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Laura Marsiliani and Thomas I Renström

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Laura Marsiliani, University of Durham
Thomas I Renström, University of Durham and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Political Institutions, Environmental Policy and Growth*

We analyse the impact of micro-founded political institutions on environmental policy and economic growth. We model an overlapping-generations economy, where individuals differ in preferences over the environment (as well as in age). Labour taxation and capital taxation is used to finance a public good and a public production factor, period by period. The underlying political institution is a parliament. Party entry, parliamentary composition, coalition formation, and bargaining are endogenous. The benchmark is when all decisions are taken in parliament. We compare this constitution with an independent regulator, elected in parliament. The regulatory regime causes lower pollution, but production inefficiency.

JEL Classification: D62, D72, E20, E62, H20, H55, O41 and Q58
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Laura Marsiliani
Department of Economics and Finance
University of Durham
23-26 Old Elvet
Durham DH1 3HY
Tel: (44 191) 334 6363
Fax: (44 191) 334 6341
Email: laura.marsiliani@durham.ac.uk

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Thomas I Renström
Department of Economics and Finance
University of Durham
23-26 Old Elvet
Durham DH1 3HY
Tel: (44 191) 334 6369
Fax: (44 191) 334 6341
Email: t.i.renstrom@durham.ac.uk

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=120183

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1. INTRODUCTION

1.1 Introduction

Policy making regarding public utilities and industries of public interest is nowadays extensively delegated to an "independent regulator", generally a corporate body, independent by the control of the government. Examples of independent regulators are Ofgem (the Office of the Gas and Electricity Markets) and Ofcom (the Office of Telecommunications) in the UK, and the NRC (the Nuclear Regulatory Commission) in the US. The main reasons for establishing independent regulators is to protect the consumers from the effects of imperfect competition and to insulate the policy decision making regarding a sector of public interest from other government objectives, such as revenue raising and redistribution. Most of the independent regulators have decision powers; for example, in the case of natural monopolies, they can decide upon the level of a price or a price cap, while the US NCR can set safety standards to protect public health on agents who use nuclear material or operate nuclear facilities.

In contrast, in environmental policy, pollution targets and therefore the level of pollution taxes and other instruments are exclusively decided by the federal or the local governments (for example, either by the Congress or by individual states in the US, and by the European Commission or by national governments in Europe).

Recent years have seen the establishment of environmental protection agencies like the EPA in the US, the Environment Agency in the UK, and the European Environmental Agency in the EU. They, however, have very little decision power, mostly conducting environmental policing (e.g. ensuring that government standards are met). The agencies can indeed propose environmental policy or advice the government, however, they have no monopoly right to making proposals, so effectively a government is not bound to translate into law any agency proposal. An agency with no decision or proposal power ultimately may have little or no influence regarding environmental policy.

An important issue is whether the role of environmental protection agencies should move beyond the present advisory-policing role. In particular if they should be given more powers in line with a "truly" independent regulator, i.e. the power to decide the level of environmental standards and taxes.

In our paper we wish to address the following questions: Should environmental policy be decided upon by an "independent regulator" for environmental policy or by the government (in Congress or Parliament) together with other policy instruments? And, what are the consequences for environmental policy and economic growth?

1.2 The Literature

More generally, in designing political institutions it is important to have an understanding of the political process, i.e. how policy proposals are made and how individuals would vote.

One way to model the political process is to use the median-voter framework. Within this approach, either one has analysed direct democracies, where individuals vote on a single-dimensional policy variable (e.g. Meltzer and Richard (1981), Persson and Tabellini (1994*a*), and for environmental policy, Eriksson and Persson (2003), McAusland (2003)), or one has analysed "median dictatorships," where the single person who gets most votes implement her preferred policy (e.g. Persson and Tabellini (1994*b*), Renström (1996), and for environmental policy, Marsiliani and Renström (2000), (2004)). The two approaches do not give different predictions if one restricts to one-dimensional policy variables (unless there is a time-inconsistency problem present, Persson and Tabellini (1994*b*)). The latter approach has the advantage that several policy instruments may be analysed, but typically only if individuals differ in one dimension. However, those models are highly stylised in modelling political decision making, and little can be said about constitutional design (other than restricting voting rights).[1] For example, in addressing our question, having independent regulator would not change anything in the median-voter model. In political equilibrium, the elected individual taking the environmental policy decision would be of the same type that takes the decisions on the remaining policy instruments! It is not the median-voter model itself which is "problematic." Rather it is the restriction to agents differing only in one dimension. After all, we should expect such neutrality in a one-dimensional world.

An alternative to the median-voter models is the citizen-candidate model (Besley and Coate (1997), and Osborne and Slivinski (1996)). Also there, there is one individual who gets her ideal point (most preferred policy). Furthermore, when individuals differ in several dimensions, there may be several equilibria, and little can be said about policy. Therefore, many applications of citizen candidate models involve economies with individuals of no more than two types. In the latter case, we should expect neutrality with respect to constitutional design.[2]

Recently a literature has evolved trying to carefully model different political processes, especially trying to handle multidimensional situations. A number of papers have tried to explore this issue, in particular Persson, Roland, and Tabellini (1998), (2000), and Persson and Tabellini (1999). Common to those models is the way in which legislators reach an

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[1] Of course one can investigate other restrictions on government policy making in this class of models. Restrictions on policy may be desirable if there is a time-inconsistency problem. An example is the tax-earmarking restriction proposed in Marsiliani and Renström (2000).

[2] A different approach to elections is to view voters and the government as a principal-agent relationship. Here voters set reservation utilities for re-electing a government. The government is re-elected if it delivers the reservation utility for the majority. This endows the polititian with less freedom than in the citizen-candidate model (if the polititian wishes to be re-elected). See List and Sturm (2004) for application to environmental policy.

agreement: *legislative bargaining* (as in Baron and Ferejohn (1989)). The (randomly) selected legislator makes a take-it-or-leave-it proposal to the others. Characteristic about those models are that a winning policy proposal is some individual's ideal point (i.e. most preferred proposal). This implies that the winning policy is "confiscatory" in the sense that it leaves some individuals with no consumption at all.

Finally, for environmental economics a very popular political-economy model is the lobbying model (see Aidt (1998), Fredriksson (1997), Johal and Ulph (2002)). Within that framework it is not clear how to handle elections. An attempt was done by Besley and Coate (2001). They found while introducing elections, strategic voting neutralised the effect of lobbying. For our question we think elections are important. Because, if there is neutrality with respect to separation of powers, it probably comes from elections. So if we can find non-neutrality, and we still allow for elections (and strategic voting) we have a strong result.

1.3 Our Approach

In order to address our question we should take care of potentially many effects that arise as a consequences of constitutional changes. For example, lifting out the environmental dimension in parliament alters all other policy decisions in parliament. Voters would realise this and vote in such a way that the composition in parliament would be altered. Furthermore, the identity of the regulator cannot be assumed. The way in which the regulator is chosen may affect the equilibrium.

To capture these effects, we introduce a micro-founded political institution (parliament). We also introduce an underlying economy, where individuals make choices over time, and where the second-best tax system is present. We use an overlapping-generations economy where individuals differ in their tax bases (due to differences in age) and in their preferences over the environment. In our economy the policy instruments are: labour, capital and environmental taxes, a public production input and a public good. There will be a conflict of interest when choosing the environmental tax. A higher tax reduces production and less can be spent on private consumption and public consumption. Since individuals value the environment differently they will generally disagree. There will also be a conflict of interest over which tax base to tax more (labour or capital). Since individuals differ along two dimensions (age and preferences) and policy is multidimensional (four dimensions) we will in general not have a Condorcet winning policy quadruple. We overcome this problem by model policy through (micro-founded) parliamentary decision making. We then make a constitutional experiment and investigate the equilibrium under separation of powers (independent regulator).

Our baseline institution is a parliament, which is modelled differently from the existing literature on legislatures (see Persson and Tabellini (2000) and in particular (2004)).[3] We assume that policy proposals can be negotiated upon.[4] We also introduce a further stage in endogenising the composition of the legislature through voting. This is important since the composition of the legislature cannot be invariant with respect to constitutional comparisons. When comparing political systems one cannot assume that the elected representatives are the same under each of the systems. For example, if a certain system allocates more power to some individuals than in another system, then the electorate ought to vote strategically to offset some of this difference. We should therefore expect equivalence of political systems

[3] The common feature of those models is the way in which legislators reach an agreement through *legislative bargaining* (as in Baron and Ferejohn (1989)). A randomly selected legislator makes a take-it-or-leave-it proposal to the others. Characteristic about those models are that a winning policy proposal is some individual's ideal point (i.e. most preferred proposal). This implies that the winning policy is "confiscatory" in the sense that it leaves some individuals with no consumption at all.

[4] Besley and Coate (1998) also use a bargaining model of this kind.

to a larger extent.

We use the model of the parliament to investigate whether environmental policy should be taken by an independent regulator or in the parliament and the consequences for pollution and economic growth. We find, even though the electorate offset the difference to some degree, and a system with an independent regulator gives rise to lower pollution, but at the same time it causes the parliament to adopt a productively inefficient policy, contrary to Diamond and Mirrlees (1971). The reason is not that the voters try to offset the environmental policy (though they do) but the coalition in parliament is trying to do it. Furthermore, if there is population growth (so the pivotal voter is young) then separation of power leads to higher growth. On the other hand if there is population decline, so the pivotal is old, then growth is lower under separation of powers. This is a striking result, since if countries differ in their constitutional arrangements, one can observe tough environmental policy and high economic growth go hand in hand! One should not draw the conclusion that tougher environmental policy causes growth (the relationship is just due to differences in constitutions).

The rest of the paper is structured as follows. In section 2 the overlapping-generations economy is introduced and the economic equilibrium is solved for. Section 3 outlines the constitution, and analyses bargaining, coalition formation, and the political equilibrium under the bench mark constitution. Section 4 introduces an independent regulator and analyses the consequences for the equilibrium in the parliament.

2. THE ECONOMY

Individuals live for two periods, consuming both as young and as old, but work only when young. They have preferences over period-one consumption, period-two consumption, period-one and period-two provision of public goods and period one and two pollution externalities. Individuals within each age group differ in preferences over pollution. For simplicity we assume that they are of two types. In period one individual i born at t supplies one unit of labour (inelastically) on the market and consume c_t^{it} units of the only consumption good.[5] She is paid ω_t per unit of supplied labour and she saves k^{it}_{t+1} for the next period. Let τ_t^l and τ_t^k denote the wage-income tax rate and the capital-income tax rate respectively. It is convenient to define the *after-tax* prices as $\mathrm{P}_t \equiv (1-\tau_t^k)R_t$ and $\omega_t \equiv (1-\tau_t^l)w_t$. In period two she receives after-tax return, P_{t+1}, on her savings all of which is used for consumption c^{it}_{t+1}. Per-capita consumption of the public good (equal for all individuals) is denoted g_t, and pollution is denoted X_t.

2.1 Assumptions

A1 Population

The size of generation t is denoted N_t, and grows (declines) at a constant rate n >(<) 0. Within each generation individuals are endowed with either low taste, θ^l, or high taste, θ^h, for the environment. The fraction of total population endowed with low (=no) taste for the environment (θ^l=0) is denoted γ, and is constant over time. Furthermore, we assume $\beta/(1+\beta) > \theta^h/(1+\theta^h) > \beta\mu(1+\varepsilon)/[(1+\beta)\alpha]$.

A2 Individual Preferences

For analytical tractability the utility function is assumed to be of the form

[5] For the preferences we are going to work with (Cobb-Douglas), nothing changes if labour supply was elastic. The income and substitution effects on labour would cancel, and labour supply would just be a constant (provided the after-tax wage is positive).

$$U^{it}(\,\cdot\,) \;=\; c_t^{it}\left(c_{t+1}^{it}\right)^{\beta}\left(g_t\right)^{\epsilon}\left(g_{t+1}\right)^{\beta\epsilon} e^{-\theta^i (X_t + \beta X_{t-1})} \tag{1}$$

where the parameters β, ε, and θ^i are strictly positive.

A3 Individuals' Constraints

The individual budget constraints are

$$c_t^{it} + k_{t+1}^{it} = \omega_t \tag{2}$$

$$c_{t+1}^{it} = \mathrm{P}_{t+1} k_{t+1}^{it} \tag{3}$$

A4 Production

Production is a function of capital, labour, and pollution (which is taxed by the government), as well as a productivity enhancing factor, Z_t, provided by the government. We assume congestion in this factor so only its per-capita level, $z_t=Z_t/N_t$, augments productivity. This factor eventually produces long-run growth. For simplicity we assume that technology is Cobb-Douglas:

$$Y_t = F(K_t, z_t N_t, z_t X_t) = A K_t^{\alpha} (z_t N_t)^{1-\alpha-\mu} (z_t X_t)^{\mu} \tag{4}$$

A5 Government's Constraint

The tax receipts at time *t* are fully used to fund the public good G_t and the public production factor Z_t

$$G_t + Z_t = Y_t - P_t K_t - \omega_t N_t \tag{5}$$

A6 Parliamentary democracy

I Bench mark constitution

Economic policy at time t (the tax rates (τ_t^l, τ_t^k, τ_t^k) and the public production input, Z_t, and consequently the public goods level) is determined by majority vote in parliament. A proposal may be worked out by one party if in majority, or by negotiations among two or more parties in parliament, if no single party has majority. Only the party with most seats may choose coalition partner(s), and only once. If no proposal is worked out, parliament dissolves and there is no government for one period. Each individual type may constitute a party, and members are only of the same type. Individual citizens vote on parties that participate in the election. Prior to the voting stage parties decide whether to enter (costlessly) or not. The number of seats obtained in parliament is proportional to the number of votes.

II Separation of powers (independent regulator)

As bench mark constitution, except that prior to coalition formation in parliament, a regulator is majority elected in parliament. The regulator takes the decision on the environmental tax prior to the parliamentary coalition works out the policy proposal on the remaining variables.

2.2 Economic Equilibrium

In this section the individual and aggregate economic behaviour are solved for, given any arbitrary sequences of tax rates and public expenditure.

By profit maximisation the before-tax prices (the interest rate and the wage rate) are given by

$$\boldsymbol{R}_t = \alpha y_t(1+n)/k_t \qquad (6) \qquad\qquad w_t = (1-\alpha-\mu)y_t \qquad (7)$$

respectively, and the pollution level is chosen to satisfy

$$\tau_t^x = \mu y_t / x_t \tag{8}$$

where
$$y_t = A z_t^{1-\alpha} \left(\frac{k_t}{1+n} \right)^{\alpha} x_t^{\mu} \tag{9}$$

Maximisation of (1) subject to (2)-(3) gives the individuals' decision rules

$$c_t^{it} = \frac{\omega_t}{1+\beta} \quad (10) \qquad k_{t+1}^{it} = \frac{\beta\,\omega_t}{1+\beta} \quad (11) \qquad c_{t+1}^{it} = \frac{\beta P_{t+1}\,\omega_t}{1+\beta} \quad (12)$$

and indirect utility (up to a multiplicative constant)

$$V_t^{it} = (\omega_t)^{1+\beta} (P_{t+1})^{\beta} (g_t)^{\epsilon} (g_{t+1})^{\beta\epsilon} e^{-\theta^i (X_t + \beta X_{t+1})} \tag{13}$$

An old individual's indirect utility is

$$V_t^{jt-1} = (P_t k_t)(g_t)^{\epsilon} e^{-\theta^j X_t} \tag{14}$$

Finally, the government's budget constraint in per-capita form may be written as

$$g_t \equiv G_t / N_t = \pi_t y_t - z_t \tag{15}$$

where
$$\pi_t \equiv 1 - \alpha(1-\tau_t^k) - (1-\alpha-\mu)(1-\tau_t^l) \tag{16}$$

3 POLITICAL INSTITUTIONS

3.1 Political Rules

We view political institutions as rules under which policy decisions are taken. We now outline two set of rules: The bench-mark constitution (where all policy decisions are taken in parliament) and Separation of Powers (where the environmental tax decision is taken by an independent regulator, and the other policies in the parliament).

The sequence of events under the bench-mark constitution is as follows:

1. Entry of parties (individuals can register parties containing members of their own type only).
2. Electorate vote (each individual casting one vote on a party of her choice), and parties are represented proportionally to the number of votes.
3. Coalition formation in parliament (largest party chooses coalition partner, rationally anticipating the bargaining outcome). Coalition partner can only be chosen once.
4. Bargaining in the coalition takes place (with threat points of parliament dissolving for one period).
5. Policy formed by a majority coalition is implemented.

For separation of powers we modify the sequence of events as follows:

1. Entry of parties.
2. Electorate vote (still proportional representation).
3. Environmental regulator is chosen (through a vote in parliament).
4. Environmental regulator decides on the environmental tax.
5. Coalition formation in parliament.
6. Bargaining in the coalition (over the remaining policy instruments).

7. Policy formed by a majority coalition is implemented.

Once individuals have been elected for parliament, they have to form a group and present a policy proposal supported by more than one half of the elected members. Contrary to the legislative bargaining literature, were a chosen legislator makes a take-it-or-leave-it proposal, we assume that both sides have a say. We model the proposal as a solution to Nash bargaining, with weights proportional to the number of seats. We can view this as each person within the coalition enters with the same weight, and since each person of the same group is the same, this is equivalent to the group getting a weight proportional to the number of seats.[6] A political equilibrium is defined as follows:

(i) Given any voting outcome, and thereby given any composition of parties in parliament, the largest party must find the choice of coalition partner(s) optimal, rationally anticipating the Nash bargaining solution (with weights proportional to the size of the party and threat points equal to the utilities in case of no government) for each possible coalition that contains a majority of members of parliament.

(ii) Given the parties that have chosen to run for election, and rationally anticipating the coalition to form, an individual must find her choice of party to vote for optimal, given everybody else's vote, knowing that she marginally affect the bargaining outcome by marginally changing the size of the parties.[7]

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[6] This can also be rationalised by thinking of an alternating-offer bargaining game, where the person to make an offer is chosen randomly within the coalition, and there is a finite time where the game must end. If one group is larger, the probability that a person from this group is chosen to make an offer is also larger. Then, in equilibrium of this game, the larger group gets a larger "share of the cake." Also, if nobody has accepted an offer before the last round, the person who can make an offer last will make an offer who leaves the opponent at her reservation utility (i.e. the utility if the parliament dissolves). Therefore the threatpoints will matter in a similar way as in the Nash bargaining solution.

[7] An equilibrium to the voting game is a Nash equilibrium.

(iii) Members of a party (that is a group of people of the same type) must find the entry decision (that is run or not to run for election) optimal, given the other three parties entry decisions.[8,9]

(i), (ii), and (iii) must be mutually consistent.

The equilibrium concept tells us how to solve for the political equilibria. First we characterise the bargaining outcome between various parties. Next we examine which coalitions can form. Given each possible coalition we check whether it is consistent with a Nash equilibrium in the voting game, where voters anticipate the coalition to form. Finally we check whether the entry decisions constitute a Nash equilibrium in the entry game.

In the two dimensional model (age and taste heterogeneity) there are two kinds of equilibria (which one occurs depend on the underlying parameter values). One type of equilibrium is when a single party has majority and does not have to form a coalition at all. This happens when the difference in the taste parameter is small so that the model is close to one dimensional (only age heterogeneity becomes relevant). Then if the young (old) are the largest age group, they will also have single majority in parliament. Policy then becomes the ideal point of one individual and effectively collapses to the median-voter model. These equilibria are of less interest for conducting constitutional experiments. We ill instead in this paper focus on the coalition equilibria (when no single party has majority). This involves restrictions on the underlying parameters of the model (see Renström 2002).

[8] An equilibrium to the entry game is a Nash equilibrium.

[9] In explicitly considering an entry stage, we borrow from the citizen-candidate literature (Besley and Coate (1997), Osborne and Slivinski (1996)).

A particular feature of the model is that the only coalitions that can form (consistent with rational voting) is across preferences and across age. We will therefore only examine the bargaining allocations for those coalitions.

A further feature is that the coalitional equilibrium policy is a compromise (on the contract curve between two individuals). The voters of the same types as the coalition partners have a dominant strategy to vote on themselves (to pull the compromise closer the their ideal points). This implies that one of the groups that are not represented in the coalition must, in equilibrium, be indifferent in altering the relative coalition size. We call this group the *pivotal voter*. If the pivotal group was not indifferent, they would vote on their own age group (as everybody else) and the largest age group would have single majority and the coalition would not be formed. It is necessary that one group is indifferent in altering the relative coalition size (and will vote in mixed strategies), i.e. it is necessary that the pivotal voter exist.

We will proceed as follows. First solving for the bargaining allocation as function of the relative bargaining power (relative coalition size). Then finding the relative bargaining power that maximises the utility of the individual group not represented in the coalition (i.e. the pivotal voter). This pins down the equilibrium.

3.2 Bargaining

We will only consider equilibrium coalitions. Those are between young and old, and where young and old differ in their preferences over the environment.

Let the young group have pollution preferences θ^i, and the old θ^j. Let the relative size of the young in the coalition be ρ, and the consequently the old's relative size is $1-\rho$. The default options are specified as the utilities if the parliament is dissolved, and consequently there are no public goods, nor taxes in that period (this gives zero utility for both). The Nash maximand is

$$\Psi(\tau_t^l,\ \tau_t^k,\ z_t,\ (\tau_t^x);\ \boldsymbol{i},\boldsymbol{j},\ \rho) \ = \ \left(V_t^{it}\right)^{\rho}\left(V_t^{jt-1}\right)^{1-\rho} \tag{17}$$

A young individual must realise that the current wage tax will affect the savings, and hence the capital stock in the next period. This will potentially affect the next period's political-equilibrium policies: τ^k_{t+1}, g_{t+1}, and x_{t+1}. We have to treat these as functions of k_{t+1}. We guess those functional forms, then solve the Nash maximand, and lastly verify that the guesses were correct. It turns out that τ^k_{t+1} and x_{t+1} are independent of the future capital stock (and consequently independent of the current wage tax) and that ln g_{t+1} = constant + ln $(1-\tau^l_t)$ + ln y_t. Taking the logarithm of the Nash maximand, substituting away the after tax prices by using (6) and (7), and substituting for g_{t+1}, we may write the problem as

$$\begin{aligned}\max_{\tau_t^l,\,\tau_t^k,\,z_t,\,(\tau_t^x)} \quad & \rho[1+\beta(1+\epsilon)]\ln(1-\tau_t^l) \ + \ (1-\rho)\ln(1-\tau_t^k) \ + \ [1+\rho\beta(1+\epsilon)]\ln y_t \\ & + \ \epsilon \ln \boldsymbol{g}_t \ - \ [\rho\,\theta^{\boldsymbol{i}} + (1-\rho)\theta^{\boldsymbol{j}}]\,N_t x_t\end{aligned} \tag{18}$$

s.t. (8), (9), (15), and (16).

Solving gives:

Proposition 1 *Assume* A1-A6, *and that a group consisting of young i-types form a coalition with a group consisting of old j-types, then the bargaining-solution policy is as follows*

$$1-\tau_t^l \ = \ \frac{1+\beta(1+\epsilon)}{(1+\epsilon)(1-\alpha-\mu)}\,\frac{\rho}{1+\rho\beta}\,(1-\eta) \tag{19}$$

$$1-\tau_t^k \ = \ \frac{1}{\alpha(1+\epsilon)}\,\frac{1-\rho}{1+\rho\beta}\,(1-\eta) \tag{20}$$

$$g_t = \frac{\epsilon}{1+\epsilon}\frac{1-\eta}{1+\rho\beta}y_t \tag{21}$$

$$x_t = \frac{1+\epsilon}{N_t}\frac{1+\rho\beta}{\rho\theta^i + (1-\rho)\theta^j}\frac{1-\frac{1-\mu}{1-\alpha}\eta}{1-\eta} \tag{22}$$

$$z_t = \eta\, y_t \tag{23}$$

If all policy instruments are decided upon in the coalition then

$$\eta = 1-\alpha \tag{24}$$

otherwise η *is a function of the pollution tax as follows*

$$[\mu^\alpha A]^{1/(\alpha-\mu)}\eta^{(1-\alpha)/(\alpha-\mu)}\left(\frac{k_t/\tau_t^x}{1+n}\right)^{\alpha/(\alpha-\mu)} = \frac{1+\epsilon}{N_t}\frac{1+\rho\beta}{\rho\theta^i + (1-\rho)\theta^j}\frac{1-\frac{1-\mu}{1-\alpha}\eta}{1-\eta} \tag{25}$$

Proof: See Appendix A.

The solution gives linear sharing rules (after tax incomes are linear fractions of GDP). This is intuitive because of the Cobb-Douglas utility specification. The share depends on the relative weight a group carries in the bargaining. Equations (19) and (20) give the tax rates applied to the two generations. It is rather obvious that the larger the young are in relation to the old (i.e. the larger ρ) the lower will the labour tax be. The opposite for the capital tax. The provision of z_t, in the bench-mark constitution is according to the production-efficiency level (a constant 1-α of GDP). This is not surprising since Diamond-Mirrlees (1971) production efficiency holds in the second best. However, when the environmental tax cannot be set in the coalition, there is a potential deviation from production efficiency. The reason is that the coalition is deprived of one instrument (i.e. the pollution tax). It will turn out that there will be production inefficiency under separation of powers. The reason is that the regulator uses the pollution tax to reduce pollution in excess of what the coalition would have done. The coalition uses z_t to partially undo this. Furthermore, the pivotal voter will try to partially unto this effect (but not totally) by voting strategically.

3.3 Pivotal Voter

We will now identify the pivotal voter, i.e. the group outside the coalition that is indifferent (in equilibrium) in altering the relative coalition size. This group is picking their most preferred point on the contract curve between the two coalition partners. If a pivotal voter did not exist, it would imply that agents vote on their own age group, and the largest age group would have majority without forming the coalition. Thus, the pivotal voter is necessary for a coalitional equilibrium.

Proposition 2 *Assume* A1-A6, *and that a group consisting of young i-types form a coalition with a group consisting of old j-types, then individuals with low preference for the environment that are not included in the coalition, vote for the individual in the coalition of their own age group.*

The pivotal voter is young (old) with high preference for the environment if i-types have low (high) preference, and j-types high (low) preference.

Proof: See Appendix A.

If preferences over the environment are distant enough (according to the condition in Assumption 1) then we have a situation where the young (or old) outside the coalition may or may not favour their own age group in the coalition. For example if θ^h is sufficiently larger than θ^l, then there is an ideal relative coalition size (between young θ^l and old θ^h) preferred by the young θ^h outside the coalition (i.e. the pivotal voter). Thus, if such a coalition were to form the young θ^h have no incentive to try to maximise the size of the young θ^l or of the old θ^h. In fact, there is a relative coalition size which makes the outside group indifferent in altering the relative powers of the partners inside the coalition. Similarly, there is an ideal relative coalition size (between young θ^h and old θ^l) preferred by the old θ^h (pivotal) outside the coalition.

If θ^h and θ^l are too close (Assumption 1 prevents this), then any individual outside the coalition will prefer to increase the size of their own age group. The political equilibrium then reduces to a median-voter equilibrium, with the largest age group dictating policy (and consequently confiscating from the minority age group). This is plausible since when one dimension of heterogeneity disappears (θ), there is only one dimension left (age), and with one dimensional heterogeneity, logically, the model should collapse to a median-voter model.

3.4 Coalition Equilibrium

Proposition 3 *Assume* A1-A6, *and that population growth is positive. Then the coalitional equilibrium is characterised by a coalition of young* θ^l *and old* θ^h.

Three parties enter: *young* θ^l, *young* θ^h, *and old* θ^h. *All old individuals vote for old* θ^h. *The pivotal voter is young with* θ^h *and vote in mixed strategies on the three parties, being indifferent altering the relative coalition size*.

Proof: Suppose there was a coalition across age groups but with same environmental preferences. Then all agents have an incentive to vote on their own age group. Then the young θ^i would have majority and the coalition would not form, which is a contradiction. The same argument hold for coalitions within age groups. Finally consider the mirror image of the coalition above: old θ^l and young θ^h. Then by proposition 2 the pivotal voter is old, implying that all young vote young θ^h. But then the young θ^h obtain majority without forming the coalition. The coalition above is the only one consistent with rational voting when n>0.

QED

Proposition 4 *Assume* A1-A6, *and that population growth is negative. Then the coalitional equilibrium is characterised by a coalition of young* θ^h *and old* θ^l.

Three parties enter: *old* θ^l, *old* θ^h, *and young* θ^h. *All young individuals vote for young* θ^h. *The pivotal voter is old with* θ^h *and vote in mixed strategies on the three parties, being indifferent altering the relative coalition size.*

Proof: See proof of Proposition 3.

The main intuition for the equilibria above is as follows. If population growth is positive the young are in majority (by age). There is then a possibility that the old will get their income confiscated. By entering as one party (as old θ^h), all old votes are concentrated on one party. Whenever there is a possibility that young θ^l can enter in a coalition with the old, they are better off running separately, and splitting the votes of the young. This, at the same time, makes a single young party not in majority. The same holds the other way around when population declines.

4 COMPARATIVE POLITICS

4.1 Election of regulator and regulator's behaviour

Proposition 5 *Assume* A1-A6. *If population growth is positive (negative), then the majority elected (in parliament) regulator is young (old) with high preferences for the environment, that is, of the same type as the pivotal voter.*

Proof: The regulator coincides with the median in parliament.

Proposition 6 *Assume* A1-A6. *For a given coalition and a given coalition size, an old regulator implements lower pollution level, and as a result the coalition provides more of the public production factor.*

Proof: See Appendix B.

The intuition is that an old individual cares more for the environment than a young. The reason is that a young wishes to transfer consumption possibilities to the next period. By polluting a bit more, there is more production which can be saved for the next period.

When an old individual seeks to implement less pollution (by increasing the environmental tax) the coalition counteracts, by trying to increase pollution again. This is done by providing more of the public production factor which is a complement to pollution.

4.2 Behaviour of the coalition

Proposition 7 *Assume* A1-A6. *An independent regulator causes, through the counteracting behaviour of the coalition, a higher level of the public production factor than is prescribed by production efficiency (whether or not the pivotal voter counteracts).*

Proof: See Appendix B.

A regulator (regardless if young or old) cares more about the environment than the "coalition preferences." When the regulator increases the environmental tax, the coalition provides the public production factor at a level higher than productively efficient.

4.3 Behaviour of voters

Proposition 8 *Assume* A1-A6. *Under separation of powers (independent regulator) a young pivotal voter provides a larger fraction of votes for the young (low* θ*) than under the bench-mark constitution. An old pivotal voter provides a larger fraction of votes for the old (low* θ*) than under the bench mark.*

Proof: See Appendix B.

This result implies that a pivotal voter counteracts by changing her vote fractions. The pivotal provides more votes to the less environmentally friendly. This is in order to offset the attempt by the regulator to legislate a tougher environmental policy. This shows that the composition in the parliament are different under different constitutions.

If one tries to design a constitution, giving more power to certain groups, this may be (at least partially) offset by strategic voting.

Proposition 9 *Assume* A1-A6. *Under separation of powers (independent regulator) pollution is at a lower level than under the bench-mark constitution.*

Proof: See Appendix B.

This result implies that the pivotal voter only partially offset the environmental regulator's attempt to reduce pollution. Separation of powers reduces pollution, but at the cost of production inefficiency.

Proposition 10 *Assume* A1-A6. *If population growth is positive, so that the young is pivotal, then GDP growth is greater under separation of powers (independent regulator) than under the bench-mark constitution. If population growth is negative, so that the old is pivotal, then GDP growth is lower under separation of powers (independent regulator) than under the bench-mark constitution.*

Proof: See Appendix B.

Economic growth is affected by the constitutions in various ways. First, any constitution giving greater power to the young (higher ρ) reduces the wage tax and increases the savings (and thereby the growth rate). This happens when young are pivotal and we go to separation of powers. However, separation of powers implies less pollution, and therefore less production and less savings. Next, an increase in the public production factor above $1-\alpha$ is not productively efficient. However, the overall effect is to increase growth, as Proposition 10 says. When old are pivotal, separation of powers will reduce the power of the young so the savings effect via the tax on the young works the other way, so growth is lower.

5. CONCLUSIONS

The paper develops a political-economy model to analyse whether decisions upon environmental policy should be taken by a parliament or an independent regulator.

The underlying economy is an overlapping-generations economy, where individuals differ in preferences over the environment (as well as in age). Labour taxation, capital taxation, and pollution taxation is used to finance public goods provision, period by period, as well as a public production factor. Economic growth is generated by the public production factor.

As a contribution to the literature, we have carefully modelled a political system (parliament) and underlined the consequences for growth in addition to pollution of changing constitutions. The legislature is modelled as a parliament. Individuals may form parties, and the electorate vote on the parties that have decided to run for election. The number of seats obtained by a party in parliament is proportional to the number of votes it gets. Given the election result parties form coalitions to bargain over policy proposals. The implemented proposal is the one getting more than half of the votes in parliament.

We have compared two constitutions: (I) a bench-mark case where all policy decisions (including environmental) are taken in parliament, (II) a case of separation of powers, where the parliament elects a regulator, who in turn sets environmental policy independently. To summarise, we found the following main results:

Table 1 - Pollution and growth effects in relation to bench-mark constitution

	separation of powers	
	pollution	growth
pop. growth > 0	lower	higher
pop. growth < 0	lower	lower

We found that a system with an independent regulator gives rise to lower pollution, but at the same time it causes the parliament to adopt a productively inefficient policy. The reason is not that the voters try to offset the environmental policy (though they do) but the coalition in parliament is trying to do it. Furthermore, if there is population growth (so the pivotal voter is young) then separation of power leads to higher growth. On the other hand if there is population decline, so that the pivotal is old, then growth is lower under separation of powers. This is a striking result, since if countries differ in their constitutional arrangements, one can observe tough environmental policy and high economic growth go hand in hand! One should not draw the conclusion that tougher environmental policy causes growth (the relationship is just due to differences in constitutions).

One can think of alternative constitutional arrangements.[10] One when the regulator is appointed by the largest party in parliament (i.e. by the government). The largest party has an incentive to appoint someone of the same type as themselves. Therefore, the regulator would be of the opposite age group as the pivotal voter (instead of the same type as the pivotal voter as was the case in our paper). This will expectedly lead to a greater conflict between the pivotal voter and the regulator, which may lead the pivotal voter to counteract, through strategic voting, even more than was the case in our paper. Another constitutional arrangement is when the voters elect the regulator. We may need further parametric restrictions on the model to ensure that there is a Condorcet winner in choosing the regulator. The reason is that there are four groups in the electorate, differing in two dimensions. We leave this for future work.

[10] A recent literature (see Besley and Coate, 2003, for a review) claims that there is indeed a difference in the policy outcomes depending on whether the regulator is appointed or elected by voters. They suggest that elected regulators tend to be more consumer-oriented, while the appointed ones seem to be more prone to regulatory capture. Their theory is supported by empirical evidence for the US electricity industry (Besley and Coate, 2000).

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APPENDIX A

Proof of Proposition 1

The first-order conditions are

$$\frac{\partial \ln \Psi}{\partial \tau_t^l} = -\rho \frac{1+\beta(1+\epsilon)}{1-\tau_t^l} + \frac{\epsilon}{g_t}(1-\alpha-\mu)y_t = 0 \tag{A.1}$$

$$\frac{\partial \ln \Psi}{\partial \tau_t^k} = -\frac{1-\rho}{1-\tau_t^k} + \frac{\epsilon}{g_t}\alpha y_t = 0 \tag{A.2}$$

Inserting those into (16) and substituting into (15) gives

$$g_t = \frac{\epsilon}{1+\epsilon}\frac{y_t - z_t}{1+\rho\beta} \tag{A.3}$$

When all decisions are taken in the legislature we optimise with respect to z_t and x_t as well (this is equivalent to optimising with respect to z_t and τ^x_t).

$$\frac{\partial \ln \Psi}{\partial z_t} = [1+\rho\beta(1+\epsilon)]\frac{1-\alpha}{z_t} + \frac{\epsilon}{g_t}\left(\pi_t(1-\alpha)\frac{y_t}{z_t} - 1\right) = 0 \tag{A.4}$$

Using (15) to substitute away $\pi_t y_t$ gives

$$z_t = \frac{1+\epsilon}{\epsilon}\frac{1-\alpha}{\alpha}[1+\rho\beta(1+\epsilon)]g_t \tag{A.5}$$

Substituting for g_t by using (A.3) gives

$$z_t = (1-\alpha)y_t \tag{A.6}$$

Substituting this into (A.3) gives (21) when η=1-α. Next

$$\frac{\partial \ln \Psi}{\partial x_t} = [1+\rho\beta(1+\epsilon)]\frac{\mu}{x_t} + \frac{\epsilon}{g_t}\pi_t\mu\frac{y_t}{x_t} - [\rho\theta^i + (1-\rho)\theta^j]N_t = 0 \tag{A.7}$$

by using (15) to substitute away $\pi_t y_t$ we obtain

$$\frac{\partial \ln \Psi}{\partial x_t} = (1+\rho\beta)(1+\epsilon)\frac{\mu}{x_t} + \epsilon\frac{\mu}{x_t}\frac{z_t}{g_t} - [\rho\theta^i + (1-\rho)\theta^j]N_t = 0 \tag{A.8}$$

Use (A.5) to substitute for z_t/g_t then (22) is obtained for η=1-α. Finally using (21) in (A1) and

(A2) gives (19) and (20) for η=1-α.

When τ^x_t is taken as given (i.e. when it is chosen by an independent regulator) then z_t and x_t cannot be independently chosen in the legislature. We proceed as follows. Pollution's marginal product is equal to the environmental tax

$$\tau_t^x = \mu A z_t^{1-\alpha}\left(\frac{k_t}{1+n}\right)^{\alpha} x_t^{\mu-1} \tag{A.9}$$

Use (8) to substitute for x_t and rearrange to obtain

$$y_t = \mu^{\mu/(1-\mu)} A^{1/(1-\mu)} z_t^{(1-\alpha)/(1-\mu)}\left(\frac{k_t}{1+n}\right)^{\alpha/(1-\mu)} (\tau_t^x)^{\mu/(\mu-1)} \tag{A.10}$$

Using (A.3) and (8) the relevant part of the Nash maximand becomes

$$\max_{z_t} \; [1+\rho\beta(1+\epsilon)]\ln y_t + \epsilon\ln(y_t - z_t) - [\rho\theta^i + (1-\rho)\theta^j] N_t \mu y_t/\tau_t^x \tag{A.11}$$

s.t. (A.10)

The first-order condition

$$\left[1+\rho\beta(1+\epsilon) + \epsilon\frac{y_t}{y_t - z_t} - [\rho\theta^i + (1-\rho)\theta^j] N_t x_t\right]\frac{1}{y_t}\frac{\partial y_t}{\partial z_t}\bigg|_{\tau_t^x} - \frac{\epsilon}{y_t - z_t} = 0 \tag{A.12}$$

By defining $\eta = z_t/y_t$ and taking the derivative of (A.10) we have

$$1+\rho\beta(1+\epsilon) + \frac{\epsilon}{1-\eta} - [\rho\theta^i + (1-\rho)\theta^j] N_t x_t - \epsilon\frac{1-\mu}{1-\alpha}\frac{\eta}{1-\eta} = 0 \tag{A.13}$$

Rearranging gives (22).

Finally, use $\eta = z_t/y_t$ in (A.10) to obtain

$$y_t = \mu^{\mu/(\alpha-\mu)} A^{1/(\alpha-\mu)} \eta^{(1-\alpha)/(\alpha-\mu)}\left(\frac{k_t}{1+n}\right)^{\alpha/(\alpha-\mu)} (\tau_t^x)^{\mu/(\mu-\alpha)} \tag{A.14}$$

Next, by (8) we have $x_t = \mu y_t/\tau^x_t$ and by using (A.14) we obtain x_t as a function of τ^x_t. Inserting this into (22) gives (25). QED

APPENDIX B

Preliminaries

We first derive indirect utilities as functions of the relative bargaining powers and potentially choice of η. Substitute $z_t=\eta y_t$ into equation (9) and rearrange to obtain

$$y_t = A^{1/\alpha}\eta^{(1-\alpha)/\alpha}\frac{k_t}{1+n}x_t^{\mu/\alpha} \tag{B.1}$$

The indirect utility (excluding constants) of a young individual is

$$\begin{aligned}
\ln V^{yt} &= (1+\beta)\ln\omega_t + \epsilon\ln g_t + \beta\epsilon\ln g_{t+1} - \theta^y N_t x_t \\
&= [1+\beta(1+\epsilon)]\ln\omega_t + \epsilon\ln(g_t/y_t) + \epsilon\ln y_t - \theta^y N_t x_t \\
&= [1+\beta(1+\epsilon)]\ln(1-\tau_t^l) + (1+\beta)(1+\epsilon)\ln y_t + \epsilon\ln(g_t/y_t) - \theta^y N_t x_t \\
&= [1+\beta(1+\epsilon)]\ln\left(\frac{\rho(1-\eta)}{1+\rho\beta}\right) + (1+\beta)(1+\epsilon)\ln y_t + \epsilon\ln\left(\frac{1-\eta}{1+\rho\beta}\right) - \theta^y N_t x_t \\
&= [1+\beta(1+\epsilon)]\ln\left(\frac{\rho}{1+\rho\beta}\right) + (1+\beta)(1+\epsilon)\left[\ln(1-\eta) + \frac{1-\alpha}{\alpha}\ln\eta + \frac{\mu}{\alpha}\ln x_t\right] - \theta^y N_t x_t
\end{aligned} \tag{B2}$$

where the second line follows from ln g_{t+1} = constants + ln y_{t+1} = constants + ln k_{t+1} = constants + ln ω_t, the third line from the definition of ω_t, the fourth line from the equations for 1-τ^l_t and g_t/y_t, and the last line by using (B.1).

Similarly, the indirect utility (excluding constants) of an old individual is

$$\begin{aligned}
\ln V^{ot-1} &= \ln(P_t k_t) + \epsilon\ln g_t - \theta^o N_t x_t \\
&= \ln(1-\tau_t^k) + (1+\epsilon)\ln y_t + \epsilon\ln(g_t/y_t) - \theta^o N_t x_t \\
&= \ln\left(\frac{1-\rho}{1+\rho\beta}\right) + (1+\epsilon)\left[\ln(1-\eta) + \frac{1-\alpha}{\alpha}\ln\eta + \frac{\mu}{\alpha}\ln x_t\right] - \theta^o N_t x_t
\end{aligned} \tag{B.3}$$

Proof of Proposition 2

Under the bench-mark constitution η=1-α and is constant. Differentiating (B.2) with respect to ρ gives

$$(1+\rho\beta)\frac{\partial \ln V^{yt}}{\partial \rho} = \frac{1+\beta(1+\epsilon)}{\rho} + \left[(1+\beta)(1+\epsilon)\frac{\mu}{\alpha} - \theta^y N_t x_t\right]\frac{(1+\beta)\theta^j - \theta^i}{\rho\theta^i + (1-\rho)\theta^j} \tag{B.4}$$

and similarly for an old individual (equation (B.3))

$$(1+\rho\beta)\frac{\partial \ln V^{ot-1}}{\partial \rho} = -\frac{1+\beta}{1-\rho} + \left[(1+\epsilon)\frac{\mu}{\alpha} - \theta^o N_t x_t\right]\frac{(1+\beta)\theta^j - \theta^i}{\rho\theta^i + (1-\rho)\theta^j} \tag{B.5}$$

Using (22) and evaluating (B.4) at $\theta^i=\theta^h$, $\theta^y=\theta^j=0$ shows that the first-order variation is positive. Young individuals with low preferences for the environment have a dominant strategy to increase the size of the young with high preferences for the environment. Evaluating at $\theta^y=\theta^h=\theta^j$, $\theta^i=0$ shows that there is an interior solution. In particular, as $\rho=0$ marginal utility is plus infinite, and as $\rho=1$ marginal utility is minus infinite.

Similarly, evaluating (B.5), and using (22), at $\theta^j=\theta^h$, $\theta^o=\theta^i=0$ shows that the first-order variation is negative. Old individuals with low preferences for the environment have a dominant strategy to increase the size of the old with high preferences for the environment. Evaluating at $\theta^o=\theta^h=\theta^i$, $\theta^j=0$ shows that there is an interior solution. In particular, as $\rho=0$ marginal utility is plus infinite, and as $\rho=1$ marginal utility is minus infinite. QED

Proof of Proposition 6

In characterising the preferences of an environmental regulator, we can use (B.2) and (B.3). The regulator takes the parliamentary composition as given (i.e. takes ρ as fixed). Instead of maximising with respect to the environmental tax we can use the relation (25) and maximise with respect to η instead.

$$\frac{\partial \ln V^{yt}}{\partial \eta} = (1+\beta)(1+\epsilon)\frac{1-\alpha-\eta}{(1-\eta)\eta\alpha} + \left[(1+\beta)(1+\epsilon)\frac{\mu}{\alpha} - \theta^y N_t x_t\right]\frac{1}{x_t}\frac{\partial x_t}{\partial \eta} \tag{B.6}$$

Substituting for the derivative of (22) with respect to η gives

$$(1-\eta)\frac{\partial \ln V^{yt}}{\partial \eta} = (1+\beta)(1+\epsilon)\frac{1-\alpha-\eta}{\eta\alpha} - \left[(1+\beta)(1+\epsilon)\frac{\mu}{\alpha} - \theta^y N_t x_t\right]\frac{\alpha-\mu}{1-\alpha-(1-\mu)\eta} \tag{B.7}$$

This gives η as a function of ρ. Taking the derivative of the first-order condition with respect to ρ gives us the sign of the derivative of η with respect to ρ (because the derivative of the first-order condition with respect to η is negative by the second-order condition). Notice that

ρ enters only through x_t. By (22) we see that x_t is increasing in ρ (decreasing) if $(1+\beta)\theta^j >$ (<) θ^i. Consequently we have

$$sign\left(\frac{\partial\eta}{\partial\rho}\right) = sign\left((1+\beta)\theta^j - \theta^i\right) \tag{B.8}$$

Notice that this also holds if there is an old environmental regulator in office. The first-order condition is the same as (B.7) except for the $1+\beta$ terms. In particular

$$(1-\eta)\frac{\partial \ln V^{ot-1}}{\partial\eta} = (1+\epsilon)\frac{1-\alpha-\eta}{\eta\,\alpha} - \left[(1+\epsilon)\frac{\mu}{\alpha} - \theta^o N_t x_t\right]\frac{\alpha-\mu}{1-\alpha-(1-\mu)\eta} \tag{B.9}$$

The first-order conditions would look the same if $\theta^y=(1+\beta)\theta^o>\theta^o$. This means that an old regulator (everything else equal) would implement a higher η. By inspection of (22) there is a negative relationship between x_t and η. Consequently, everything else equal, an old regulator implements stricter environmental policy. QED

Proof of Proposition 7

In characterising the preferences of a pivotal voter, we can use (B.2) and (B.3). When the regulator is of the same type as the pivotal voter we can use the envelope condition. In the total derivative

$$\frac{d\ln V^{yt}}{d\rho} = \frac{\partial \ln V^{yt}}{\partial\rho} + \frac{\partial \ln V^{yt}}{\partial\eta}\frac{d\eta}{d\rho} \tag{B.10}$$

we can ignore the partial with respect to η. Thus we have the same derivatives as in (B.4) and (B.5). A young individual is pivotal when $\theta^y=\theta^j=\theta^h$, $\theta^i=0$. Then (B.4) implies that the term in square brackets is negative. This is the same term as in the square brackets in (B.7). For (B.7) to be zero, the very first term must be negative. Therefore $\eta>1-\alpha$, so the environmental regulator induces the coalition to oversupply the public production factor.

Similarly, an old individual is pivotal when $\theta^o=\theta^i=\theta^h$, $\theta^j=0$. Then (B.5) implies that the term in square brackets is negative. This is the same term as in the square brackets in (B.9). For (B.9) to be zero, the very first term must be negative. Therefore $\eta>1-\alpha$, so also an old environmental regulator induces the coalition to oversupply the public production factor. Notice that this conclusion holds regardless if the pivotal voter tries to counteract a higher η or not. QED

Proof of Proposition 8

We will now prove the results on the pivotal voter's strategic behaviour. Equations (B.4) and (B.5) give the pivotal's (young and old, respectively) voting behaviour as a function of η. Since this is a first-order condition, taking the derivative with respect to η gives the sign of the derivative of ρ with respect to η. Notice that η enters only through x_t (which is decreasing in η, for given ρ). The term $-N_t\theta x_t$ is multiplied by $(1+\beta)\theta^j - \theta^i$. Consequently the first-order variations are increasing in η if $(1+\beta)\theta^j - \theta^i > 0$, that is

$$sign\left(\frac{\partial\rho}{\partial\eta}\right) = sign\left((1+\beta)\theta^j - \theta^i\right) \tag{B.11}$$

A young individual is pivotal when $\theta^y=\theta^j=\theta^h$, $\theta^i=0$, then ρ is larger for larger η. When it is known that the regulator is setting the environmental tax (and thereby inducing the coalition to choose a larger η) the pivotal voter chooses to devote a larger fraction of votes to the young individuals with no preference for the environment, thus counteracting.

Similarly, an old individual is pivotal when $\theta^o=\theta^i=\theta^h$, $\theta^j=0$, then ρ is smaller for larger η. When it is known that the regulator is setting the environmental tax (and thereby inducing the coalition to choose a larger η) the pivotal voter chooses to devote a larger fraction of votes to the old individuals with no preference for the environment, thus counteractingQED

Proof of Proposition 9

The total effect on pollution is found as follows. Equations (B.4) and (B.5) give total pollution as a function of ρ only. Equation (B.4), when $\theta^y=\theta^j=\theta^h$, $\theta^i=0$, gives $\partial x_t/\partial\rho < 0$. Since ρ is higher (than under the bench-mark constitution) pollution is lower. This implies that the young pivotal only partially counteracts, so equilibrium pollution is lower under separation of powers. Next, equation (B.5), when $\theta^o=\theta^i=\theta^h$, $\theta^j=0$, gives $\partial x_t/\partial\rho > 0$. Since ρ is lower (than under the bench-mark constitution) pollution is lower. This implies that the old pivotal only partially counteracts, so equilibrium pollution is lower under separation of powers. QED

Proof of Proposition 10

Combining B.4 and B.7 to substitute for the term in square brackets, and doing the same with B.5 and B.9 gives eta as function of rho, for young and old pivotal respectively:

$$\left(1-\frac{1-\alpha}{\eta}\right)(1-\alpha-(1-\mu)\eta) \;=\; \alpha\,\frac{\alpha-\mu}{1+\epsilon}\,\frac{1+\beta(1+\epsilon)}{(1+\beta)^2}\,\frac{1-\rho}{\rho} \tag{B.12}$$

$$\left(1-\frac{1-\alpha}{\eta}\right)(1-\alpha-(1-\mu)\eta) \;=\; \alpha\,\frac{\alpha-\mu}{1+\epsilon}(1+\beta)\frac{\rho}{1-\rho} \tag{B.13}$$

Differentiating gives

$$\frac{d\eta}{d\rho} \;=\; \alpha\,\frac{\alpha-\mu}{1+\epsilon}\,\frac{1+\beta(1+\epsilon)}{(1+\beta)^2}\,\frac{(\eta/\rho)^2}{1-\alpha-(1-\mu)\eta^2} \tag{B.14}$$

and

$$\frac{d\eta}{d\rho} \;=\; \alpha\,\frac{\alpha-\mu}{1+\epsilon}(1+\beta)\frac{(\eta/(1-\rho))^2}{1-\alpha-(1-\mu)\eta^2} \tag{B.15}$$

respectively. Substitute (11) lagged one period into (B.1), use the definition of ω, then

$$\frac{y_t}{y_{t-1}} \;=\; \frac{A}{1+n}\,\frac{\beta}{1+\beta}(1-\alpha-\mu)(1-\tau^l_{t-1})\eta^{(1-\alpha)/\alpha}x_t^{\mu/\alpha} \tag{B.16}$$

Take logs and use (19)

$$\ln(y_t/y_{t-1}) \;=\; \ln\left(\frac{\rho}{1+\rho\beta}\right) \;+\; \ln(1-\eta) \;+\; \frac{1-\alpha}{\alpha}\ln\eta \;+\; \frac{\mu}{\alpha}\ln x_t \tag{B.17}$$

or by using (22)

$$\ln(y_t/y_{t-1}) \;=\; \ln\rho \;-\; \ln\left(\rho\,\theta^i+(1-\rho)\theta^j\right) \;+\; \ln\left(1-\frac{1-\mu}{1-\alpha}\eta\right) \;+\; \frac{1-\alpha}{\alpha}\ln\eta \;+\; \frac{\mu-\alpha}{\alpha}\ln x_t \tag{B.18}$$

The derivative is

$$\frac{d\ln(y_t/y_{t-1})}{d\rho} = \frac{\theta^j}{\rho(\rho\theta^i+(1-\rho)\theta^j)} + \frac{\mu-\alpha}{\alpha}\frac{1}{x_t}\frac{\partial x_t}{\partial\rho} + \frac{1}{\alpha\eta}\frac{1-\alpha-\frac{1-\mu}{1-\alpha}\eta}{1-\frac{1-\mu}{1-\alpha}\eta}\frac{d\eta}{d\rho} \quad \text{(B.19)}$$

When young is pivotal, take the partial derivative of (22) with respect to ρ, insert into (B.19) and evaluate at $\theta^j=\theta^h$, $\theta^i=0$, and substitute (B.14) into (B.19). This gives

$$\frac{d\ln(y_t/y_{t-1})}{d\rho} = \frac{1}{\rho(1-\rho)} + \frac{\alpha-\mu}{\alpha}\left[\frac{\alpha}{\eta}\frac{1-\alpha-\frac{1-\mu}{1-\alpha}\eta}{1-\frac{1-\mu}{1-\alpha}\eta}\frac{1+\beta(1+\epsilon)}{(1+\epsilon)(1+\beta)^2}\frac{(\eta/\rho)^2}{1-\alpha-(1-\mu)\eta^2}\right] \quad \text{(B.20)}$$

$$-\frac{\alpha-\mu}{\alpha}\frac{1+\beta}{(1+\rho\beta)(1-\rho)}$$

$$= \frac{\frac{1}{\rho}+\frac{\mu}{\alpha}\frac{1+\beta}{1-\rho}}{\rho(1-\rho)} + \frac{\alpha-\mu}{\alpha}\left[\frac{\alpha}{\eta}\frac{1-\alpha-\frac{1-\mu}{1-\alpha}\eta}{1-\frac{1-\mu}{1-\alpha}\eta}\frac{1+\beta(1+\epsilon)}{(1+\epsilon)(1+\beta)^2}\frac{(\eta/\rho)^2}{1-\alpha-(1-\mu)\eta^2}\right] > 0$$

Proposition 8 implies that a young pivotal increases ρ, and consequently increases the growth rate. This is relative to the bench-mark constitution.
When old is pivotal, evaluate at (B.19) $\theta^i=\theta^h$, $\theta^j=0$,

$$\frac{d\ln(y_t/y_{t-1})}{d\rho} = \frac{\mu-\alpha}{\alpha}\frac{1}{x_t}\frac{\partial x_t}{\partial\rho} + \frac{1}{\alpha\eta}\frac{1-\alpha-\frac{1-\mu}{1-\alpha}\eta}{1-\frac{1-\mu}{1-\alpha}\eta}\frac{d\eta}{d\rho} \quad \text{(B.21)}$$

By Proposition 8, we have $d\eta/d\rho<0$. Then by (B.15) $(1-\mu)\eta^2>1-\alpha$, implying that the term immediately in front of $d\eta/d\rho$ in (B.21) is negative, so this term is positive.
Next, take the partial derivative of (22) with respect to ρ, evaluate at $\theta^i=\theta^h$, $\theta^j=0$, then this derivative is negative, however the term in front μ-α is negative, so this term is also positive. Consequently the growth rate is increasing in ρ. Next, Proposition 8 implies that an old pivotal lowers ρ, i.e. lowering the growth rate. Again, relative to the bench-mark constitution. QED