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Efficient environmental standards with imperfect completion

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EFFICIENT ENVIRONMENTAL STANDARDS WITH IMPERFECT COMPETITION

Jeffrey D Petchey[1]

Abstract

Economists have been concerned that sovereign communities may distort environmental policies to attract mobile capital. This paper provides something of a challenge to this idea. It does so by extending the model of Oates and Schwab (1988) to allow the supply of capital to a state, whether acting independently or strategically as part of a federation, to be *less* than perfectly elastic due to capital market imperfections. This gives the state an incentive to distort its policies in order to manipulate its domestic capital price relative to the given world return for capital. The key result is to show that the state always prefers to use a dedicated capital tax to achieve its desired domestic price, leaving environmental standards at efficient levels. Only when the state is denied access to a capital tax will it resort to distorting environmental standards. Thus, distortions to environmental standards arise from restrictions on the set of policy instruments rather than non-cooperative behavior or capital mobility per se, at least when the incentive to distort policy arises from capital market imperfections.

Key words: Emissions, environmental standards, taxes, mobile capital, race to the bottom.

***JEL Codes*:** H21, H23, H73, H77.

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1. Introduction

Academics have been concerned that sovereign communities acting as independent countries or jurisdictions in federations distort environmental policies to attract firms, labor and capital, engaging in a race to the bottom. This was expressed by Cumberland (1979, 1981) though Oates and Schwab (1988) were the earliest to examine the idea formally. These authors developed a model of small communities each with two instruments, a capital tax and environmental policy. A fixed stock of capital migrates freely across communities and in equilibrium any particular community takes the community-wide return as given: communities face a perfectly competitive capital market. Oates and Schwab show that majority rule voting leads to efficient environmental standards and a zero tax on capital. They also examine cases where the community's choices are sub-optimal. From this paper a race to the bottom literature has emerged[2]. Depending on the models used this literature generates race to the bottom (or top) results, perpetuating the idea that environmental standards are distorted if communities choose policies in the presence of capital or firm mobility.

The purpose of this paper is to provide something of a challenge to this notion. It does this by showing that distortions to environmental standards arise from restrictions on the set of policy instruments rather than non-cooperative behavior or capital mobility per se at least when the incentive to distort policy arises from inelastic capital supply. The paper demonstrates this by extending the Oates and Schwab model to a world in which a (small) community faces a market for mobile capital that is *imperfectly* competitive. This yields an incentive for a community to distort policies in order to manipulate the domestic capital price, even though the world return to capital is given. The key insight is to show that such distortions only eventuate when the policy vector is restricted, and in particular, if the community has no capital tax. In this instance, environmental standards are distorted relative to efficient levels, as is commonly found. However, such a race *never* eventuates if the community's policy vector includes a capital tax. In this case, the community always prefers to use the tax to manipulate its capital price, rather than distort environmental policy. This is shown to hold whether the community is an independent

[2] For a survey see Wilson (1996), Wellisch (2000) and Oates (2002). Recent examples of race to the bottom papers include Kunce and Shogren (2005, 2006).

country or a state in a federation. As long as the policy vector is unrestricted there is no evidence that welfare maximizing communities facing an imperfectly competitive capital market, and hence incentives to distort policies in order to influence prices, engage in any race to the bottom (or top).

The intuition for this insight is as follows. Distorting environmental policy to influence the domestic capital price when capital is imperfectly mobile yields a similar benefit for the community as changing the capital tax, but at a higher *cost* in terms of utility foregone. Thus, it is less costly to use the capital tax to exploit imperfections in the capital market to manipulate the domestic capital price, leaving environmental policy at efficient levels. If the community chooses policies to maximize household welfare it will want to use the least cost policy instrument to achieve its aims with respect to the favored domestic capital price. But if this least cost policy instrument is removed from the set of feasible policies the community uses the next lowest cost instrument - distortions to environmental standards - to manipulate the domestic capital price. It is in this case only that environmental standards are distorted.

The model developed initially is one of a single community that can be thought of as a country[3]. Domestic households own firms and the government has two instruments, a per-unit capital tax and environmental emissions. Output is a function of emissions and the total capital supply while emissions also directly affect household utility. Capital imperfections are introduced using a function in which the supply of capital to the community can be perfectly inelastic, a non-decreasing function of the (net) domestic capital price relative to the given outside (world) return, or perfectly inelastic. The outside (world) return to capital is given. The community's government is benevolent and selects policies to maximize household utility while taking account of feasibility and the impact of its decisions on the supply of capital. The main result is derived using the first order conditions from the government's optimization problem.

The single community model is then extended to a multi-state model to capture the case of *strategic* game playing states within a federation who levy a capital tax and provide environmental standards. It is shown that the efficient environmental policy result holds in this setting as well. This conclusion is placed into the context of the race

[3] The single country model is presented first because the result is clearest in this case.

to the bottom literature with the implication that game playing states do not engage in any race to the bottom or top if they can tax capital. Therefore, if a single community (country) facing an imperfectly competitive capital market uses the tax to manipulate its domestic capital price while providing efficient environmental standards then so too will states acting strategically in a federation. Non-cooperative behavior per se has no qualitative impact on the central idea that environmental standards are efficient if countries, or states within federations, have a policy vector that includes a capital tax.

The outline of the paper is as follows. Section 2 develops the model for the single community. Section 3 derives the first order necessary conditions for the tax and emissions standards. The key efficiency results are derived in section 4. The two-state model is developed in section 5 and Section 6 concludes.

2. A single community

The first model considered is of a single community (e.g. country) with H immobile (domestic) households and an industry producing output $y \geq 0$ using two inputs, mobile capital k and un-priced pollutant emissions g. Emissions are a public bad (the inverse of environmental standards) chosen directly by the government and output is

$$y = f(k, g). \tag{1}$$

The price of output is assumed to be one so (1) also defines the value of output. The marginal product of capital and emissions are positive, hence $f_k > 0$ and $f_g > 0$ where $f_{kk} < 0$ and $f_{gg} < 0$. The domestic return to capital is just the marginal product

$$f_k = r(k, g). \tag{2}$$

Here $r_k(k, g) < 0$ and $r_g(k, g) > 0$.

The community has a second policy instrument, a per unit source-based capital tax denoted as t. This could also be modeled as an ad valorem tax but the results are clearer with a per-unit tax.[4] The per unit (net) domestic return to capital is

$$x = r(k, g) - t. \tag{3}$$

[4] The result with an ad-valorem tax is available on request.

The total supply of mobile capital to the community is a monotonically non-decreasing function of the net domestic price relative to the given world return ω

$$k = k\left(\frac{x}{\omega}\right). \tag{4}$$

Consistent with many tax competition models the supply of capital to the community is the result of an equilibrating rule where the world return ω is given and not affected by the community's policies. In contrast to the usual approach, where the supply of capital to the community is also perfectly elastic at the given world return, (4) implies that the community can face a capital supply curve that is *(i)* perfectly inelastic (vertical); *(ii)* upward sloping; or *(iii)* perfectly inelastic (horizontal). Hence, the more standard model is a special case of (4) where the supply curve is horizontal. By allowing other capital market structures, especially *(ii)*, equation (4) captures the possibility of *imperfections* in the capital market. As noted, this possibility provides the community an incentive to use its policies to influence its net capital price, while taking the world return as given.[5]

A simplification of (4) makes the presentation simpler, namely, that the world return is fixed at one. With this the capital supply function (4) becomes

$$k = k(x). \tag{5}$$

This still allows for the *three* capital supply curves discussed above. Any particular capital supply curve for the community is now conditional on $\omega = 1$. The supply curve shifts up and down depending on the value of the world return. Normalizing the world return at one makes no difference to the qualitative conclusions since the key relationship between x, the domestic capital price and k, capital supply, is retained in (5).

The community's immobile households have identical incomes and preferences so the analysis can proceed from the perspective of a representative household who consumes a private good X and the public bad. The utility function for the household is

$$U(X, g). \tag{6}$$

Here $U_X > 0$, $U_{XX} \leq 0$, $U_g < 0$ and $U_{gg} \leq 0$.

[5] A perfectly inelastic capital supply might arise if the country's borders are closed using capital controls. The capital supply curve can be upward sloping if capital has attachment to home or faces transactions costs when moving across borders. The perfectly elastic case arises for capital which has zero attachment and no transactions costs. The specification of (4) allows for all possibilities.

Households are residual claimants and total household income is $f(k,g) - xk$ implying that all mobile capital is foreign owned. Consumption per household is[6]

$$X = \frac{f(k,g) - xk}{H}. \tag{7}$$

Using (7) and (6) utility for a representative household is

$$U\left(\frac{f(k,g) - xk}{H}, g\right). \tag{8}$$

Let the government be benevolent[7] and represent the interests of households. Foreign owners of imported capital are disenfranchised. Since households own all domestic firms this implies that government, household and firm interests coincide. The government chooses t and g to maximize (8) while taking account of the capital supply effects of its decisions. It has an incentive to use its policies to manipulate the terms on which capital is purchased from the outside. From (8) it is clear that x affects the utility of households and from (3) x can be manipulated by the choice of g and t.

Since the model is of a single community with an imperfectly competitive supply curve for mobile capital there is no consideration of other communities (countries) or the manner in which capital migrates between communities to satisfy any equal return condition, as there is in many tax competition papers, including Oates and Schwab. As will be shown below, the main results of the paper can be obtained in the single country case without any need to model a system of communities. That said the model is extended in Section 4 to allow for multiple states within a federation where capital flows freely between states but the federation faces a capital supply function analogous to (5).

3. First order necessary conditions

Whether the potential to manipulate the domestic capital price translates into distortions to environmental standards is now examined. This is accomplished by examining the first order necessary conditions, initially for the tax and then for emissions.

[6] Thus the community is thought of as a net importer of foreign owned capital. Note that the specification at (7) also implies that revenue from the capital tax on the foreign owned capital is returned lump sum to households.

[7] This assumption allows one to focus on the potential for imperfections in the capital market to induce policy distortions without other sources of inefficiency such as states acting malevolently being present.

The first order necessary condition for the *tax* is

$$r_k k \frac{\partial k}{\partial t} - t\frac{\partial k}{\partial t} - k = 0. \tag{9}$$

From (5) the domestic capital supply response to an incremental increase in the tax is

$$\frac{\partial k}{\partial t} = -\frac{k_x}{\left[1 - k_x r_k\right]} < 0. \tag{10}$$

The first term $r_k k \frac{\partial k}{\partial t}$ in (9) is positive. This is the increased gross payment that must be made to all units of capital in the economy as a result of its higher return that is in turn caused by the reduced capital supply with a higher tax. The community perceives this to be a cost of a higher tax. The term $t\frac{\partial k}{\partial t} < 0$ is the revenue lost from the capital that leaves in response to a higher tax - also a cost - while k captures the higher revenue received on the remaining capital base as the tax increases - a benefit. Hence, (9) can be expressed as an equality of marginal benefit and marginal cost

$$\underbrace{k}_{MB_t} = \underbrace{\left(r_k k - t\right)\frac{\partial k}{\partial t}}_{MC_t}. \tag{11}$$

An expression for the optimal tax can be derived to see how the different capital supply elasticity possibilities discussed previously translate into the tax choice. This is important for placing the main result about the efficiency of environmental policy into context. In this regard, using (10) in (9) and rearranging the optimal tax is

$$t^* = \frac{k}{k_x}. \tag{12}$$

Next define $k_x = \varepsilon\left(k / x\right)$ where $0 \le \varepsilon \le \infty$ is the elasticity of capital supply, assumed to be a parameter. Recalling that $x = r - t$ this is $k_x = \varepsilon\left(k / (r - t)\right)$ and (12) becomes

$$t^* = \frac{r}{(1+\varepsilon)}. \tag{13}$$

The different capital market structures alluded to after equation (4) can now be characterized more formally. First when $\varepsilon = 0$ the community's capital market is closed to the world and $t^* = r$ from (13). It is optimal to set a tax that appropriates all capital income so $x = r - t$ and the (net) domestic capital price is zero. Second as $\varepsilon \to \infty$ the community's capital supply becomes perfectly elastic. Here the capital supply curve is horizontal. Moreover

$$\frac{r}{(1+\varepsilon)} \to 0 \text{ as } \varepsilon \to \infty .$$

One can also see that $t^* \to 0$ as $\varepsilon \to \infty$ and the optimal tax approaches zero. Recalling that $x = r - t$ the net domestic capital price approaches its marginal product ($x \to r$). It is also the case that the domestic capital price must approach the given world price ω for equilibrium to exist.[8] This is the case adopted in the standard tax competition models (e.g. Oates and Schwab) where capital is perfectly mobile, the optimal tax is zero and the domestic capital price is equal to the given world return. One can see this is a *special* case of the more general capital model. If $0 < \varepsilon < \infty$ the capital supply curve is an increasing function of the domestic capital price, the tax is non-zero and defined at (13).

Hence, the optimal capital tax deployed by the single community depends upon the exact nature of the capital market it faces. The most interesting case is the 'intermediate' one where epsilon is greater than zero but not infinite since this is the case most likely to arise in a world where capital is attached to home or has transactions costs and is not perfectly free to move across national boundaries.

The first order necessary condition for *emissions* is

$$H\frac{U_g}{U_X} + f_g - r_k k\frac{\partial k}{\partial g} + t\frac{\partial k}{\partial g} - r_g k = 0 . \qquad (14)$$

From (5) the capital supply response to an incremental increase in emissions is

$$\frac{\partial k}{\partial g} = k_x \frac{r_g}{\left[1 - k_x r_k\right]} > 0 . \qquad (15)$$

Here $k_x = \frac{\partial k}{\partial x}$. The term $H\frac{U_g}{U_X}$ in (14) is the marginal rate of substitution between g and X summed across all households. Since g is a public bad this is equivalent to the marginal cost of g in terms of foregone household utility. The term f_g is the marginal benefit of increased g in terms of higher output while $r_k k\frac{\partial k}{\partial g} < 0$ is the decline in the payment made to the existing capital base as g and consequently k increases. This is a

[8] The demonstration of this is available on request.

benefit from more emissions. The term $t\frac{\partial k}{\partial g}$ is the increase in tax revenue that results from a larger tax base as g increases for a given t (a marginal benefit) while $r_g k$ is the increased payment to capital as more g increases capital's productivity; this is a marginal cost since $r_g > 0$. Hence, the first order necessary condition for emissions can be expressed as an equality between marginal benefit and cost as follows

$$\underbrace{f_g - (r_k k - t)\frac{\partial k}{\partial g}}_{MB_g} = \underbrace{r_g k - H\frac{U_g}{U_X}}_{MC_g}. \tag{16}$$

For emissions to be efficient (16) should be a Samuelson condition since emissions are a public bad. At *first* sight this is unlikely because of the distorting capital response terms. They are present because policy choices affect the net domestic capital price, capital supply and household welfare. Thus, if a community can use its policies to manipulate its capital price it seems that it may distort environmental standards.

4. The provision of environmental standards

It is now shown that this is *not* the case. When one takes the tax into account the first order necessary condition for emissions collapses to a Samuelson condition.

4.1 Two instruments (tax and emissions)

From (10) and (15) the following relationship between capital supply responses to a change in each instrument holds

$$\frac{\partial k}{\partial g} = -r_g \frac{\partial k}{\partial t}. \tag{17}$$

The only factor that differentiates the capital supply responses to a change in each policy instrument is r_g the partial derivative that expresses how the gross domestic return responds to an increase in emissions. In the event that $r_g = 1$ the effect of an incremental increase in emissions (on capital supply) is identical to the effect of a one-unit decrease in the tax. This might happen fortuitously but in general the capital supply effects resulting from changes in the two policy instruments will differ, though they remain related through (17). If $r_g < 1$ the impact of a one-unit increase in *g* is smaller than the effect of a one-unit decrease in the tax and if $r_g > 1$ then the opposite is true.

The different impact of each instrument on the net capital price, and hence capital supply, arises from the form of the capital price function, $x = r(k, g) - t$. Specifically, emissions directly enhance output, and hence *g* is an argument of $r(k, g)$, whereas *t* does not. However, the tax influences $r(k, g)$ only indirectly through *k*, though it does affect *x* directly, and linearly, through the term $-t$ because it is a unit tax. If not for these differential impacts arising from the form of the price equation the two instruments would be perfect substitutes in terms of their impact on the capital price and supply.[9]

The *key* result is now presented in the following theorem and proof:

Theorem 1: *If the government chooses the tax and emissions levels to satisfy the first order necessary conditions (9) and (14) then environmental policy is always efficient.*

Proof: Using (17) in (16) and multiplying through by $1/r_g$ the first order condition for emissions can be expressed in terms of the *tax* capital supply responses as follows

$$f_g \frac{1}{r_g} + \left(r_k k - t\right)\frac{\partial k}{\partial t} = k - H\frac{U_g}{U_X}\frac{1}{r_g}. \qquad (18)$$

The *first* term on the right side of (18) is equivalent to the left side of the tax first order necessary condition (11) while the *second* and *third* terms on the left side of (18) are equivalent to the right side of (11). Furthermore, in equilibrium the left side of (11) must be *equal* to the right side of (11). This implies *cancellation* of the first term on the right side of (18) with the second and third terms on the left side of (18) and the first order necessary condition for emissions collapses to

$$f_g = -H\frac{U_g}{U_X}. \qquad (19)$$

[9] If the tax is ad valorem the two instruments still have a different impact on the net capital price and are not perfect substitutes. Again, this is due to the fact that they each enter the price function differently.

This is a Samuelson condition where f_g is the social marginal benefit of emissions (higher output) and the right side is the social marginal cost in terms of household utility foregone.//

The theorem and proof hold *only* if the community levies an optimal tax on capital since the result relies on the tax first order condition leading to a cancelation of the ‘distorting’ terms in (18). If a tax consistent with equation (13) is implemented the first order condition for emissions is just (19) above. Essentially, the two first order necessary conditions collapse to equation (13) defining the optimal tax, and equation (19) defining (efficient) provision of environmental policy. The government never disturbs the marginal social benefit/cost rule for provision of emissions in order to manipulate the price of capital, and the capital supply.

Importantly the result holds for all capital market structures and the optimal tax that goes with each. For example, the optimal tax is equal to the marginal product of capital in the community when $\varepsilon = 0$. If this capital market structure applies then as long as the government chooses a tax on capital consistent with $t^* = r$ one can be sure that emissions are provided consistent with (19). Similarly, when $0 < \varepsilon < \infty$ then if the tax (or subsidy) satisfies (13), emissions are efficient. Yet this is a clear case which diverges from the Oates and Schwab model since here the supply of capital to the economy is imperfectly elastic and the government has an incentive to use its policies to favorably influence its net capital price relative to the given world price. But from Theorem 1 only the tax is used to manipulate the capital price and environmental policy remains undistorted. Finally, if $\varepsilon \to \infty$ capital supply is perfectly elastic and $t^* \to 0$. This is the Oates and Schwab result that when capital is perfectly mobile the optimal tax is zero.

The Theorem and proof broaden the Oates and Schwab case to show that even when a community diverges from a zero tax policy to manipulate its own capital price, environmental policy is still efficient; the tax alone is assigned to the task of obtaining the most favorable capital price and environmental policy is undistorted.

The following explanation for this preference to use the tax to manipulate the domestic capital price relative to the world price, rather than distort environmental policy, is offered. The two fiscal instruments g and t are similar in terms of their impact on capital price and supply with *two* differences. First any change in emissions has a cost (or benefit) in terms of its direct impact on household welfare that the tax does not. This arises because households' care directly about emissions and g is an argument of the utility function. Second changes in emissions have a direct effect on output and hence consumption that the tax does not. This arises because g is an argument of the production function. The implication is that a given change in emissions has marginal costs and benefits that *exceed* the marginal costs and benefits of a given change in the tax yet they have (almost) identical effects on the price of capital and its supply. So it is always optimal for a welfare maximizing (and hence cost minimizing) government to vary the tax and not emissions to obtain its desired domestic capital price and supply.

4.2 Single instrument (no capital tax)

Now suppose that the community cannot levy the per unit capital tax and chooses only g to maximize per capita household utility subject to the capital market condition (5). The net return to capital is $x = r(k,g)$ and the first order condition for emissions becomes

$$r_k k \frac{\partial k}{\partial g} + f_g = -H \frac{U_g}{U_X} + r_g k \tag{20}$$

The second term f_g on the left side is the social marginal benefit of emissions and the first term on the right is the social marginal cost, as shown in Theorem 1. In an equilibrium satisfying (20) the outcome is inefficient since there is no longer an optimal tax to cancel the distorting terms present in (20), as occurs in Theorem 1 and its proof.

However, it is not possible to show whether environmental policy is under or over provided relative to levels consistent with the Samuelson condition. This can be appreciated by noting that the marginal cost of emissions with no tax is *higher* than the marginal cost with the tax, that is

$$-H \frac{U_g}{U_X} + r_g k > -H \frac{U_g}{U_X}. \tag{21}$$

The marginal benefit of emissions with no tax is also *higher* than the marginal benefit with a tax, that is

$$r_k k \frac{\partial k}{\partial g} + f_g > f_g \,. \quad (22)$$

Hence, the marginal cost *and* marginal benefit of emissions are both higher when the government has no tax instrument relative to the marginal costs and benefits when it does have the tax. As a result, one cannot say in general whether environmental policy is under or over provided relative to socially optimal levels, only that it is inefficient.

A theorem on efficiency absent the capital tax is now stated without proof:

Theorem 2: *If the government has no tax on mobile capital then any choice of emissions consistent with the first order necessary condition (20) is in general inefficient.*

When denied its lowest cost instrument for manipulating the domestic capital price relative to the fixed world price, the welfare maximizing government accepts *some* distortion to environmental policy to achieve its desired capital price. It should also be noted here that environmental standards are inefficiently provided under all three capital market structures, including the Oates and Schwab case where $t^* \to \infty$, the domestic return approaches the given world return and capital is perfectly mobile.

5. Two-states: Is there a race to the bottom?

Suppose now that the community is one of two sub-national jurisdictions (or states) within a federation. Each state provides environmental policy and sets a tax on capital. This extension allows one to say something about the environmental *race to the bottom* literature which argues that game playing states engaged in non-cooperative behavior degrade environmental standards to attract mobile capital, labor or firms.

The added complexity from this extension relates to the capital market. In this respect, it is assumed that capital is *perfectly* mobile between states while the federation as a whole faces a capital supply analogous to (5). Thus, capital flows without restriction within the federation in response to state policies (a common capital market) but capital supply to the federation is subject to potential imperfections. The other assumptions for the single community model are assumed to hold for each state except that now all capital is assumed to be foreign owned. The analysis proceeds by assuming that state *i* is the decision-maker but the results apply whichever state has this role.

In view of this set up capital is assumed to move *freely* between states to satisfy

$$x_i = x_j = x \tag{23}$$

where $x_i = r_i(k_i, g_i) - t_i$ is the net capital price in state *i* and x_j is the net capital price in state *j*. In equilibrium both returns must be equal to the federation-wide net return x.

This no-arbitrage condition is often seen in models of federations with tax competition where some given supply of capital migrates freely across jurisdictions. However, consistent with the way in which capital supply to the single country was modeled above, here the total supply of capital K to the federation is assumed to be a monotonically non-decreasing function of the federation-wide net price *x*. From (23) the equal net return *x* is also the net return in state *i* so one can define the total supply of capital to the federation as a non-decreasing function of the net return in state *i* alone

$$K = k_i + k_j = K(x_i) \tag{24}$$

As in the single economy case capital supply can be perfectly inelastic (vertical supply curve), non-decreasing in the federation-wide return or perfectly elastic. There are now two capital market equilibrium conditions but they can be collapsed into one condition by rewriting (24) as $k_j = K(x_i) - k_i$ and using this in (23) to obtain

$$r_i(k_i, g_i) - t_i = r_j(K(x_i) - k_i, g_j) - t_j\,. \tag{25}$$

The utility of a household in state *j* is

$$U\left(\frac{f_i(k_i, g_i) - x_i k_i}{H_i}, g_i\right). \tag{26}$$

The combined equilibrium condition (25) implies that the choice of emissions in state *i* influences its own supply of capital, but also the capital supply to the federation through its effect on the gross return to capital in state *i*. Since the welfare of households in state *j* depends on the total supply of capital to the federation the emissions choice of state *i* influences welfare in state *j* and vice versa. By the same logic the tax choice made by state *i* affects welfare in state *j* and vice versa. Hence, the problem is considered to be a non-cooperative game. With Nash conjectures a state chooses its policies conditional on the choices of its neighbor to maximize the utility of a representative household. The first order necessary conditions are identical to (11) and (16) respectively.

However, the capital supply responses are more complex since they now account for the migration of capital *between* states as well as the (imperfect) migration of capital in (and out) of the federation. Nevertheless it can be shown[10] that the relationship identified at (17) for the single community also applies to states in a federation, that is,

$$\frac{\partial k_i}{\partial g_i} = -\frac{\partial r_i}{\partial g_i}\frac{\partial k_i}{\partial t_i}. \tag{27}$$

As in the single community model this can be used to show that the first order necessary condition for emissions in state *i* collapses to a Samuelson condition. If the state uses its tax optimally the distorting terms that would otherwise affect provision of environmental standards cancel and the 'efficient emissions' result applies to states in a federation.[11] Hence, if a community chooses efficient emissions as an autonomous decision-maker so too will a community within a federation. It can also be shown that if the state does not have access to a capital tax only then will it engage in inefficient provision of environmental standards (as in the single country case). Also, as shown for the single community case the efficiency results hold for all types of capital market assumptions. Unlike the common finding in the race to the bottom literature, in the model developed here deviations from efficient behavior only emerge when one restricts the policy set to exclude the capital tax. Otherwise there is no 'race'.

6. Conclusion

This paper has examined whether communities, acting autonomously or as sub-national jurisdictions within federations, distort environmental policy to manipulate their capital terms of trade. The model adopted is similar to Oates and Schwab with one main difference; the supply of capital to the community is not perfectly elastic. Rather, capital supply is *(i)* perfectly inelastic; *(ii)* a non-decreasing function of the domestic capital price relative to the given outside (world) price or *(iii)* perfectly elastic.

[10] The derivation of (27) for the two-state case is available on request.
[11] A formal demonstration of this is available on request.

This feature of the model, and in particular *(ii)* above, endows a community with an incentive to use its policies to influence its capital price. The paper shows that if the community does *not* have a capital tax then it will distort environmental policy to take advantage of this opportunity. Hence, capital market imperfections can lead to distortions in environmental policy. This result is very much in keeping with the flavor of the findings in the race to the bottom literature, namely, that capital mobility entices communities to adopt inefficient environmental policies in exchange for some other benefit, such as a more favorable domestic capital price.

The contribution of the paper is to show that such inefficiency *never* eventuates if the community, whether acting alone, or as part of a federation, has a policy vector that includes a capital tax. In this instance it always prefers to use the tax to manipulate its capital price, rather than distort environmental policy. This is because the cost-benefit calculus associated with using the tax to manipulate the domestic capital price is more favorable. The results challenge the race to the bottom (or top) idea, at least when the desire to distort policies arises from capital market imperfections. The paper also highlights that inefficient outcomes are only obtained when capital markets are imperfect *if* the strategy set is restricted to exclude the capital tax. It is this restriction that creates inefficient standards rather than the presence of non-cooperative game playing between states, or the capital market imperfections that give rise to incentives to distort policies.

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