e}^2_{LL}, \delta_H, \gamma_1) + (1-p)U(\tilde{e}^1_{LH}, \tilde{e}^2_{HL}, \delta_H, \gamma_1) + M^1_L
\end{aligned} \qquad (8)
$$

$$
\begin{aligned}
&pU(\tilde{e}^2_{LL}, \tilde{e}^1_{LL}, \delta_L, \gamma_2) + (1-p)U(\tilde{e}^2_{LH}, \tilde{e}^1_{HL}, \delta_L, \gamma_2) + M^2_L \geq \\
&pU(\tilde{e}^2_{HL}, \tilde{e}^1_{LH}, \delta_L, \gamma_2) + (1-p)U(\tilde{e}^2_{HH}, \tilde{e}^1_{HH}, \delta_L, \gamma_2) + M^2_H
\end{aligned} \qquad (9)
$$

$$
\begin{aligned}
&pU(\tilde{e}^2_{HL}, \tilde{e}^1_{LH}, \delta_H, \gamma_2) + (1-p)U(\tilde{e}^2_{HH}, \tilde{e}^1_{HH}, \delta_H, \gamma_2) + M^2_H \geq \\
&pU(\tilde{e}^2_{LL}, \tilde{e}^1_{LL}, \delta_H, \gamma_2) + (1-p)U(\tilde{e}^2_{LH}, \tilde{e}^1_{HL}, \delta_H, \gamma_2) + M^2_L
\end{aligned} \qquad (10)
$$

and the individual rationality constraints:[19]

$$pU(\tilde{e}^1_{LL}, \tilde{e}^2_{LL}, \delta_L, \gamma_1) + (1-p)U(\tilde{e}^1_{LH}, \tilde{e}^2_{HL}, \delta_L, \gamma_1) + M^1_L \geq \hat{U}_1(\gamma_1, \gamma_2, \delta_L) \qquad (11)$$

$$pU(\tilde{e}^1_{LH}, \tilde{e}^2_{HL}, \delta_H, \gamma_1) + (1-p)U(\tilde{e}^1_{HH}, \tilde{e}^2_{HH}, \delta_H, \gamma_1) + M^1_H \geq \hat{U}_1(\gamma_1, \gamma_2, \delta_H) \qquad (12)$$

$$pU(\tilde{e}^2_{LL}, \tilde{e}^1_{LL}, \delta_L, \gamma_2) + (1-p)U(\tilde{e}^2_{LH}, \tilde{e}^1_{HL}, \delta_L, \gamma_2) + M^2_L \geq \hat{U}_2(\gamma_1, \gamma_2, \delta_L) \qquad (13)$$

$$pU(\tilde{e}^2_{HL}, \tilde{e}^1_{LH}, \delta_H, \gamma_2) + (1-p)U(\tilde{e}^2_{HH}, \tilde{e}^1_{HH}, \delta_H, \gamma_2) + M^2_H \geq \hat{U}_2(\gamma_1, \gamma_2, \delta_H) \qquad (14)$$

[18] To save notation we omit the dependence of these policy instruments on the configuration of government types Γ.

[19] It might be asked why we impose these constraints if it has already been decided at a prior constitutional stage that policy should be set at the federal level. Our justification is that our use of the concept of a federation and a constitution are designed to cover less formal structures such as, say, the European Union, when at the implementation stage it may still be necessary to ensure that state governments have no incentive to defect from any prior constitutional agreement to set policy at the federal level. As we show later the constraints are frequently not binding, so we do not believe our result would be sensitive to dropping these constraints.

Incentive compatibility constraints (7) and (8) are for state 1 with low and high damage costs respectively, while (9) and (10) are for state 2 with low and high damage costs respectively. Similarly individual rationality constraints (11) and (12) are for state 1 with low and high damage costs while (13) and (14) are for state 2 with low and high damage costs respectively.

So for any configuration of government types, Γ, we solve the mechanism design problem above. Having obtained the optimal values of the policy instruments we can then calculate the expected utilities for the federal government, and the two state governments: $\tilde{U}_1(\Gamma), \tilde{U}_2(\Gamma), \tilde{U}_F(\Gamma)$. By replacing the political weights on environmental damages with the weight 1 we can also calculate expected welfare for the three governments: $\tilde{W}_1(\Gamma), \tilde{W}_2(\Gamma), \tilde{W}_F(\Gamma)$ where $\tilde{W}_F(\Gamma) = \tilde{W}_1(\Gamma) + \tilde{W}_2(\Gamma)$.

Finally we take expectations over the eight possible configurations of government to calculate expected utility and expected welfare for each state and the federal government. By the *ex ante* identity of the two states expected utility is the same for both states, and so too is expected welfare, so we drop the state identifiers:

$$\tilde{U} = q^3\tilde{U}(\gamma_L,\gamma_L,\gamma_L) + q^2(1-q)[\tilde{U}(\gamma_L,\gamma_L,\gamma_H) + \tilde{U}(\gamma_L,\gamma_H,\gamma_L) + \tilde{U}(\gamma_H,\gamma_L,\gamma_L)]$$
$$+q(1-q)^2[\tilde{U}(\gamma_H,\gamma_H,\gamma_L) + \tilde{U}(\gamma_H,\gamma_L,\gamma_H) + \tilde{U}(\gamma_L,\gamma_H,\gamma_H)] + (1-q)^3\tilde{U}(\gamma_H,\gamma_H,\gamma_H)$$

$$\tilde{W} = q^3\tilde{W}(\gamma_L,\gamma_L,\gamma_L) + q^2(1-q)[\tilde{W}(\gamma_L,\gamma_L,\gamma_H) + \tilde{W}(\gamma_L,\gamma_H,\gamma_L) + \tilde{W}(\gamma_H,\gamma_L,\gamma_L)]$$
$$+q(1-q)^2[\tilde{W}(\gamma_H,\gamma_H,\gamma_L) + \tilde{W}(\gamma_H,\gamma_L,\gamma_H) + \tilde{W}(\gamma_L,\gamma_H,\gamma_H)] + (1-q)^3\tilde{W}(\gamma_H,\gamma_H,\gamma_H)$$

2.5 Analysis of Constitutional Choice.

We have now defined the expected welfare for each state for each of the four possible constitutional choices that can be made at stage one: $\overline{W}, W^*, \hat{W}, \tilde{W}$. For ease of remembering which constitutional choice they refer to we shall also use the mnemonics: *WSPS, WSPF, WPDS,WPDF* respectively, where *W* denotes expected welfare, *SP* denotes social pooling, *PD* political discretion, and *S, F* denote that policy is made at the state or federal level. All we have been able to establish so far is that *WSPS<WSPF*, so that if social pooling is selected, then it is better to have policy set at the federal level, for the obvious reason that, since there is no information asymmetry between federal and state governments, having policy set at the federal level overcomes the mutually damaging policy competition between the states. To make further progress we will need to use particular functional forms, and we turn to this in the next section.

3. A Special Case

In this section we set out a special case of the model in the previous section, drawing on the special case used in Ulph (1997b). In that model, the two firms produce a homogenous good and face a simple linear inverse demand function with intercept A and unit slope. There are no costs of production but there are quadratic abatement costs, $0.5a^2$ and the damage cost function is also quadratic: $D(e) = 0.5e^2$. It is then straightforward to show that the utility function for state i is:

$$U(e_i, e_j, \delta_i, \gamma_i) = 3(2A - e_j)^2 + 18e_i(2A - e_j) - (37 + 64\delta_i\gamma_i)e_i^2 \qquad (15)$$

It is now possible to derive explicitly the emission limits for the first three constitutional choices analysed in the last section.

3.1 Social Pooling -Policy set at State Level.

Setting $\delta_i\gamma_i = \bar{\delta}$ in (15) and maximising with respect to state i s emission limit yields first-order condition:

$$18(2A - e_j) - 2(37 + 64\bar{\delta})e_i = 0. \quad \text{In equilibrium } e_i = e_j = \bar{e}; \text{ so } \bar{e} = \frac{9A}{23 + 32\bar{\delta}}.$$

3.2 Social Pooling - Policy Set at the Federal level.

Imposing the same restriction as in 3.1 and maximising the sum of the utility functions for states i and j yields the first-order condition for state i's emission limit:

$$18(2A - e_j) - 2(37 + 64\bar{\delta})e_i - 6(2A - e_i) - 18e_j = 0$$

$$\text{In equilibrium } e_i = e_j = e^*; \text{ so } e^* = \frac{6A}{26 + 32\bar{\delta}} < \bar{e}$$

3.3 Political Discretion - Policy Set at the State Level.

For any values of γ_1, γ_2 let e_i^L, e_i^H be the emission limits set by state i = 1,2 if it has low or high damage costs respectively.

State 1 chooses e_1^L to maximise $pU(e_1^L, e_2^L, \delta_L, \gamma_1) + (1-p)U(e_1^L, e_2^H, \delta_L, \gamma_1)$. Substituting from (15) yields the first-order condition:

$$18A - 9[pe_2^L + (1-p)e_2^H] - \beta_1 e_1^L = 0 \qquad (16a)$$

$$\text{where } \beta_1 = 37 + 64\delta_L\gamma_1$$

Conducting a similar analysis for state 1 with high damage costs, and state 2 with low and high damage costs yields the remaining first-order conditions:

$$18A - 9[pe_2^L + (1-p)e_2^H] - \beta_2 e_1^H = 0 \qquad (16b)$$

$$18A - 9[pe_1^L + (1-p)e_1^H] - \beta_3 e_2^L = 0 \qquad (16c)$$

$$18A - 9[pe_1^L + (1-p)e_1^H] - \beta_4 e_2^H = 0 \qquad (16d)$$

where $\beta_2 = 37 + 64\delta_H\gamma_1$, $\beta_3 = 37 + 64\delta_L\gamma_2$, $\beta_4 = 37 + 64\delta_H\gamma_2$

Define: $\tilde{\delta} = p\delta_H + (1-p)\delta_L$, $\beta_5 = 37 + 64\tilde{\delta}\gamma_1$, $\beta_6 = 37 + 64\tilde{\delta}\gamma_2$,

$$X_1 = \beta_3\beta_4 - 9\beta_6,\ X_2 = \beta_1\beta_2 - 9\beta_5,\ \phi = \frac{18A}{\beta_1\beta_2\beta_3\beta_4 - 81\beta_5\beta_6}$$

Then (16a)-(16d) can be solved to yield:

$\hat{e}_1^L = \beta_2 X_1\phi$, $\hat{e}_1^H = \beta_1 X_1\phi$, $\hat{e}_2^L = \beta_4 X_2\phi$, $\hat{e}_2^H = \beta_3 X_2\phi$

It is straightforward to show that $\hat{e}_i^L > \hat{e}_i^H$, i = 1,2 and that $\gamma_i \geq \gamma_j \Rightarrow \hat{e}_i^L \leq \hat{e}_j^L, \hat{e}_i^H \leq \hat{e}_j^H$ i.e. emission limits are higher when damage costs are low than when they are high, and that the higher the political weight attached to damage costs, the lower are emission limits, for any given damage costs.

However, even for this special case it is not possible to solve explicitly for the emission limits when there is political discretion and policy is set at the federal level. Moreover, what we are ultimately interested in is not emission limits for any given configuration of types of government, but with expected welfare evaluated over all possible configurations of government types. To obtain further results we have conducted numerical calculations, and these are reported in the next section.

4. Numerical Results.

In this section we report some numerical simulations we have performed using the special functional forms introduced in the previous section. We begin by describing the choice of parameter values. From the previous section we know that with social pooling, whether policy is set at the federal or state level, emissions and welfare depend only on the expected value of damage costs, and are decreasing functions of expected damage costs. So the cases for which we need to use numerical simulations are political discretion at the state and federal level. In subsections 4.2 and 4.3 we summarise the results of the numerical simulations in terms of the impact of the damage cost parameter and the political weight attached to environmental damage costs on emissions, utilities and welfare for the cases where policy is set at the state and federal level respectively. Finally we analyse the choices that are made at the constitutional stage: whether environmental policy should be set at the federal or state level and between social pooling and political discretion.

4.1 Choice of Parameter Values.

It is clear from the previous section that, for the results we were able to derive analytically, emissions were just directly proportional to the parameter A which denotes the level of demand for the product, so A does not play any crucial role in the model. We have just set it equal to 10. The parameter s denotes the social cost of raising a unit of the numeraire in taxes in order to fund transfers. Estimates of this parameter are usually thought to be in the range 0.2 -0.4; we have used values 0.0, 0.1, 0.2, 0.3 and 0.4. It turns out that results are relatively insensitive to the choice of positive values of s, so the results we report here are for the case $s = 0.3$.

The other key parameters are the means and variances of d and g. As noted in section 2, we assume that $\bar{g} = 1.0$, so that the expected value of the political weight attached to environmental damages is equal to the weight attached to environmental damages in social welfare. To set the mean damage cost parameter, we asked what would happen if both states had the same damage cost parameter, d, and neither state government imposed any emission limits, so firms do no abatement and emissions are just equal to output. We then calculated the resulting pollution damage costs and expressed these as a proportion of gross welfare (i.e. welfare before the deduction of damage costs, which can be thought of as conventional measures of GNP, and in this simple model would just be profits). The proportion turns out to be $(27/37)d$, or approximately $0.75d$. Based on this simple analysis, we have chosen values of expected damage costs to lie between 0.1 and 0.5, implying that in a completely unregulated economy, expected pollution damage costs would lie between 7.5% and 37.5% of GNP.

Finally, to set the variances of damage costs and political weights, we have taken a very simple approach. We set $p = q = 0.5$, which yields the maximum values of the variances for any choice of upper and lower values for the variables. We then take upper and lower values of the two variables which are symmetric around their means,

and differ from the mean by a proportion of the mean which varies between 0.05 and 0.95; i.e. in the case of damage costs we take upper and lower values of damage costs $d_H = (1+u)\bar{d}; \quad d_L = (1-u)\bar{d}; \quad u = 0.05, 0.1, 0.15, \ldots, 0.95$. For this simple model, the coefficient of variation is just u, and when we compare social pooling and political discretion we shall do so for different values of $u(d)$ and $\upsilon(\gamma)$.

4.2 Political Discretion When Policy is Set at the State Level.

We know from the previous section that in the Bayesian-Nash equilibrium, emissions in a state are a decreasing function of both the damage cost parameter and the political weight used by the government in that state. The impact of the damage cost parameter on utility and welfare is straightforward: a higher damage cost parameter in one state always lowers that state's utility and welfare, and raises the utility and welfare and utility of the other state, no matter what values are taken by the damage cost parameter of the other state or the political weights attached to environmental damage costs in both states.

Turning to the impact on utility and welfare of the political weight attached to environmental damage costs, in terms of both utility and welfare, a state with an industrial government is always better off when faced by a state with a green government than a state with another industrial government, (it gets a higher market share in the former case than the latter). Conversely, a state with a green government is always better off faced with a state which also has a green government than one that has an industrial government. These statements are true no matter what the damage costs parameters are in each state. We now pose the question the other way round: if the other state has a particular type of government is it better for a state to have a green or an industrial government? That question cannot be posed in terms of utility, since the utility functions are different. In terms of welfare, there is no unambiguous answer, either for particular values of damage cost parameters in each state, or even when we calculate expected welfare across all combinations of damage cost parameters. However, both states have higher welfare when both governments are green than when both governments are industrial. The reason is simply that the when states act independently they tend to set too lax emission limits, so electing green governments is a way of committing themselves to setting tougher emission limits. It does not follow that if states could simply choose which type of government to elect (rather than having the random process for determining which type of government is in a majority) they would necessarily choose to have green governments. Indeed, for low values of the variance of government types, states would face a Prisoner's Dilemma in which the choice of an industrial government would be a dominant strategy for each state, while, as already noted, both states would be better off if they had chosen a green government.

Finally, we assess the impact of the variances of damage costs and political weights on the expected welfare of political discretion at the state level (WPDS). These are shown respectively in Figures 1 and 2 for different values of expected damage costs. Figure 1 shows that for low values of expected damage costs ($\bar{d} \leq 0.5$), WPDS is a *decreasing* function of $\upsilon(\delta)$, while for higher values of expected damage costs it is an

initially decreasing and then increasing function. It might have been expected, from the Boyer and Laffont (1996) results, that WPDS would be an increasing function of $\upsilon(\delta)$, reflecting the fact that the benefit of allowing state governments to fine tune their policies to the true level of damage costs should be greater the larger is the variance in damage costs. The reason why this result does not apply at low levels of expected damage costs, is that, given the particular functional forms chosen, for low expected damage costs emission limits chosen in a Bayesian-Nash equilibrium are rather insensitive to differences in actual damage costs, (this reflects the low elasticity of demand at low costs/prices), so state governments do not significantly fine-tune their policies to damage costs. The increased variance of the damage cost parameter just increases the uncertainty facing individuals in the constitutional stage, and since they are risk-averse, this reduces expected welfare. Figure 2, shows the anticipated result that expected welfare with political discretion is a decreasing function of the variance of the political weight attached to damage costs, since the greater the variance the greater is the difference between the government utility function and the true welfare function.

4.3 Political Discretion When Policy is Set at the Federal Level.

Recall that for any configuration of government types at the state and federal levels the federal government needs to solve a mechanism design problem of setting emission limits and financial transfers for each state, which depend on the information revealed by the states about their damage costs, so as to maximise expected federal utility subject to both incentive compatibility constraints that states correctly reveal their damage costs and to individual rationality constraints that each state, knowing its type, expects to be at least as well off (in terms of utility) when policy is set at the federal level as it would have been if policy had been set at the state level. We begin by commenting on two features of the solution to this problem. First, for many parameter values the individual rationality constraints do not bite. They tend to bite for high values of average damage costs and large variances in the political weight attached to damage costs, and then only for the configuration of political weights such that the federal government attaches a low weight to environmental damage costs while both states attach a high weight to damage costs. For example, individual rationality constraints bite when $\bar{d} = 0.5, u(d) = 0.5, u(g) = 0.6, 0.8$. The reason it happens in these cases is that as $\upsilon(\gamma)$ increases, the state governments, which use the high political weight, attach greater weight to environmental damage costs and so cut emissions in the Bayesian-Nash equilibria while the federal government, which uses the low political weight, attaches lower weights to environmental damages, and sets increasing emission limits for the states. Now, generally the level of emissions set by the federal government are lower than those set by the state governments because of the incentives for ecological dumping present when policy is set at the state level, but with the parameter values cited, the federal government sets higher emission limits for high damage cost countries than would state governments, and this causes the individual rationality constraints to bite. The second point we make is that, with the value of $\sigma = 0.3$ for most parameter values the federal government makes no use of financial transfers, since the social cost of funds is rather high. The cases where it does use financial transfers are again where expected damage costs are high, and there

is a moderately high value of the variance of either δ or γ (e.g. $u(d) = u(g) = 0.6$). The financial transfers are always to a high damage cost state, since the incentive for misrepresentation is for high damage cost state to be pretend to have low damage costs in order to be awarded a larger emission limit and hence market share. The most usual configuration of government types for which financial transfers are made is when the two state governments have different government types and the federal government is green; the financial transfer is to the state with an industrial government.

Turning now to the impact of damage costs and political weights on emissions utilities and welfare, the results are less clear-cut than when policy is set at the state level. For damage costs, if a state has an increase in its damage cost parameter it will be given a lower emission limit no matter what the damage costs of the other state are or what the configuration of government types is. It will also generally be the case that if, say, state 2 has a higher damage cost then state 1 will also be given a lower emission limit, again regardless of other parameters, although this result does not hold for high values of expected damage costs and variances of damage costs and political weights. In terms of *expected* utility and welfare (taking expectations across the damage costs of the other state) a state is always better off with low damage costs than with high damage costs, no matter what is the configuration of government types.

We now turn to the impact of different government types. In terms of the impact on emissions, a green federal government will always set lower emission limits for each state than an industrial federal government for any given configuration of damage costs or state government types. However the effect of changes in state government type is not as clear cut. For low values of expected damage costs and variances of damage costs and political weights, changing the political weight at the state level has almost no impact on emission of either state. For large values of expected damage costs and variances, a green state government will be set lower emission limits than an industrial state government; for intermediate parameter values an increase in the political weight of a state will tend to lead to higher emission limits for low damage costs and lower emission limits for high damage costs. For the impact of government types on utility, the only general statements are for expected utility (across all damage costs). It is *almost* always the case that the expected utility of a state is higher when the federal government is of the same type as the state. The cases where this breaks down is where there are high expected damage costs, high variances of damage costs and government types, and the two states governments are of different types. So if the two states have the same type of government, then states are better off when the federal government is of the same type than when the federal government is different. To assess the impact of variations in state government types on state utilities, the only valid comparison is across differences in the type of the other state government, and there are no general results available. Finally, we report the impact of government types on expected welfare of states. Again the only general results are when both states have the same type of government. The first result is that having a green federal government makes both states better off than having an industrial federal government, even if both states have industrial governments. However, we emphasise that this effect is small, and for small expected damage costs and small variances the effect is very small, so it might be possible to find extreme parameter values for which this result is overturned. It is also the case that for any given type of federal government,

both states are better off when both states have green governments than when they have industrial governments, though again this effect is small. [20]

Finally we report how the overall expected welfare from political discretion at the federal level (WPDF) varies with respect to $\upsilon(\delta)$ and $\upsilon(\gamma)$ for different values of expected damage costs. The results are summarised in Figures 3 and 4 respectively. These show that the results are in line with those of Boyer and Laffont, namely that WPDF is an increasing function of $\upsilon(\delta)$ and a decreasing function of $\upsilon(\gamma)$. The intuitions underlying these results are the same as for Boyer and Laffont.

4.4 Should Policy be Set at State or Federal level?

We now turn to the first of the choices that face society at the constitutional stage - whether to set environmental policy at the state or federal level. With social pooling, expected welfare must always be higher when policy is set at the federal level than when it is set at the state level, because the federal government must satisfy the individual rationality constraint. This constraint never bites, however, because setting policy at the federal level eliminates the damaging policy competition between states, and so states are strictly better off when policy is set at the federal level. With political discretion, however, the individual rationality constraints only require that, for any configuration of government types, expected *utility* of each state must be at least as high when policy is set at the federal level than when it is set at the state level, and this need not guarantee that expected *welfare* should be higher when policy is set at the federal rather than state level. Indeed, for some parameter values and for some configurations of government types, expected welfare of each state can be higher when policy is set at the state rather than federal level. This is true when there is a high variance of government types, $\upsilon(\gamma) \geq 0.9$, high expected damage costs, $\bar{d} \geq 0.3$, and low variance of damage costs, $\upsilon(\delta) \leq 0.3$, and when both state governments are green, irrespective of the type of federal government. The reason follows from three results we derived in the previous sections. First, the response of expected welfare to changes in parameters is greater the higher is expected damage costs. Second, expected welfare as a function of $\upsilon(\delta)$ is *decreasing* when policy is set at the state level, but *increasing* when policy is set at the federal level, so, presuming that expected welfare will generally be higher when policy is set at the federal than state level, the gap between the two is going to be smallest when there are *low* values of $\upsilon(\delta)$. Third, we have shown that welfare is higher when both state governments are green than when they are both industrial, but that the effect of state government types on welfare is greater when policy is set at the state level than when policy is set at the federal level. Thus it is more likely that expected welfare will be higher at the state than at the federal level when both governments are green and when the variance of government types is high. The combination of all these factors produces cases where the generally positive gap between expected welfare when policy is set at the federal and state level is not just narrowed, but actually becomes negative.

[20] Alternatively, one could establish a stronger link between state and federal governments by imposing the assumption that if both state governments were of one type then the federal government must also be of that type. This would mean a total of six rather than eight possible political configurations. When estimated however, the results proved to be no different.

However, what actually matters at the constitutional stage is not a comparison between expected welfare levels when policy is set at the federal and state levels for a *given* configuration of government types, but when expectations are also taken across all possible types of government. When this calculation is done it turns out that for all the combinations of expected damage costs, variances of damage costs and variances of political weights that we have computed, expected welfare with political discretion is higher when policy is set at the federal level than at the state level. Thus the gains to eliminating wasteful policy competition between states apply under both social pooling and political discretion.

4.5 Social Pooling or Political Discretion?

For each value of expected damage costs, $\bar{d} = 0.1,\ldots,0.5$, we evaluate for each of the 361 combinations of $\upsilon(\delta)$ =0.05,...,0.95 and $\upsilon(\gamma)$ = 0.05,...,0.95 whether social pooling or political discretion is preferred at the state and federal levels. We summarise the outcome for each value of expected damage costs by dividing the $u(d)-u(g)$ parameter space into four regions: I, in which social pooling is preferred at both federal and state level; II, in which social pooling is preferred at the federal level but not at the state level; III, in which social pooling is preferred at the state but not federal level; and IV, in which political discretion is preferred at both levels. Table 1 reports the proportion of parameter space accounted for by each of these regions. We also summarise the proportion of parameter space in regions I and II (social pooling preferred at federal level) and regions I and III (social pooling preferred at state level). Figures 5 and 6 display the same information for $\bar{d} = 0.1 \text{ and } 0.5$ respectively.

There are several points to note. First, as expected damage costs increase, it becomes (slightly) less likely that social pooling will be preferred if policy is set at the federal level but becomes significantly more likely if policy is set at the state level. Second, social pooling is always more likely to be preferred at the federal level than at the state level. This may reflect the fact that with political discretion the federal government needs to resolve a problem of asymmetric information, which has a welfare cost. Third, a corollary of the previous point is that, particularly for low values of expected damage costs, the region of parameter space (region II), for which social pooling is preferred at the federal but not state level, is much larger than the region of parameter space for which social pooling is preferred at the state but not federal level. Recalling that social pooling, at least in the context of this model, implies harmonisation of environmental policies across countries, this suggests that there could be some justification for resisting harmonisation of environmental policies if they are set at the state level but advocating such harmonisation when such policies are set at the federal level.

5. Conclusions

In the introduction we argued that there may be two reasons why individual states may not implement the kind of first-best environmental policies economists advocate to deal with purely local environmental problems: (i) that imperfect competition generates incentives even for welfare maximising governments to engage in 'ecological dumping'; (ii) that the political process may mean that governments pursues objectives other than maximisation of welfare. The first of these arguments provides a rationale for co-ordination of environmental policies across states, but this need not imply harmonisation of policies; the second of these arguments suggests there may be a need to limit political discretion. In this paper we have brought these two strands together. But in order not to give an obvious justification for either federal government involvement in state environmental issues or for limiting political discretion, we have introduced an important asymmetry of information about damage costs, which become known only to the state government. Thus there is an asymmetry of information between the state and federal governments, which provides a possible justification for leaving policy at the state level, and also an asymmetry of information between governments and voters which restricts the policies voters can mandate elected governments to implement. In particular voters can only mandate governments to implement policies based on *ex ante expected* damage costs, rather than on the actual *ex post* damage costs that become known to elected state governments. In the particular model used here, *ex ante expected* damage costs are the same across states, so when voters tie the hands of governments to implement specified policies this will require harmonisation of policies across states.

Using a very simple model of both imperfect competition and of the political processes by which governments (federal and state) are both elected and influenced by pressure groups we have shown that the usual argument for having environmental policies set at the federal level to overcome the incentives for state governments to engage in 'ecological dumping' goes through, despite the fact that there is an asymmetry of information between state and federal governments, and the fact that governments are subject to political biases. We have also shown that when policy is set at the federal level it is more likely that voters will want to tie the hands of governments, while if policy is set at the state level they are more likely to favour giving politicians discretion to implement policies based on their knowledge of true damage costs. As already noted, in the context of the simple model used here, tying governments hands implies harmonisation of environmental policies across states. Thus the simple model used here suggests that in the face of incentives for ecological dumping it is desirable to co-ordinate environmental policies at the federal level, and when this is done there is also a stronger case for limiting political discretion, which here implies harmonisation of policies. Of course the assumption that countries are identical in terms of *ex ante expected* damage costs is a very special one. However, one would suppose that countries are more similar in terms of *ex ante expected* damage costs than in terms of *ex post* realised damage costs, so the more general claim from this paper would be that when there is 'ecological dumping' there is a strong case for policy to be set at the federal than state level, but there is also a stronger case for limiting political discretion at the federal than at the state level, and this may result in smaller differences in environmental policies in individual states than would be supposed by looking at *ex post* differences in damage costs.

This paper has extended previous literature in linking both strategic and political economy analysis of environment-trade issues, in introducing asymmetries of information between governments at different levels and between governments and voters, and in analysing the case for restricting political discretion when there is more than one government. To do this we have had to use a very simple model, and the next task is to extend the analysis in this paper to a richer framework for analysing 'environmental dumping' (e.g. by allowing for mobile capital), and by providing a more explicit analysis of the political processes involved in both influencing governments and electing governments.

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Fig.1 Welfare At The State Level Under Political Discretion As The Variance In Damage Costs Increase

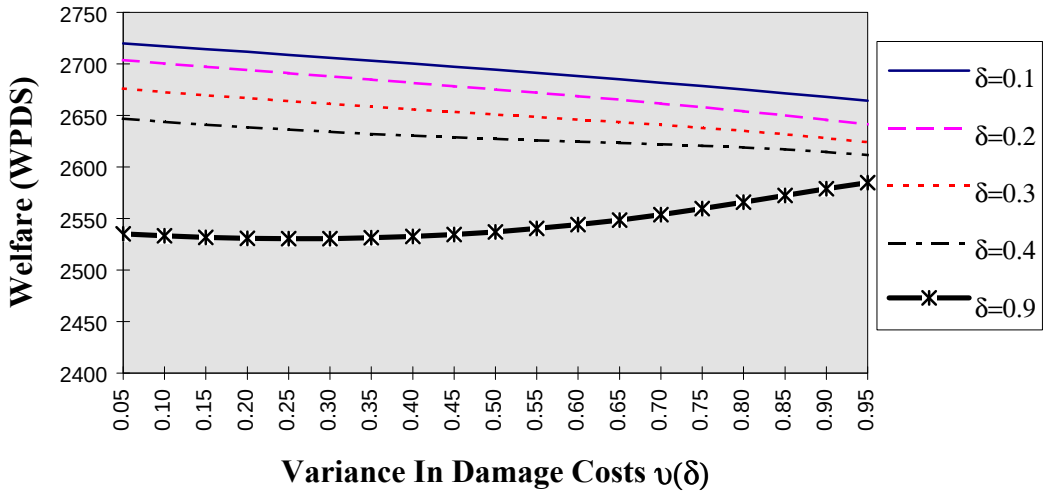

Fig. 2 Welfare At The State Level Under Political Discretion As The Variance In Political Weightings Increase

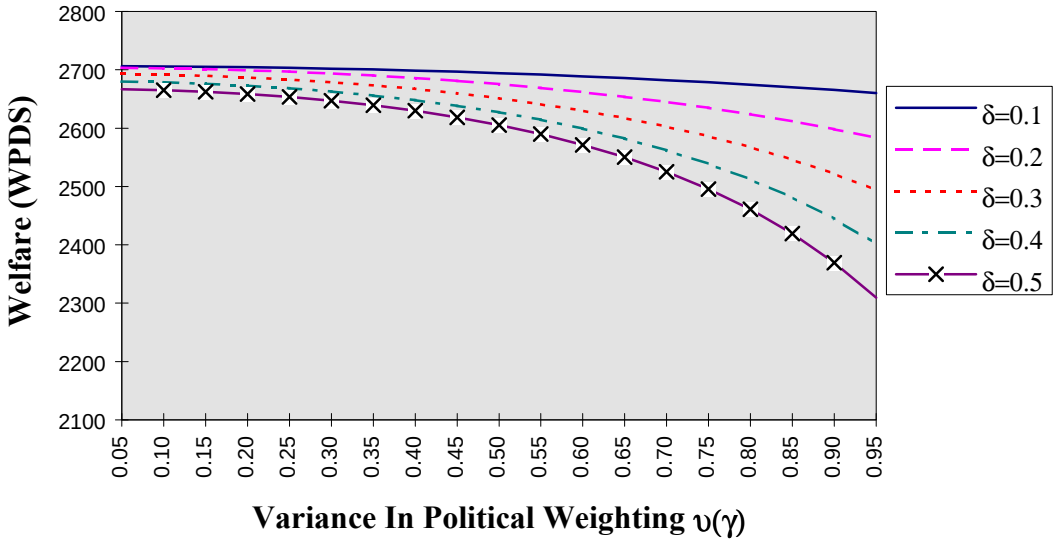

Fig. 3 Welfare At The Federal Level Under Political Discretion As The Variance In Damage Costs Increase

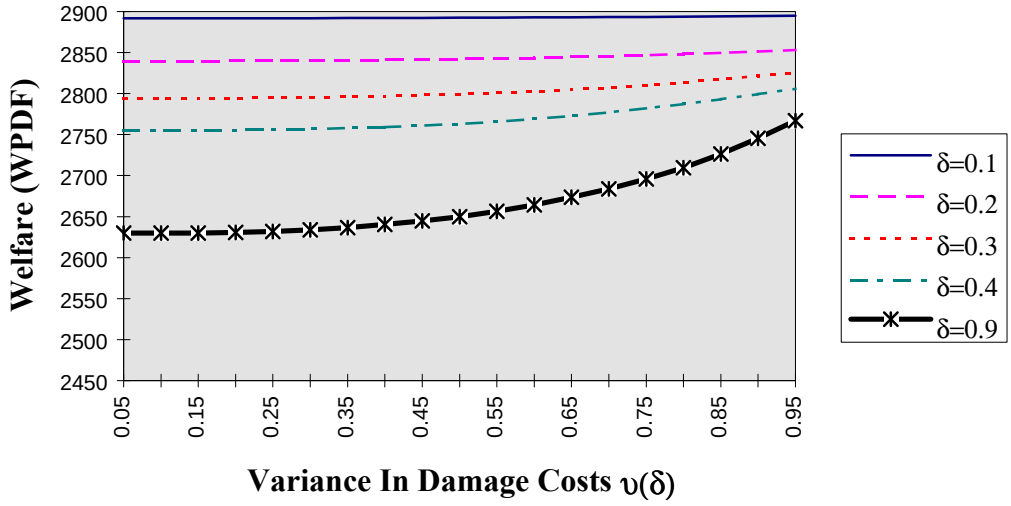

Fig. 4 Welfare At The Federal Level Under Political Discretion As The Variance In Political Weightings Increase

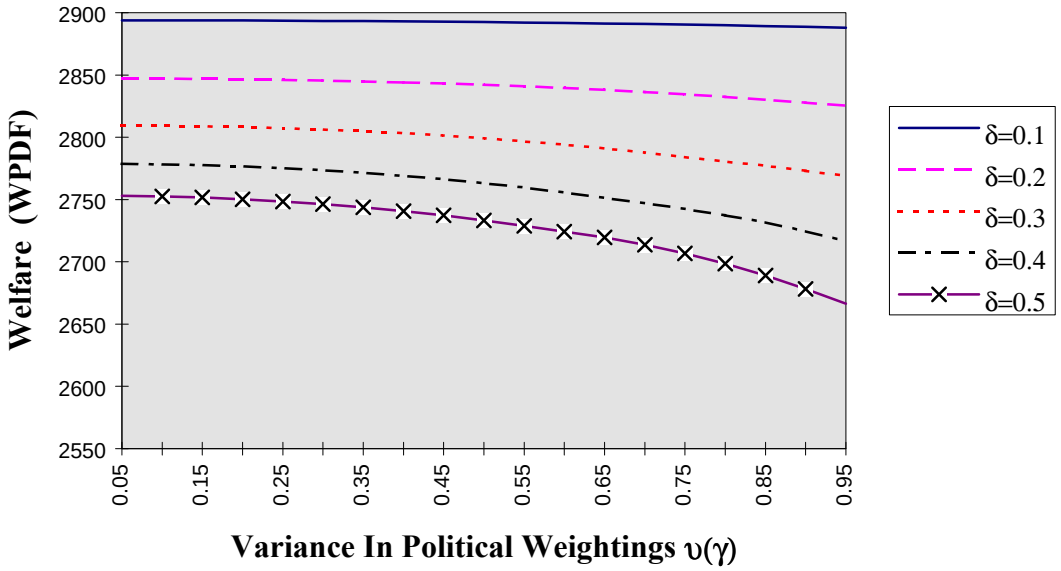

Figure 5. Social Pooling vs. Political Discretion With $\bar{\delta} = 0.1$

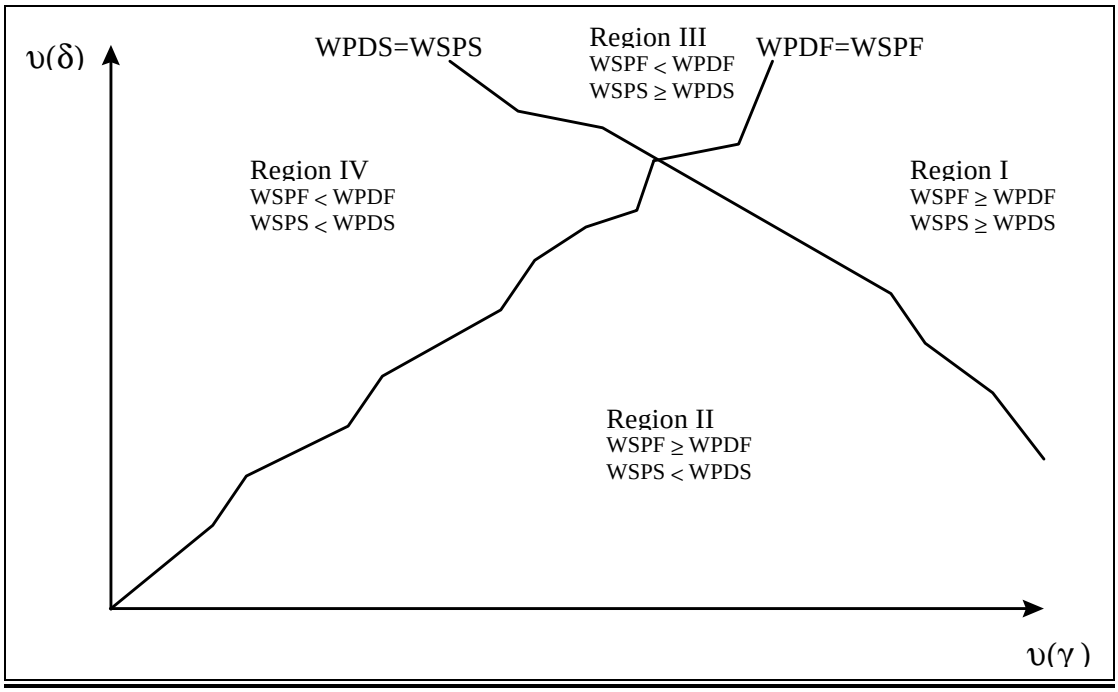

Figure 6. Social Pooling vs. Political Discretion With $\bar{\delta} = 0.5$

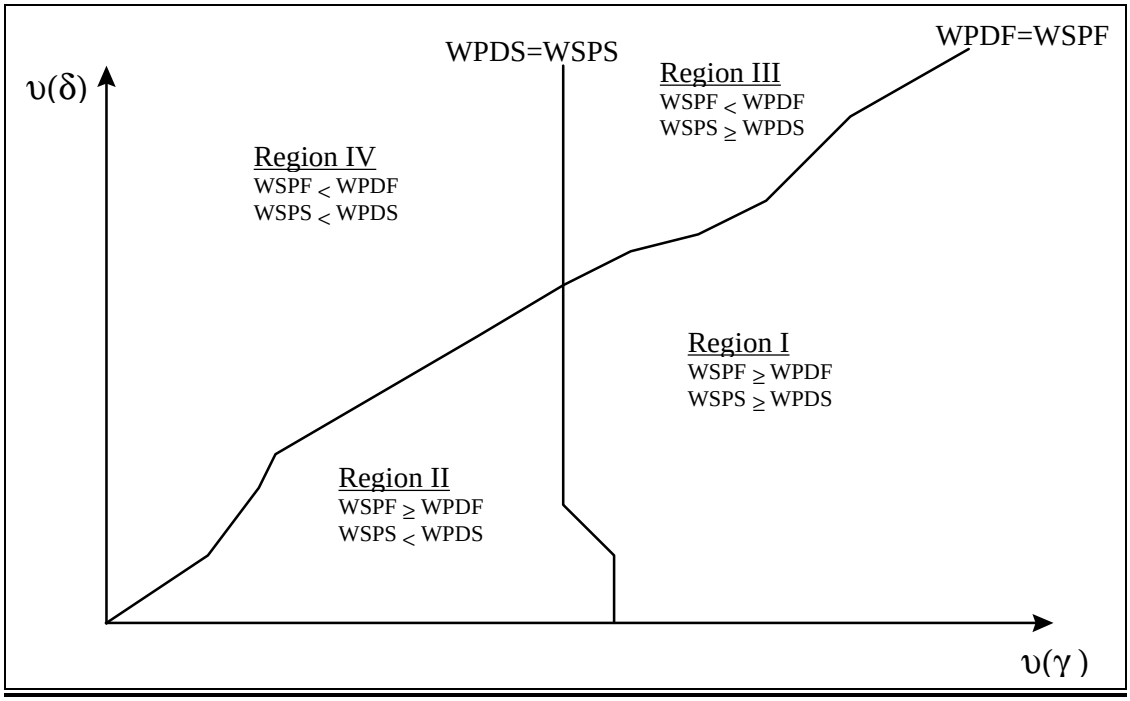

Table 1. Results Summary

σ	$\bar{\delta}$	Region I	Region II	Region III	Region IV	Region I + II	Region I + III
0.3	0.1	16	48	4	32	0.64	0.20
0.3	0.2	31	31	6	32	0.62	0.37
0.3	0.3	37	24	8	32	0.61	0.45
0.3	0.4	41	20	8	31	0.61	0.49
0.3	0.5	43	17	9	31	0.60	0.52