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The Role of Government Commitment

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Working Paper No. 31
October 2002

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ECONOMY

UNIVERSITY OF
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Environmental Policy and Capital Movements: The Role of Government Commitment[*]

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This paper explores the relationship between environmental protection and international capital movements, when tax policy is endogenous (through voting). A two-period general equilibrium model of a small open economy is specified to compare the effects of two different constitutions (commitment or no commitment in tax policy), as well as income inequality. Under the commitment regime, the equilibrium is characterised by a lower labour tax, higher environmental tax and less capital moving abroad than in the no-commitment equilibrium. Furthermore, given the degree of commitment, more equal societies are characterised by tougher environmental policy and less capital moving abroad.

JEL Classification: F2, H21, H23

Keywords: Environmental policy, capital movements, time-inconsistent fiscal policy, income inequality, politico-economic equilibrium, human capital.

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[*] We wish to thank Wolfram Richter, Sjak Smulders, Simon Vicary and participants at the Second Workshop on "Environmental Policy, Competitiveness and the Location Behaviour of Firms", Maastricht, October 1999 and the Public Economic Theory Conference, Warwick, July 2000, the 54th IIPF Conference, Seville, August 2000, the first EURESCO Conference on "The International Dimension of Environmental Policy", Kerkrade, October 2000, and The Royal Economic Society Annual Conference, Durham, April 2001 for very useful comments on earlier versions of this paper. The first author gratefully acknowledges financial support from the Dutch Scientific Organisation NWO. All errors and shortcomings are our own.

1. INTRODUCTION

Policymakers often express concern that strict environmental protection will lead to capital moving abroad with a consequent deterioration of international competitiveness, a rise in unemployment and a slowdown of economic growth. This view has been reflected in the recent political debate. For example, the European carbon/energy tax proposal of the early 1990s included the exemption of energy-intensive industries, in order to preserve their international competitiveness. The proposal has not been implemented yet, one of the reason being a likely loss in competitiveness of European countries. At the same time, the debate concerning the implementation of the North-American-Free-Trade-Agreement (NAFTA) focused at a large extent on the fear that US industries would relocate in Mexico, where the environmental standards are more lax. Furthermore, environmentalists argue that governments may have incentives to relax environmental policy in order to attract foreign capital and that they may engage in a race to the bottom in environmental standards. This has also been loudly claimed by some interest groups at the congress of the World Trade Organisation, held in Seattle in September 1999.

Economists have analysed the effects of environmental policy either on the movements of capital across regions or on the location behaviour of firms (see Jaffe et al., 1995, for a useful survey, and Rauscher, 1997 and Wilson, 1996 for an overview).[1] The existing theoretical studies typically find a positive correlation between stringency of environmental policy and outflow of capital or industries. In particular, a study of capital flows and environmental concern in a small open economy has been conducted by Bovenberg and van der Ploeg (1994). They find that stronger preferences for the environment result in a reduction in output and capital demand, which in turn causes capital flight.[2]

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[1] In this paper we do not focus on decisions about firms' or plants' location but we focus on capital movements, that is whether individuals invest assets at home or abroad. In this respect our paper is different from the literature on strategic environmental policy and plant location. The two issues are however, often mentioned together in the policy debate. For the role of government commitment on firms' location decisions, see Ulph and Valentini (2002).

[2] A few theoretical papers, however, do not support a positive correlation between stringency of environmental protection and capital flight. See, for example, Rauscher (1995) who claims that if a firm uses a clean environment (rather than pollution) as a factor of production, strict environmental standards can reduce production costs, enhance economic activity and attract foreign capital; and in a tax competition framework, with redistributive concerns, Oates and Schawb (1988) and Wilson (1996). In this paper we want to point out another reason, that is effect of government commitment.

In contrast, the majority of the existing empirical studies, almost exclusively concerning the US, find that environmental policy typically is *not* significant in explaining capital movements and firms' migration.[3]

This reveals that standard theoretical models of environmental policy and capital movements may fail to capture some important aspects of the problem at hand. For example, the majority of the theoretical studies are set up in a static framework, whereas dynamic considerations may play an important role. A relevant issue is at which date the environmental policy is implemented with respect to the household's decisions on consumption and investment (which is not an issue in a static framework). In a dynamic set up, whether the government can or cannot commit to the environmental policy will make a considerable difference, due to the time-inconsistency problem.[4]

Another feature of most of the existing studies is that only one policy instrument, namely the environmental tax (or standard), is modelled. We think it is important to incorporate a standard second-best framework, allowing for distortionary taxes as well (see among others, Sandmo, 1975, and Bovenberg and de Mooij, 1994). Furthermore, redistributive concerns from rich to poor individuals may play an important role in the government's decision about environmental policy (see Oates and Schwab, 1988, and Marsiliani and Renström, 2000*a,b*).

Moreover, observed policies are endogenous, and the decisions taken by majority elected individuals. Only a few papers (see, for example, Marsiliani and Renström (2000*a,b*) model environmental and fiscal policy endogenously, through voting. In a democratic system, individuals have the possibility of voting on representatives. Whether the majority elected candidate represents the preferences of the poor or rich part of the population, obviously influences the policy choice. In fact, if the environment is a normal good, poorer individuals demand less of it (see Marsiliani and Renström, 2000*b*).

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[3] For a survey of the existing empirical studies see Levinson (1996). An exception is List and Co (2000) who find empirical evidence for the impact of environmental policy on firms'location behaviour.

[4] A government's policy is dynamically inconsistent when, although being optimal at the outset, it is not longer optimal at a later date even if no new information has appeared. This means that the government has some incentive to change its plans (see the seminal paper by Kydland and Prescott, 1977, and for an application to environmental policy, see Marsiliani and Renström, 2000*a*).

In this paper, we want to examine the relationship between the degree of commitment in policy, environmental protection, and capital movements. Our main interest is how a different degree of commitment influences environmental protection and capital imports, when both are endogenous. We take the view that governments adopt the optimal policy given the constitution (i.e. given commitment or no commitment), and verifies under which circumstances higher environmental taxes go hand in hand with capital outflow, when both are endogenous. Furthermore, rather than focusing on a government's incentive for changing one policy instrument (such as environmental policy) we focus on the incentives related to the entire tax system.

We develop a model that is rich enough for analysing this question. In doing so we would need (at least) two periods (to capture intertemporal decisions), and we need a second-best framework (to model distortionary taxation).[5] We introduce the second best by analysing an economy with heterogeneous individuals, ruling out individual-specific lump-sum taxes. Finally, policy is endogenised by letting individuals vote on representatives, and the majority-elected representative implements her preferred policy. To capture the degree of capital flow, we present an open economy where individuals own assets domestically and abroad; the domestic assets are rented to firms. Consequently, capital outflow is given by the difference between the stock of total assets and capital invested in domestic production.

Specifically, individuals differ in their learning abilities and this will make them spend different amounts of time on learning, and thereby accumulate different amounts of human capital, which in turn will give rise to wage differentials. Firms are perfectly competitive and employ a CRS technology in physical capital, human capital and emissions. We will consider a tax system consisting of a linear labour tax and an environmental tax (a tax on firms' emissions that generates pollution externalities). The tax receipts are used for provision of a lump-sum transfer. Individuals vote on candidates and the majority elected candidate implements her preferred fiscal policy. Throughout the paper we refer to the *second best* when a government can commit to future tax policy, and the *third best* when it cannot.

[5] The time-inconsistency problem is a feature of second-best analysis (it never arises in the first-best). They may arise either in one-person economies if lump-sum taxes are ruled out, or in many-person economies if individual-specific lump-sum taxation is impossible. In both cases the problem arises if the elasticities of the tax bases are dependent on *when* the policy decision is taken.

We show that the commitment and the no-commitment equilibrium differ. The reason is that a time-inconsistency problem in labour taxation arises. When the government can commit to a level of the future labour tax, it takes into account that a higher level of the tax causes individuals to switch from labour to study-time. If the government can reoptimise in the future, the individuals have already invested in human capital and that stock is fixed. The individuals only change their labour supply. The elasticity of the labour tax base is (expectedly) smaller. Thus, labour is overtaxed in the third best (when the government takes the tax decision after the individuals have chosen their investment in human capital), because labour supply in efficiency units is less elastic.

Furthermore, we find that changing the constitution from discretion to commitment makes the optimal environmental tax greater and at the same time reduces capital outflow. Then commitment in tax policies results to be a factor which can explain a negative correlation between environmental protection and capital outflow. The reason is that the efficiency gain in moving to commitment increases the consumption possibilities of all goods, and if the environment is a normal consumption good, the majority elected representative tends to want to provide more of it, i.e. implementing a larger environmental tax. At the same time capital outflow is less under commitment. The reason is that the labour tax is smaller, and human capital investment larger. The larger supply of human capital increases the productivity of physical capital and therefore tends to retain physical capital at home.

This paper is structured as follows. In Section 2 the economy is introduced and the assumptions are formalised, and in Section 3 the economic equilibrium is solved. In Section 4 we characterise individuals' preferences over policy, under the various timing assumptions. In Section 5 we solve three politico-economic equilibria: the first when elections take place in the second period and the majority elected individual implements policy in the second period, the second when elections take place in the first period, but the majority elected individual cannot commit to future taxation, and the third when elections take place in the first period and the majority elected individual can commit. Several questions are of interest. Does a stricter environmental policy go hand in hand with capital outflows, when redistributive concerns play a role? And under which constitutions? What is the role of inequality (in terms of learning ability and consequently income distribution) for the implementation of a stringent environmental policy? And how does inequality relate to capital movements? Section 6 concludes the paper.

2. THE ECONOMY

We shall specify an economy which is rich enough to analyse the relationship between environmental policy and capital movements and that formalises the time-inconsistency problem, but simple enough to keep the analysis tractable.

Individuals have preferences over period-one consumption, c_0^i, period-one time spent learning h^i, period-two labour supply, l^i, period-two consumption, c^i, and period-two provision of clean environment, $(-x)$, where x denotes pollution. Individuals are indexed by i and characterised by their learning ability parameter γ^i, which is distributed according to the distribution function $\Gamma(i)$. The labour productivity of the individual in the second period is her time spent learning in period one times her learning ability. Through most of the paper we shall assume that the median (second-period) productivity is not greater than the mean.[6] Furthermore, we normalise the population size to unity.

In the first period individual i (with ability γ^i) receives a lump-sum endowment W_0, which is used for period-one consumption, and saving in assets a^i. In the second period, these assets can be invested both domestically (i.e. rented as physical capital to domestic firms, with R the rental price of capital) and abroad (foreign investments). The difference between total assets and productive capital denotes capital outflow. In the second period, the individual supplies labour, and earns the pre-tax wage rate w, per unit of efficient labour. The after-tax wage income plus a lump-sum transfer from the government, T, and the returns on assets are used for consumption. The price of consumption is normalised to unity. Pollution x is generated by production, which takes place in period two. The government provides lump-sum transfers by taxing labour income at rate τ^l, and pollution at rate τ^x. The after-tax wage is denoted ω. In order to gain tractability, we assume specific functional forms. The next section states these assumptions.

[6] This implies an assumption on the distribution of learning abilities, Γ. See further section 3.

2.1. Assumptions

A1 Individuals' preferences

The utility function is assumed to be of the form

$$U_0^i = \ln\left(c_0^i - \eta\frac{h^{i\,1+\epsilon}}{1+\epsilon}\right) + \beta U^i \tag{1a}$$

where the second period utility is

$$U^i = \ln\left(c^i - \eta\frac{l^{i\,1+\epsilon}}{1+\epsilon}\right) - \Psi(x) \tag{1b}$$

and where $h^i, l^i \geq 0$, $\varepsilon > 1$, and the parameters β, and η are strictly positive. Leisure has been normalised to 1 and x denotes aggregate pollution. $\Psi'(x) > 0$, and $\Psi''(x) \geq 0$.

A2 Individuals' constraints

The individuals' budget constraints are

$$c_0^i + a^i \leq W_0 \tag{2a}$$

$$c^i \leq Ra^i + \omega h^i \gamma^i l^i + T \tag{2b}$$

where $\omega \equiv (1-\tau^l)w$ is the after tax wage.

A3 Production

A large number of firms operate with a Cobb-Douglas technology in physical capital, labour (in efficiency units) and pollution. Production y_t, can therefore be calculated as if there was a representative firm employing aggregate labour H, physical capital k and emissions x

$$y = A k^{\alpha} x^{\mu} H^{1-\alpha-\mu} \quad (3) \qquad \text{where} \qquad H \equiv \int h^i \gamma^i l^i \, d\Gamma(i) \quad (4)$$

A4 Government's constraint

The tax receipts are fully used for lump-sum transfers

$$T = \tau^l w H + \tau^x x \tag{5}$$

A5 Representative democracy

The tax rates, τ_t^l, τ_t^x and, consequently, the spending decision are determined by a majority elected representative, under either of three constitutions:

(*a*) elections are held in period 2, and the majority elected representative choose taxes before the choice on period-2 labour supply and consumption is taken, and before the allocation of assets at home and abroad are made;

(*b*) elections are held in period 1, and the majority elected representative choose taxes in period 2, before the choice on period-2 labour supply and consumption is taken, and before the allocation of assets at home and abroad are made;

(*c*) elections are held in period 1, and the majority elected representative choose taxes before both period 1 and period 2 decisions are taken.

Case (*a*) is referred to as *no commitment* (third best);
Case (*b*) is referred to as *partial commitment* (third best);
Case (*c*) is referred to as *full commitment* (second best).

3. ECONOMIC EQUILIBRIUM

In this section, the individual and aggregate economic behaviour are solved for given arbitrary tax rates and public expenditure. We solve the model recursively, first the second period equilibrium, then the first.

3.1. Second period individual economic behaviour

Maximisation of (1*b*) subject to (2*b*) gives the individuals' labour supply

$$l^i = \left(\frac{\gamma^i}{\eta}\right)^{\frac{1}{\epsilon}} (\omega h^i)^{\frac{1}{\epsilon}} \tag{6}$$

and indirect utility (up to an additive constant)

$$V^i = \ln\left(Ra + \frac{\epsilon}{1+\epsilon}\left(\frac{1}{\eta}\right)^{\frac{1}{\epsilon}} (\gamma^i)^{\frac{1+\epsilon}{\epsilon}} (\omega h^i)^{\frac{1+\epsilon}{\epsilon}} + T\right) \tag{7}$$

We notice that the higher the after-tax salary is, the higher is the labour supply. Individuals with more human capital (larger h^i) will supply more labour (everything else being equal). A direct property of the preferences in (1) is that all income effect is removed from the labour supply and carried over to consumption. An increase in lump-sum allowance therefore makes the individual consume more, without changing the labour decision. In the second period, h^i and a^i are constant and taken as given.

3.2. First period individual economic behaviour

Maximisation of (1*a*) subject to (2*a*) gives an individual's choice of the level of h and a as function of second period after-tax wage rate, ω, and second-period productivity,

$$h^i = R^{-\frac{\epsilon}{\epsilon^2-1}} \left(\frac{\omega \gamma^i}{\eta}\right)^{\frac{1}{\epsilon-1}} \tag{8}$$

$$a^i = -\frac{T}{(1+\beta)R} - \frac{\epsilon+\beta}{(1+\epsilon)(1+\beta)} \eta R^{-\frac{\epsilon}{\epsilon-1}} \left(\frac{\omega\gamma^i}{\eta}\right)^{\frac{1+\epsilon}{\epsilon-1}} + \frac{\beta}{1+\beta} W \tag{9}$$

We notice that there is a trade-off between time spent studying and investment in assets: a higher rate of interest causes individuals to study less and to invest more in assets. We also see that the higher the after-tax wage is, the longer is the time spent learning. Also, what will matter for the individual's attitude towards redistribution is not the ability to learn, but the productivity in work in the second period. The productivity in work is $\gamma^i h^i$, which is proportional to $\gamma^{i(1+\epsilon)/(\epsilon-1)}$. This is the key measure we will refer to in the rest of the paper.

3.3. Aggregate economic behaviour

The second- and first-period aggregate economic behaviour is generated by aggregating the individuals' quantities obtained in Sections 3.1 and 3.2 respectively. To obtain the aggregate labour supply (in efficiency units), defined in (4), we integrate (8) over the population to get

$$H = \tilde{h} \left(\frac{\omega}{\eta}\right)^{\frac{1}{\epsilon}} \tag{10}$$

where

$$\tilde{h} \equiv \int \left(\gamma^i h^i\right)^{\frac{1+\epsilon}{\epsilon}} d\Gamma(i) = R^{-\frac{1}{\epsilon-1}} \left(\frac{\omega}{\eta}\right)^{\frac{1}{\epsilon}\frac{1+\epsilon}{\epsilon-1}} \tilde{\gamma} \tag{11}$$

$$\tilde{\gamma} \equiv \int \left(\gamma^i\right)^{\frac{1+\epsilon}{\epsilon-1}} d\Gamma(i) \tag{12}$$

The difference between the second and first periods is that in the second period individuals have invested in their human capital and assets and consequently h and a are fixed, while viewed from the first period h and a are functions of the taxes. $\tilde{\gamma}$ is the $(1+\varepsilon)/(\varepsilon-1)^{\text{th}}$ moment of the ability distribution, and is linearly related to the average work productivity. Whether an individual earns a higher/lower wage rate (per hour) than average depends whether the ratio $\gamma^{i(1+\varepsilon)/(\varepsilon-1)}/\tilde{\gamma}$ is greater/smaller than unity.

3.4. Firms' behaviour

The firms' optimality condition with respect to k (i.e. F_k=R) gives optimal k, and production, as functions of x and H

$$k = (\alpha A/R)^{\frac{1}{1-\alpha}} x^{\theta} H^{1-\theta} \qquad (13) \qquad\qquad y = \tilde{F} = \tilde{A} x^{\theta} H^{1-\theta} \qquad (14)$$

where

$$\theta \equiv \mu/(1-\alpha) \qquad (15) \qquad\qquad \tilde{A} \equiv A^{\frac{1}{1-\alpha}} (\alpha A/R)^{\frac{\alpha}{1-\alpha}} \qquad (16)$$

In the next section, we shall examine policymakers' preferences over fiscal policy.

4. PREFERENCES OVER POLICY

Any individual elected into office will choose policy to maximise her own utility, subject to the government budget constraint. We therefore need to characterise how each type would choose policy. Policy will then be a function of the type in office, and we can construct a voting equilibrium (in section 5) where individuals vote over candidates.

First, it is more convenient optimising with respect to the after-tax wage, ω, and the amount of the polluting factor, x, used, rather than with respect to the tax rates themselves. In fact, in equations (6)-(11), (13)-(14) only ω and x appear. We only need to rewrite the government's budget constraint in terms of those quantities. Equation (5) can be written as

$$T = (1-\alpha) \tilde{A} x^{\theta} H^{1-\theta} - \omega H \qquad (17)$$

The timing matters only to the extent that H (aggregate efficient supply of human capital) responds differently to changes in the after-tax wage, depending on when the tax decision is taken. In fact, the first-order conditions will take the same form under the various assumptions about timing. This is due to the fact that the elected individual chooses l^i (and a^i, h^i if commitment) as well as policy, so the derivatives of l^i (and a^i, h^i if commitment) with respect to policy can be ignored (by the Envelope condition). The problem of a hypothetical candidate is to

$$\max_{\omega, x} \ \ln\left(Ra^i + \omega h^i \gamma^i l^i + T - \eta \frac{(l^i)^{1+\epsilon}}{1+\epsilon}\right) - \Psi(x) \tag{18}$$

subject to (17), (effects on l^i, a^i, and h^i can be ignored by the Envelope condition).
The first-order conditions to (18) are

$$h^i \gamma^i l^i + \frac{\partial T}{\partial \omega} = 0 \tag{19}$$

$$\frac{\partial T / \partial x}{Ra^i + \omega h^i \gamma^i l^i + T - \eta (1+\epsilon)^{-1} (l^i)^{1+\epsilon}} - \Psi'(x) = 0 \tag{20}$$

These conditions have to be evaluated under the different assumptions of timing. First we clarify how they differ.

(*a*) *No commitment*

An individual, if elected in the <u>second</u> period, will take the decision upon ω and x, given the quantity of $\tilde{h}$. Optimal policy will be a function of the identity of the candidate and $\tilde{h}$, which in turn is a function of ω^e (i.e. of <u>expected</u> ω).

(*b*) *Partial commitment*

An individual, if elected in the <u>first</u> period, will take the decision upon ω and x, given the quantity of $\tilde{h}$. However, the choice of ω and x have to be compatible with the expectations of ω in $\tilde{h}$. This is so because individuals will observe who the elected candidate is already in the first period and can form expectations of ω based on the identity of the candidate. Optimal policy will be a function of the identity of the candidate only.

(*c*) *Full commitment*

An individual, if elected in the first period, will take the decision upon ω and x, recognising the influence on $\tilde{h}$.

Since from the policymaker's point of view $\tilde{h}$ is given under both partial and no commitment, partial commitment can be treated as no commitment for time being.

Aggregate labour in efficiency units as a function of policy can be written in one equation, with the parameters reinterpreted under the various timing assumptions. Combining (10) and (11) we can write

$$H = \sigma \, \omega^{1/\nu} \tag{21}$$

where

$$\sigma = \begin{cases} \left(R\eta^2\right)^{\frac{-1}{\epsilon-1}} \tilde{\gamma} & \textit{if commitment} \\ \left(R\eta^2\right)^{\frac{-1}{\epsilon-1}} \tilde{\gamma} \left(\omega^e\right)^{\frac{1}{\epsilon}\frac{1+\epsilon}{\epsilon-1}} & \textit{if no commitment} \end{cases} \quad (22) \qquad \nu = \begin{cases} \dfrac{\epsilon-1}{2} & \textit{if commitment} \\ \epsilon & \textit{if no commitment} \end{cases} \quad (23)$$

Next, since all individuals have the same expectations (regardless timing) we can write

$$h^i \gamma^i l^i = H \hat{\gamma}^i \quad (24) \qquad \text{where} \qquad \hat{\gamma}^i \equiv \gamma^{i(1+\epsilon)/(\epsilon-1)} \big/ \tilde{\gamma} \quad (25)$$

Differentiating (17) with respect to ω, using (21), and inserting the derivative into the first-order condition (19) gives

$$h^i \gamma^i l^i + \left[(1-\theta)(1-\alpha)\tilde{A} x^\theta H^{-\theta} - \omega\right] \frac{1}{\nu} \frac{H}{\omega} - H = 0 \tag{26}$$

Using (24) and rearranging gives

$$\omega = m^i x^\theta H^{-\theta} \tag{27}$$

where

$$m^i \equiv \frac{(1-\theta)(1-\alpha)\tilde{A}}{1+\nu(1-\hat{\gamma}^i)} \tag{28}$$

Also, substituting (27) into (21) gives

$$\begin{aligned} \omega &= (m^i)^{\frac{\nu}{\nu+\theta}} (x/\sigma)^{\frac{\theta\nu}{\nu+\theta}} \\ H &= (m^i)^{\frac{1}{\nu+\theta}} \sigma^{\frac{\nu}{\nu+\theta}} x^{\frac{\theta}{\nu+\theta}} \end{aligned} \tag{29}$$

Since $w=(1-\alpha-\mu)\tilde{A}x^{\theta}H^{-\theta}$, and $1-\tau^{l}=\omega/w$, equation (27) gives (also using (15))

$$\tau^{l} = \frac{\nu(1-\hat{\gamma}^{i})}{1+\nu(1-\hat{\gamma}^{i})} \tag{30}$$

as the labour tax rate preferred by individual i.

Recall that $\hat{\gamma}^{i}$ is the ratio of individual i's labour productivity to the average labour productivity. If $\hat{\gamma}^{i}$ is smaller than unity the individual earns less wage per hour worked than the average. Since ν takes on different values depending on the timing, the same individual prefers a different tax rate under different timing assumptions. In fact, since ν is larger under no commitment than under commitment, the labour tax is larger under no commitment than under commitment. The reason is that the tax base H is less elastic under no commitment and thus would be over taxed. We also see that, given the timing, an individual with greater learning ability prefers to tax labour less.

We will now make a complete characterisation of the choice of a hypothetical individual in office. This will involve substituting for ωH, as a function of the identity of the decision maker and of x (equation (28)), into (19) and finding $\partial x/\partial\hat{\gamma}^{i}$. It turns out that $\partial x/\partial\hat{\gamma}^{i} > 0$ under all timing assumptions (see the appendix). Since $\partial m^{i}/\partial\hat{\gamma}^{i} > 0$, then by (28) $\partial\omega/\partial\hat{\gamma}^{i} > 0$, so the decisions are monotone in the decision maker's learning ability.

Lemma 1 *Assume* A1-A5, *and consider a hypothetical decision maker* $\hat{\gamma}^{*}$. *The decision maker's choice will be functions of* $\hat{\gamma}^{*}$ *with the following properties*

$$\frac{\partial\tau^{l}}{\partial\hat{\gamma}^{*}} < 0\,,\quad \frac{\partial\omega}{\partial\hat{\gamma}^{*}} > 0\,,\quad \frac{\partial x}{\partial\hat{\gamma}^{*}} > 0\,, \tag{31}$$

and given any $\hat{\gamma}^{*}$

τ^{l} (*no commitment*) > τ^{l} (*commitment*).

Proof: See the appendix.

We will now turn to the characterisation of the various politico-economic equilibria, and examine the consequences of time inconsistency on environmental policy and capital movements.

5. POLITICO-ECONOMIC EQUILIBRIA

Regarding voting we have a one-dimensional choice space (the identity of the decision maker). We now need to examine the individuals' preferences over candidates (potential decision makers). If preferences over candidates are single peaked, then we know that the candidate preferred by the median individual in the voting distribution cannot lose against any other candidate in a binary election. Denote a hypothetical decision maker by superscript *. Substitute the policy functions in Lemma 1 into individual i's indirect utility, to obtain an indirect utility in terms of $\hat{\gamma}^*$. This indirect utility has the following properties

Lemma 2 *Assume* A1-A5, *then individual i's preferences over candidates'* $\hat{\gamma}^*$ *are single peaked, with the maximum attained*

at $\hat{\gamma}^*=\hat{\gamma}^i$ *if no commitment,*

at $\hat{\gamma}^*=(1+\varepsilon)/(2\varepsilon) + [(\varepsilon-1)/(2\varepsilon)]\hat{\gamma}^i$ *if partial commitment, and*

at $\hat{\gamma}^*=\hat{\gamma}^i$ *if full commitment.*

Proof: See the appendix.

Lemma 3 *Assume* A1-A5, *then the economic equilibrium under partial commitment with policymaker* $\hat{\gamma}^*$ *coincides with the economic equilibrium under full commitment with policymaker* $\hat{\gamma}^{*\prime} = (1+\varepsilon)/(2\varepsilon) + [(\varepsilon-1)/(2\varepsilon)]\,\hat{\gamma}^*$.

Proof: Inserting $\hat{\gamma}^{*\prime}$ in equation (30), and evaluating under no commitment ($\nu=\varepsilon$), gives the same labour tax as when inserting $\hat{\gamma}^*$ in equation (30) and evaluating under full commitment ($\nu=(\varepsilon-1)/2$). If the labour tax is the same in both equilibria, then by equation (20), also the pollution level x is the same in both equilibria. QED

Lemma 2 implies that we have a median-voter equilibrium, and that we can completely characterise policy making given the underlying distribution of abilities. The single peakedness follows from the monotonicity in the policy variables with respect to the ability of the decision maker.

Lemma 2 also implies that when individuals vote in the first period, but the elected policymaker implements policy in the second period, they will vote strategically on a representative with a different (higher) ability than themselves.

Proposition 1 *Assume* A1-A5, *then in politico-economic equilibrium, the economic equilibrium under partial commitment* (*voting in period* 1, *policy decision in period* 2) *coincides with the economic equilibrium under full commitment* (*voting and policy decision in period* 1). *The policymaker has a higher ability in the partial commitment than in the full commitment equilibrium.*

Proof: Follows from Lemma 1, 2, 3. QED

Proposition 1 implies that due to strategic voting, the period-one elected representative will implement the same policy in period 2, as a period-one elected representative would have implemented in period 1. Thus the partial-commitment equilibrium will coincide with the full-commitment equilibrium.[7] Since the partial commitment equilibrium coincides with the full commitment equilibrium we will not distinguish between them two. We will henceforth only refer to <u>commitment</u> versus <u>no commitment</u>.

Proposition 2 *Assume* A1-A5, *then in politico-economic equilibrium the following holds*

$$\frac{\partial \tau^l}{\partial \hat{\gamma}^*} < 0, \quad \frac{\partial \omega}{\partial \hat{\gamma}^*} > 0, \quad \frac{\partial x}{\partial \hat{\gamma}^*} > 0, \tag{32}$$

where $\hat{\gamma}^*$ *is the median. Furthermore, given any* $\hat{\gamma}^*$

$$\tau^l \text{ (}\textit{no commitment}\text{)} > \tau^l \text{ (}\textit{commitment}\text{)}.$$

Proof: Follows from Lemma 1-2. QED

We notice that the wage tax decreases in the productivity of the decisive individual. This is a standard result, and is caused by the fact that a less productive individual has more to gain from redistributive taxation.

Furthermore, labour is *overtaxed* when no commitment is possible (i.e. in the third best). This is because once the individuals have invested in their human capital, the elasticity of labour supply in efficiency units with respect to taxes is less elastic (at that stage, it is too late to spend more time learning). When commitment is possible, individual responses to

[7] We do not expect this is a general property though, but is due to the assumptions regarding utilities and technologies. Generally one should not expect all policy variables to exactly coincide. When policy is one-dimensional, though, and the candidate space is rich (continuous), the full commitment and partial commitment ought to coincide. This happens indeed in Persson and Tabellini (1994).

changes in wages are greater. We see also from (30) that the greater the difference between the median productivity and the average, the greater is the difference between the commitment and the no commitment solution. Thus, inequality (in the form of skewness of the distribution) makes the time-inconsistency problem more severe.

Finally, pollution in absolute terms is increasing in the productivity of the decisive individual. This is so because this individual wishes to tax labour less, inducing individuals to accumulate more human capital, which in turn makes pollution more productive.

Next, when we make all individuals identical we have the following result:

Corollary 1 *Assume* A1-A5. *If all individuals are the same, the commitment and no commitment equilibria coincide, and the environmental tax is at the Pigouvian level.*

Proof: When all individuals are the same $\hat{\gamma}^*=1$, and the labour tax is zero regardless of timing. Equation (20) then gives the Pigou rule (which is the same regardless of timing).

QED

Thus, we verify that there is no time-inconsistency problem in the first best. This is a general property, since the time-inconsistency problem is only a second-best phenomenon. In the first best the wage tax is zero and any funding in addition to the environmental tax receipts is obtained by lump-sum taxation, $-T$.

Furthermore, we get the following results

Proposition 3 *Assume* A1-A5, *then total emissions, the after-tax wage, and production are smaller under no commitment than under commitment. For given level of commitment, the lower the ability of the decisive individual is, the lower are emissions, the after-tax wage, and production.*

Proof: See the appendix.

Proposition 4 *Assume* A1-A5, *then the pollution tax is smaller and the ratio between emissions and production is greater under no commitment than under commitment. For given level of commitment, the lower the ability of the decisive individual is, the lower is the pollution tax, and the higher is the ratio of emissions to production.*

Proof: See the appendix.

Intuitively, under commitment the consumption possibilities are greater; if the environment is a normal good (which is ensured by additive separability in (1*b*)), the efficiency gains achieved in the second best (in comparison to the third best) means more consumption of the environment. This is achieved by taxing pollution more. Furthermore, if the labour tax is small, investment in human capital is large and the marginal productivity of emissions is large too. Consequently, it is optimal to increase emissions, but not to the extent that *x/y* increases.

We will next address the question of capital movements. Using the decision rules for individuals' savings as a function of the taxes we can state:

Proposition 5 *Assume* A1-A5. *The politico-economic equilibrium under no commitment has larger capital outflow than the politico-economic equilibrium under commitment. For given level of commitment, the lower the ability of the decisive individual is, the larger is the capital outflow.*

Proof: Since the after-tax wage is greater under commitment (or under a policymaker with higher ability), individuals invest less in physical assets (and more in human capital), by equation (9). Since domestic firms' capital demand is proportional to production (equation (13)), and production is greater under commitment (or under a policymaker with higher ability), domestic firms capital demand is greater under commitment. Thus, the difference domestic savings - domestic capital use, is less under commitment (or under a policymaker with higher ability). QED

Intuitively, commitment on the one hand increases the returns on human capital, which in turn reduce domestic savings, and on the other hand increases the productivity of capital, overall attracting foreign capital.

6. SUMMARY AND CONCLUSIONS

We have presented a general equilibrium model of environmental taxation and capital movements. The most important feature of this model is that it examines the effects of different constitutions, that is whether the government can or cannot commit to future tax policy.

We have shown that the commitment and the no-commitment equilibria do not coincide, since a time-inconsistency problem in labour taxation is present. It arises when individuals have the possibility of choosing the time they spend learning. They have to form expectations about the labour tax the government is going to impose in the future. Once individuals have invested in their human capital, the government is tempted to raise the labour tax in order to redistribute from high earners to low earners. Individuals expecting this will invest too little in human capital, and at the same time labour is overtaxed.

We have demonstrated that under commitment (second best), the labour tax is smaller and the environmental tax is greater than under no commitment (third best). Intuitively, there is a conflict between environmental and labour taxation and lump-sum transfers. If the labour tax is small, the distortions caused by the tax system will be small as well. In this case, the marginal utility of transfers is lower and the median voter will prefer to protect the environment more (by paying a higher environmental tax). Furthermore, under commitment, the increasing returns on human capital reduce domestic savings and increase the productivity of capital, which in turns attracts foreign capital or discourages capital outflow.

Everything else being equal, societies with more commitment in fiscal policy would have a tougher environmental policy and less capital outflow. Governments should avoid a discretionary fiscal policy if they want to protect the environment and at the same time attract foreign investment. Thus, this paper provides us with a theoretical explanation for why no empirical evidence can generally be found of a positive relationship between the stringency of environmental policy and capital migration.

In addition, our analysis has suggested that the non-committed tax differs more from the committed one, the larger the difference in learning ability between the decisive individual (median voter) and the average individual. This suggests that the time-inconsistency problem becomes more severe when there is more inequality (in terms of mean-median distance). In this case, a poorer decisive individual will prefer a higher labour tax and also have a greater marginal utility of private consumption and lump-sum transfers, and therefore will be less willing to protect the environment; at the same time capital productivity decreases and capital migrates abroad. Viceversa, a more equal society, given the level of commitment, would have tougher environmental policy and less capital outflow. Thus, through the inequality channel we can also generates a negative correlation between environmental policy and capital outflow.

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APPENDIX

Proof of Lemma 1

First $\partial\tau^l/\partial\hat{\gamma}^i < 0$ follows from equation (30). Next, we only need to prove that $\partial x/\partial\hat{\gamma}^i > 0$ under all assumptions on timing. This is so since $\partial x/\partial\hat{\gamma}^i > 0$ implies, (by (29) in the full commitment and no-commitment cases, and by (50) (below) in the partial commitment case), that $\partial\omega/\partial\hat{\gamma}^i > 0$ (notice that by (28) $\partial m^i/\partial\hat{\gamma}^i > 0$). Taking the partial derivative of (17) w.r.t. x gives

$$\frac{\partial T}{\partial x} = \theta\,(1-\alpha)\,\tilde{A}\,x^{\theta-1}\,H^{1-\theta} = \theta\,(1-\alpha)\,\tilde{F}/x \tag{33}$$

which is the numerator in (20) (the second equality follows by (14)). Next, the denominator in (20) may be written as follows (by using (6))

$$R\,a^i + \frac{\epsilon}{1+\epsilon}\,\omega\,h^i\gamma^i l^i + T = R\,a^i + \frac{\epsilon}{1+\epsilon}\,\hat{\gamma}^i\,\omega\,H + T \tag{34}$$

where the equality follows from (24). Then the first order condition (20) may be written as

$$\frac{\theta(1-\alpha)\,x^{-1}}{Z} - \Psi'(x) = 0 \qquad (35) \qquad \text{where} \qquad Z \equiv \left[Ra^i + \frac{\epsilon}{1+\epsilon}\,\hat{\gamma}^i\,\omega\,H + T\right]\Big/\tilde{F} \qquad (36)$$

We treat Z as a function of $\hat{\gamma}^i$ and x: $Z(\hat{\gamma}^i, x)$. Denote the derivatives by subscripts. We then find the sought derivative by differentiating (35)

$$\frac{\partial x}{\partial\hat{\gamma}^i} = -x\,Z_{\hat{\gamma}^i}\left[Z + Z_x\,x + Z\,\frac{\Psi''(x)}{\Psi'(x)}\,x\right]^{-1} \tag{37}$$

We now need to find the derivatives of Z. First we will rewrite (36). Premultiply (27) by H and use (14), then we have the following

$$\omega\,H = m^i\,x^{\theta}\,H^{1-\theta} = m^i\tilde{F}/\tilde{A} \tag{38}$$

Next,

$$T = (1-\alpha)\tilde{F} - \omega\,H = \left[\frac{(1-\alpha)\tilde{A}}{m^i} - 1\right]\omega\,H = \frac{\theta + \nu\left(1-\hat{\gamma}^i\right)}{1-\theta}\,\omega\,H \tag{39}$$

where the first equality follows by using (14) in (17), the second equality by using (38), and the third equality by using (28). Using the last equality of (39) in (36) gives

$$Z = \left[Ra^i + \left(\frac{\epsilon\,\hat{\gamma}^i}{1+\epsilon} + \frac{\theta + \nu\left(1-\hat{\gamma}^i\right)}{1-\theta}\right)\omega\,H\right]\Big/\tilde{F} \tag{40}$$

Sofar the analysis is valid under all assumptions on timing. We now need to proceed differently, depending on which timing of events we assume. We begin with the no-commitment case.

Under no commitment the last period's learning and savings are taken as given, and only the identity of the policy maker (as well as her choice) can vary. Here we have $\nu=\varepsilon$ (by (23)), then Z^n, where superscript n denotes no commitment, (i.e. equation (40)) becomes

$$\begin{aligned} Z^n &= \left[Ra^i + \frac{\epsilon+\theta}{(1-\theta)(1+\epsilon)} \left[1+\epsilon\left(1-\hat{\gamma}^i\right)\right] \omega H \right] \Big/ \tilde{F} \\ &= \left[Ra^i + \frac{\epsilon+\theta}{1+\epsilon}(1-\alpha)\tilde{A}\ \frac{\omega H}{m^i} \right] \Big/ \tilde{F} \ = \ Ra^i/\tilde{F} + (1-\alpha)\frac{\epsilon+\theta}{1+\epsilon} \end{aligned} \tag{41}$$

where the second equality follows by using (28), and the third by using (38). Use (21), (29), and (38) to substitute for $\tilde{F}$, then we have

$$Z^n = \frac{Ra^i}{\tilde{A}} \left(m^i \sigma^\nu\right)^{\frac{\theta-1}{\theta+\nu}} x^{-\theta\frac{1+\nu}{\theta+\nu}} + (1-\alpha)\frac{\epsilon+\theta}{1+\epsilon} \tag{42}$$

Take the derivatives with respect to x and $\hat{\gamma}^i$, to obtain[8]

$$Z^n + \frac{\partial Z^n}{\partial x} x = \nu \frac{1-\theta}{\theta+\nu} \frac{Ra^i}{\tilde{A}} \left(m^i \sigma^\nu\right)^{\frac{\theta-1}{\theta+\nu}} x^{-\theta\frac{1+\nu}{\theta+\nu}} + (1-\alpha)\frac{\epsilon+\theta}{1+\epsilon} > 0 \tag{43}$$

$$\frac{\partial Z^n}{\partial \hat{\gamma}^i} = \frac{Ra^i}{\tilde{A}} \left(m^i \sigma^\nu\right)^{\frac{\theta-1}{\theta+\nu}} x^{-\theta\frac{1+\nu}{\theta+\nu}} \left(\frac{\partial a^i/\partial \hat{\gamma}^i}{a^i} - \frac{1-\theta}{\theta+\nu} \frac{\partial m^i/\partial \hat{\gamma}^i}{m^i} \right) < 0 \tag{44}$$

Substituting (43) and (44) in (37) gives $\partial x/\partial \hat{\gamma}^i > 0$ under no commitment.

Under partial commitment ω^e in $\tilde{h}$ and σ changes as $\hat{\gamma}^i$ changes. When $\hat{\gamma}^i$ is known also ω^e will be known (and coincides with ω). This has to be taken into account in differentiating Z. Under full commitment ω^e is under the control of the policymaker. The two cases can be captured simultaneously. In both cases a^i will respond to changes in the identity of the decision maker. Combining (8), (6) and (24), and substituting into (9) gives

$$Ra^i = -\frac{T}{1+\beta} - \frac{\epsilon+\beta}{(1+\epsilon)(1+\beta)} \omega H \hat{\gamma}^i + \frac{\beta}{1+\beta} RW \tag{45}$$

No expectations on ω is needed because the decision maker will be known in advance.

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[8] N.B. under no commitment a^i is invariant with respect to policy, and varies only with respect to identity i. The derivative (44) is negative since $\partial a^i/\partial \gamma^i < 0$, which follows from (9).

Substituting (45) into (36) gives

$$Z^{c,p} = \frac{\beta}{1+\beta}\left[T + \frac{\epsilon-1}{1+\epsilon}\ \omega\, H\, \hat{\gamma}^{i} + RW\right]\Big/\tilde{F} \tag{46}$$

where superscript *c,p* denote commitment, partial commitment, respectively. Substituting for T according to the second equality in (39), and for $\tilde{F}$ according to (38) gives

$$Z^{c,p} = \frac{\beta}{1+\beta}\left[1 - \alpha - \frac{m^{i}}{\tilde{A}} + \frac{\hat{\gamma}^{i}\, m^{i}}{\tilde{A}}\,\frac{\epsilon-1}{1+\epsilon} + \frac{RW}{\tilde{A}}\,\frac{m^{i}}{\omega H}\right] \tag{47}$$

or rearranged

$$Z^{c,p} = \frac{\beta}{1+\beta}\left[1 - \alpha - \frac{m^{i}}{\tilde{A}}\,\frac{2+(\epsilon-1)(1-\hat{\gamma}^{i})}{1+\epsilon} + \frac{m^{i}}{\tilde{A}}\,\frac{RW}{\omega H}\right] \tag{48}$$

Full commitment implies $\nu=(\epsilon-1)/2$, then using (28) in (48) we obtain

$$Z^{c} = \frac{\beta}{1+\beta}\left[(1-\alpha)\,\frac{\epsilon-1+2\theta}{1+\epsilon} + \frac{RW}{\tilde{A}}\left(m^{i}\sigma^{\nu}\right)^{-\frac{1-\theta}{\theta+\nu}} x^{-\theta\frac{1+\nu}{\nu+\theta}}\right] \tag{49}$$

where $m^{i}/(\omega H)$ has been substituted for by using (29).

Partial commitment implies that ω^{e} in (22) has to be replaced by ω. Setting $\omega^{e}=\omega$ in (22) and substituting into (29) gives (wherever ν appears it equals ϵ according to (23))

$$\omega = \left(m^{i}(x/\sigma_{0})^{\theta}\right)^{\frac{\epsilon-1}{\epsilon-1+2\theta}} \tag{50}$$

where $\sigma_{0} = \tilde{\gamma}(R\eta^{2})^{-1/(\epsilon-1)}$. Set $\omega^{e}=\omega$ in (22) and substitute into (21), premultiply both sides by ω, and substitute for ω on the right-hand side by using (50) to obtain (N.B. $\nu=\epsilon$)

$$\omega H = \sigma_{0}^{\frac{(1-\theta)(\epsilon-1)}{\epsilon-1+2\theta}}\left(m^{i}x^{\theta}\right)^{\frac{1+\epsilon}{\epsilon-1+2\theta}} \tag{51}$$

In (48), using (28) to eliminate m^{i} where it first appears and (51) to eliminate $m^{i}/(\omega H)$ we have

$$Z^{p} = \frac{\beta}{1+\beta}\left[(1-\alpha)\left(1 - \frac{1-\theta}{1+\epsilon}\,\frac{2+(\epsilon-1)(1-\hat{\gamma}^{i})}{1+\epsilon\,(1-\hat{\gamma}^{i})}\right) + \frac{RW}{\tilde{A}}\left(m^{i}\sigma_{0}^{\frac{\epsilon-1}{2}}\right)^{\frac{-2(1-\theta)}{\epsilon-1+2\theta}} x^{\frac{-\theta(1+\epsilon)}{\epsilon-1+2\theta}}\right] \tag{52}$$

We are now ready to take the derivatives of (49) and (52), respectively.

Differentiating Z^c (i.e. (49)) with respect to x and $\hat{\gamma}^i$ gives

$$Z_x^c x + Z^c = \frac{\beta}{1+\beta}\left[(1-\alpha)\frac{\epsilon-1+2\theta}{1+\epsilon} + \nu\frac{1-\theta}{\nu+\theta}\frac{RW}{\tilde{A}}\left(m^i\sigma^\nu\right)^{-\frac{1-\theta}{\theta+\nu}}x^{-\theta\frac{1+\nu}{\nu+\theta}}\right] > 0 \tag{53}$$

$$Z_{\hat{\gamma}^i}^c < 0 \tag{54}$$

(54) follows since Z^c is declining in m^i, and m^i is increasing in $\hat{\gamma}^i$. Then (37) implies that $\partial x/\partial\hat{\gamma}^i > 0$ holds here as well.

Finally differentiating Z^p (i.e. (52)) with respect to x and $\hat{\gamma}^i$ gives

$$Z_x^p x + Z^p = \frac{\beta}{1+\beta}\left[(1-\alpha)\left(1-2\frac{1-\theta}{1+\epsilon}\frac{1+\eta(1-\hat{\gamma}^i)}{1+\epsilon(1-\hat{\gamma}^i)}\right) + \frac{\eta(1-\theta)}{\eta+\theta}\frac{RW}{\tilde{A}}\left(m^i\sigma_0^\eta\right)^{-\frac{1-\theta}{\eta+\theta}}x^{-\frac{\theta}{2}\frac{1+\epsilon}{\eta+\theta}}\right] > 0 \tag{55}$$

$$Z_{\hat{\gamma}^i}^p = -\frac{\beta}{1+\beta}\left[\frac{(1-\alpha)(1-\theta)}{\left[1+\epsilon(1-\hat{\gamma}^i)\right]^2} + \frac{1-\theta}{\eta+\theta}\frac{Rw}{\tilde{A}}\left(m^i\sigma^\eta\right)^{-\frac{1-\theta}{\eta+\theta}}x^{-\frac{\theta}{2}\frac{1+\epsilon}{\eta+\theta}}\frac{\partial m^i/\partial\hat{\gamma}^i}{m^i}\right] < 0 \tag{56}$$

where $\eta=(\varepsilon-1)/2$. Then (37) gives $\partial x/\partial\hat{\gamma}^i > 0$. QED

Proof of Lemma 2

Taking the derivative of individual i's indirect utility function with respect to $\hat{\gamma}^*$ gives

$$\frac{h^i\gamma^i l^i + \dfrac{\partial T}{\partial\omega}}{Ra^i + \omega h^i\gamma^i l^i + T - \eta\dfrac{(l^i)^{1+\epsilon}}{1+\epsilon}}\frac{\partial\omega}{\partial\hat{\gamma}^*} + \left[\frac{\dfrac{\partial T}{\partial x}}{Ra^i + \omega h^i\gamma^i l^i + T - \eta\dfrac{(l^i)^{1+\epsilon}}{1+\epsilon}} - \Psi'(x)\right]\frac{\partial x}{\partial\hat{\gamma}^*} \tag{57}$$

The first term is the individual's first-order variation with respect to ω times the change in ω when $\hat{\gamma}^*$ changes. The second term is the first-order variation with respect to x times the change in x when $\hat{\gamma}^*$ changes. With no commitment, and with full commitment, these first-order variations are those that the individual would face if she was decisive. The peak is reached at $\hat{\gamma}^i=\hat{\gamma}^*$. If $\hat{\gamma}^* < (>)\ \hat{\gamma}^i$ the first-order variation is positive (negative) due to the monotonicity in ω and x with respect to $\hat{\gamma}^*$. With partial commitment, the first order variations are not the same as the individual would face if being in office (because of the difference in timing). However, by replacing with $\hat{\gamma}^{*\prime}=(1+\varepsilon)/(2\varepsilon) + [(\varepsilon-1)/(2\varepsilon)]\hat{\gamma}^i$, the first-order variations become the same, and the argument above applies. QED

Proof of Propositions 3-4

In the no-commitment case, individuals will predict ω^e accurately. To characterise the equilibrium, ω^e has to be substituted by ω in equation (22). This will result in equation (29), with $\nu=(\epsilon-1)/2$ in the exponents, but with m^i evaluated at $\nu=\epsilon$ (see equation (50)). Then, in equation (29) the only difference between the no-commitment and the commitment equilibria is that the former is evaluated at $m^i|_{\nu=\epsilon}$, and the latter at $m^i|_{\nu=(\epsilon-1)/2}$. Then, in comparing the two equilibria we use equation (51) and perform comparative statics with respect to m^i. First, by using (35),

$$\frac{m^i}{x}\frac{dx}{dm^i} = -\frac{Z_{m^i}\, m^i}{Z + Z_x x + Z\,\Psi''(x)x/\Psi'(x)} > 0 \tag{58}$$

since $\partial Z/\partial m^i < 0$. Since $m^i|_{\nu=\epsilon} < m^i|_{\nu=(\epsilon-1)/2}$, m^i is greater under commitment, and consequently x is greater under commitment.

Next, since the pollution tax is

$$\tau^x = \mu\,\tilde{A}\,x^{\theta-1}H^{1-\theta} \tag{59}$$

we need to evaluate the ratio H/x.

First, using (29),

$$\begin{aligned}\frac{d(H/x)}{dm^i} &= \frac{1}{\nu+\theta}\frac{H/x}{m^i} - \frac{\nu}{\nu+\theta}\frac{H/x}{x}\frac{dx}{dm^i}\\ &= \frac{H/x}{(\nu+\theta)\,m^i}\left(1-\nu\frac{m^i}{x}\frac{dx}{dm^i}\right)\end{aligned} \tag{60}$$

Next, use (58) to obtain (N.B. $\nu=(\epsilon-1)/2$)

$$\begin{aligned}1-\nu\frac{m^i}{x}\frac{dx}{dm^i} &= \frac{Z + Z_x x + Z\,\Psi''(x)x/\Psi'(x) + \nu Z_{m^i} m^i}{Z + Z_x x + Z\,\Psi''(x)x/\Psi'(x)}\\ &= \frac{\frac{\beta}{1+\beta}(1-\alpha)\frac{\epsilon-1+2\theta}{1+\epsilon} + Z\,\Psi''(x)x/\psi'(x)}{Z + Z_x x + Z\,\Psi''(x)x/\Psi'(x)} > 0\end{aligned} \tag{61}$$

Therefore, $\partial(H/x)/\partial m^i > 0$, and H/x is greater under commitment, implying that τ^x is greater under commitment. Finally since production is $\tilde{A}x^{\theta}H^{1-\theta} = \tilde{A}x(H/x)^{1-\theta}$, the result on production follows. The result on the after-tax wage follows from (29). The results regarding the identity of the policymaker go through, since m^i is greater under a policymaker with higher ability.

QED