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**DYNAMIC ENVIRONMENTAL POLICY IN DEVELOPING
COUNTRIES WITH A DUAL ECONOMY**

by

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COUNTRIES WITH A DUAL ECONOMY**

Dug Man Lee and Amitrajeet A. Batabyal

ABSTRACT

We analyze a dynamic model of environmental policy in a stylized developing country (DC) with a dual economy. This DC's economy is distorted because the government subsidizes the exports of the non-polluting sector of the economy. We analyze the employment and output effects of three different pollution taxes. These taxes incorporate alternate assumptions about the DC government's ability to commit to its announced course of action. We describe the taxes, we examine the dependence of these taxes on the extant distortion, and we stipulate the conditions that call for an activist policy, irrespective of the length of time to which the government can commit to its announced policy. *Inter alia*, our analysis shows why some DC governments may not be serious about environmental protection.

JEL Classification: O20, Q20

Key words: commitment, developing country, environmental policy, export subsidy

DYNAMIC ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES WITH A DUAL ECONOMY¹

1. Introduction

In recent times, issues at the interface of development and environmental economics have elicited a considerable amount of interest. On the one hand, researchers such as Bhalla (1992), Renner (1992), and Mehnet (1995) have argued that developing countries (DCs) need to take steps to design and follow through with policies that generate employment. On the other hand, the sizeable literature on sustainable development² has stressed the need for implementing policies that will protect the environment for the present and future generations.

The experience of industrialized countries with environmental policies tells us that these policies can have a negative effect on employment (Christainsen and Tietenberg, 1985; Bonetti and FitzRoy, 1999). This and other similar findings have led many observers to contend that in the face of urgent employment creation needs, DC governments are unlikely to be serious about environmental protection. In other words, although DC governments may begin the process of designing appropriate environmental policies, over time, their *commitment* to such policies is likely to wane.

The purpose of this paper is to study this issue formally. We do this by analyzing a dynamic model of a DC with a dual economy. This model explicitly links the DC government's period of commitment to its announced employment/environmental policies. As Lekakis (1991) and Mehmet (1995) have noted, despite its significance, this issue has received scant attention in the economics

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²For more on this literature, the reader should consult Brundtland (1987), Goldin and Winters (1995), Faucheux et al. (1996), Atkinson et al. (1997).

literature.

Very recently, Batabyal (1998) and Batabyal and Beladi (1999) have analyzed dynamic models of environmental policy in DCs. In a two sector model, Batabyal (1998) shows that the welfare gain from correcting for pollution is generally bigger than the welfare loss from being unable to commit to a particular environmental policy. As such, optimality calls for the DC government to conduct an activist environmental policy, regardless of the length of time to which this government can commit to its announced policy. Batabyal and Beladi (1999) have extended this analysis and studied the nature of dynamic environmental policy when the polluting sector—also the import competing sector—of the DC is protected with an import tariff. They show that in the presence of this existing distortion, i.e., the import tariff, the optimal pollution tax may be zero or even negative. From this, Batabyal and Beladi (1999) conclude that the existing distortion in the polluting sector can have a detrimental impact on the DC government's ability to conduct environmental policy successfully.

Historically, a number of DCs have protected their export sectors with subsidies to exporters. For instance, in the 1990s, Thailand has provided subsidies on government to government sales of rice. Tajikistan has subsidized the export of aluminum, and Venezuela has granted bonuses to the exporters of certain kinds of agricultural products (Department of State, 1996). Given this state of affairs, we analyze the conduct of environmental policy in a DC in which the export—also the environmentally benign—sector is protected with an export subsidy. The specific question that we address is the following: What are the properties of optimal environmental policy when a DC government corrects for pollution by taxing the production of the good manufactured by the polluting—also the import competing—sector, and when this government is unable to commit to

the tax policy that it announced at the beginning of its tenure in office? In contrast with some of the results obtained by Batabyal and Beladi (1999), we show that an existing distortion in the export sector will have only a slight impact on a DC government's ability to conduct environmental policy effectively.

The rest of this paper is organized as follows: Section 2 describes the theoretical framework in detail. Sections 3 through 5 examine a dynamic model of environmental policy in a DC, under three different assumptions about the ability of this DC government to commit to its initially announced policy. Section 6 concludes, and offers suggestions for future research.

2. The Theoretical Framework

This paper's model is in the tradition of Mussa (1978), Karp and Paul (1994), Batabyal (1998), and Batabyal and Beladi (1999). These papers have all studied aspects of government policymaking in an intertemporal framework. We use the specific factors model to analyze a small DC. This DC's economy is dualistic. One sector is the traditional, low wage sector in which there is no pollution. This traditional sector is also the export sector of the economy, and the DC government protects this sector by granting a subsidy to exporters. For political reasons, this subsidy cannot be repealed. Consequently, in the rest of this paper, we treat the subsidy as an exogenous parameter. The second sector is the modern, high wage sector in which production causes pollution. This modern sector is also the import competing sector of the DC.³

In order to earn higher wages, workers migrate from the traditional to the modern sector. This migration leads to increased employment in the modern sector. In turn, this increased employment

³The reader may want to think of the traditional sector as the agricultural sector, and the modern—possibly the infant industry—sector as the steel sector.

leads to higher production, and hence to higher pollution. In their role as consumers, workers are detrimentally affected by pollution. Despite this, we suppose that they do *not* account for pollution in their migration decisions. This means that the marginal migrant pays less than the marginal social cost of pollution. In this setting, the first best policy is to tax pollution directly. However as Batabyal and Beladi (1999) have noted, in many DCs, governments do not have the ability to tax pollution directly. Therefore, we suppose that the DC government functions in a second best environment in which the best that it can do is to tax the production of the polluting good.

Initially, the DC government does nothing to correct the distorted incentives faced by producers in the polluting sector. As such, the DC economy is in disequilibrium and the “balance of trade” account is unbalanced.⁴ A movement toward equilibrium involves retarding the rate at which workers migrate from the traditional sector to the modern sector. Put differently, a move toward equilibrium requires a diminution in the production of the polluting good over time. We suppose that workers have rational expectations. In our deterministic model, this means that workers have perfect foresight.

Each sector of the DC produces a single good using a fixed factor and a mobile factor called labor, with decreasing returns to scale. Superscripts on production variables will denote the sector and superscripts on consumption variables will denote the agent. Subscripts will denote partial derivatives. Let $L^i(t)$, $i=1,2$, denote the labor employed by the i th sector at time t ; time is continuous. $\hat{L}$ denotes the DC’s fixed labor endowment. This means that $\hat{L}=L^1(t)+L^2(t)$. Good 2 is the polluting—and the import competing—good. Let $\tau_s(t)$ denote the existing export subsidy in

⁴We suppose that initially, the balance of trade account is in surplus. Batabyal (1998) and Batabyal and Beladi (1999) have analyzed the case in which initially, this account is in deficit.

sector 1. The government's environmental policy instrument is a tax, $\tau_p(t)$, that is levied on the production of good 2.

Following Karp and Paul (1994), Batabyal (1998), and Batabyal and Beladi (1999), we use duality theory to model consumption and production decisions in the DC. The production function in the i th sector, $i=1,2$, is $f^i(L^i)$. Let the price of the i th sector's good be p^i , and let $L^2=L$, and $L^1=\hat{L}-L$. Then we can write the revenue functions in the two sectors as $R^1(p^1+\tau_s, \hat{L}-L)$ and $R^2(p^2-\tau_p, L)$, respectively. Note that $R_1^i(\cdot, \cdot)$ and $R_2^i(\cdot, \cdot)$ denote the output supply of good i and the wage in sector i , respectively.⁵

A continuum of identical workers exist in each sector of the DC economy and a single capitalist is the residual claimant. All agents have homothetic preferences. Hence, the expenditure function of agent j , $j=1,2,3$, can be written as $\bar{E}(p^1+\tau_s, p^2, u^j)=U^j E(p^1+\tau_s, p^2)$, where $E(\cdot, \cdot)$ is the unit expenditure function and U^j is the j th agent's real income. The DC's national income is $U \equiv (\hat{L}-L)U^1 + LU^2 + U^3$. The superscript j denotes the representative worker in sector j , and $j=3$ denotes the capitalist.

Let the private value of migration for any worker at time t be $m(t)$. In other words, $m(t)$ denotes the present value of the wage differential between the high wage polluting sector and the low wage non-polluting sector. Formally, we have

$$m(t) = \int_t^{\infty} e^{-r(s-t)} \{R_2^2(\cdot, \cdot) - R_2^1(\cdot, \cdot)\} ds, \quad (1)$$

⁵For more on the properties of these dual functions, the reader should consult Dixit and Norman (1980, chapter 2).

where r is the discount rate. This integral equation can be converted into a differential equation.

That equation is

$$dm/dt = \dot{m} = rm + R_2^1(\cdot, \cdot) - R_2^2(\cdot, \cdot). \quad (2)$$

We suppose that a worker will migrate to the modern sector if and only if the private value of migration, $m(t)$, is at least as high as the private cost of migration. Even so, because workers do not account for pollution in their migration decisions, the social cost of migration is *not* equal to the private cost of migration. For simplicity, suppose that the social cost of migration is quadratic. Then $C(\dot{L}) = \alpha(\dot{L})^2$, with $\alpha > 0$. With this specification of the migration cost function, the average social cost of migration ($\alpha\dot{L}$), is less than the marginal social cost ($2\alpha\dot{L}$). This means that in the absence of governmental intervention, migration for high wage employment in the polluting sector takes place too rapidly, thereby increasing environmental degradation.

To account for the fact that the private cost of migration is less than the social cost of migration, suppose that the decision to migrate is based on a fraction δ , $0 < \delta < 1$, of the marginal social cost $2\alpha\dot{L}$. In other words, the migrating workers do not fully internalize the externality stemming in part from their decision to migrate. Now if we equate the private value of migration with the private cost of migration, we get an equation for the dynamics of labor migration.⁶ That equation is

$$\frac{dL}{dt} = \dot{L} = \frac{m}{2\alpha\delta}. \quad (3)$$

⁶If migration is affected by the private value of migration and by the pollution tax, then the expression for $\dot{L}$ in equation (3) would have to be replaced by $\dot{L} = g(m, \tau_p)$ for some function $g(\cdot, \cdot)$. However, with this general functional form, it is not possible to derive closed form expressions for the optimal values of the pollution tax. This is the reason for working with the expression for $\dot{L}$ given in equation (3).

Although our DC economy is open, we shall disallow the possibility of international borrowing. This means that in equilibrium, trade must be balanced. In other words,

$$D(U, L, m, \tau_s, \tau_p) = UE(\cdot, \cdot) + \frac{m^2}{4\alpha\delta^2} - R^1(\cdot, \cdot) - R^2(\cdot, \cdot) + \tau_s[R_1^1(\cdot, \cdot) - UE_1(\cdot, \cdot)] - \tau_p R_1^2(\cdot, \cdot) = 0 \quad (4)$$

must hold. The first term on the RHS of equation (4) denotes consumption expenditures. The second term on the RHS of equation (4)—which equals $C(\dot{L})$ —denotes the social cost of pollution. The third and the fourth terms give the value of production. The fifth term denotes the value of the subsidy granted by the DC government to exporters of good 1. The sixth term denotes pollution tax revenue; this is assumed to be redistributed in lump sum fashion.

Let us now study the DC government's optimal intertemporal environmental policy under three assumptions about its ability to commit to a particular course of action. In the first case, the government commits to its announced tax policy for an infinite period of time. The reader may want to interpret this infinite period of commitment as a case in which environmental protection is enshrined in the constitution. When this is done, it does not matter which government is in office because the constitution will have to be followed. In the second case, the DC government commits to its tax policy for a finite period of time. This finite period of commitment can be thought of as the length of time during which a particular government is in office. As we shall see, in both these cases, the government's optimal tax policy is time inconsistent. This means that at some time $\varepsilon > 0$, the government will want to depart from the tax policy it said it would follow at time $t=0$. Because this government's pollution tax policy is time inconsistent, it is *not* credible. The unfortunate effect of this lack of credibility is that forward looking workers will not believe that the government will

actually carry through with its initially proclaimed policy. As a result, this policy will fail to achieve its objectives.

Because the credibility of government policy has been a salient issue in many DCs, it is useful to study the consequences of following a time consistent course of action.⁷ This is the third case that we study. In this case, the government commits to its tax policy for an infinitesimal period of time. In the limit as this period of commitment tends to zero, the government's tax policy is time consistent. We now analyze the government's problem when it commits to its tax policy for an infinite period of time.

3. The Perfect Commitment Case

In this case, the DC government makes a binding commitment and selects its tax policy from time $t=0$ to $t=\infty$, at $t=0$. This is the government's open loop tax policy. The open loop pollution tax is a function of calendar time only. Workers have perfect foresight and they are forward looking. Because the economy is initially in disequilibrium, the initial value of L in the modern sector, $L(0)=L_0$, is not equal to its stationary state value. Further, because the decision to migrate is an investment decision, the private value of migration at time t , $m(t)$, is determined by the current *and* the future values of the pollution tax. The important consequence of this fact is that equation (2) is actually a jump state constraint.⁸ Mathematically, this means that the initial value of m , $m(0)$, is endogenous to the problem. In this setting, the DC government solves

⁷Recall the section 1 discussion of the concern about the lack of commitment in DC government policies. for more on this, the reader should consult Fanelli *et al.* (1992).

⁸For more on jump state constraints, the reader should consult Karp and Newbery (1993), Karp and Paul (1994), and Batabyal (1998).

$$\max_{\{U, \tau_p\}} \int_0^{\infty} e^{-rs} U ds, \quad (5)$$

subject to constraints (2)-(4), with initial condition $L(0)=L_0$. The current value Hamiltonian for this problem is

$$\begin{aligned} H = & U - \lambda [UE(\cdot, \cdot) + \frac{m^2}{4\alpha\delta^2} - R^1(\cdot, \cdot) - R^2(\cdot, \cdot) + \tau_s \{R_1^1(\cdot, \cdot) - UE_1(\cdot, \cdot)\} - \tau_p R_1^2(\cdot, \cdot)] \\ & + \sigma_1 \left\{ \frac{m}{2\alpha\delta} \right\} + \sigma_2 \{rm + R_2^1(\cdot, \cdot) - R_2^2(\cdot, \cdot)\}, \end{aligned} \quad (6)$$

where λ is the Lagrange multiplier on constraint (4), and σ_1 and σ_2 are the costate variables on L and m , respectively. The first order necessary conditions are

$$\lambda = \frac{1}{E(\cdot, \cdot) - \tau_s E_1(\cdot, \cdot)}, \quad (7)$$

$$\sigma_2 R_{21}^2(\cdot, \cdot) - \lambda \tau_p R_{11}^2(\cdot, \cdot) = 0, \quad (8)$$

$$\dot{\sigma}_1 = r\sigma_1 + \lambda \{d(\cdot, \cdot) - \tau_s R_{12}^1(\cdot, \cdot) - \tau_p R_{12}^2(\cdot, \cdot)\} + \sigma_2 h(\cdot, \cdot), \quad (9)$$

and

$$\dot{\sigma}_2 = \frac{\lambda m}{2\alpha\delta^2} - \frac{\sigma_1}{2\alpha\delta}, \quad (10)$$

where $d(\cdot, \cdot) \equiv R_2^1(\cdot, \cdot) - R_2^2(\cdot, \cdot)$, and $h(\cdot, \cdot) \equiv R_{22}^1(\cdot, \cdot) + R_{22}^2(\cdot, \cdot)$. In words, $-d(\cdot, \cdot)$ denotes the current private value of migration, and $h(\cdot, \cdot)$ denotes the sum of the marginal products of labor in the two sectors.

Note that $h(\cdot, \cdot) = \partial \{-d(\cdot, \cdot)\} / \partial L < 0$.

The above first order conditions can be used to shed light on the optimal pollution tax trajectory and to study the dependence of this tax on the export subsidy $\tau_s(t)$. To this end, let us denote stationary values by the superscript S . Equation (3) tells us that $m^S=0$. Equation (2) reveals that $d^S(\cdot,\cdot)=0$. Equation (10) gives $\sigma_1^S=0$. From equation (8) we get $\sigma_2^S=[\lambda\tau_p R_{11}^2(\cdot,\cdot)/R_{21}^2(\cdot,\cdot)]^S$, and equation (9) yields $\sigma_2^S=[\lambda\{\tau_s R_{12}^1(\cdot,\cdot)+\tau_p R_{12}^2\}/h(\cdot,\cdot)]^S$. Setting these last two expressions equal gives $\tau_p^S=[\tau_s R_{12}^1(\cdot,\cdot)R_{21}^2(\cdot,\cdot)/\{R_{11}^2(\cdot,\cdot)h(\cdot,\cdot)-R_{12}^2(\cdot,\cdot)R_{21}^2(\cdot,\cdot)\}]^S$. From equation (8), it follows that $\tau_p(t)=[\sigma_2(t)R_{21}^2(\cdot,\cdot)/\lambda(t)R_{11}^2(\cdot,\cdot)]$. As Simaan and Cruz (1973) have noted, because $m(0)$ is free, the right boundary condition for σ_2 is $\sigma_2(0)=0$. This means that the DC government selects its tax policy so that the initial social shadow value of m is zero. Using $\sigma_2(0)=0$, we get $\tau_p(0)=0$. Let us now write the three tax expressions compactly. We get

$$\tau_p(0)=0, \quad \tau_p(t)=\frac{\sigma_2(t)R_{21}^2(\cdot,\cdot)}{\lambda(t)R_{11}^2(\cdot,\cdot)}, \quad \tau_p^S=\left[\frac{\tau_s R_{12}^1(\cdot,\cdot)R_{21}^2(\cdot,\cdot)}{R_{11}^2(\cdot,\cdot)h(\cdot,\cdot)-R_{12}^2(\cdot,\cdot)R_{21}^2(\cdot,\cdot)}\right]^S. \quad (11)$$

3.1. Discussion

Recall that $h(\cdot,\cdot)<0$. As discussed in Dixit and Norman (1980, pp. 35-43), the signs of the partial derivatives in equation (11) are as follows: $R_{11}^i(\cdot,\cdot)>0$, $R_{22}^i(\cdot,\cdot)<0$, $R_{12}^i(\cdot,\cdot)>0$, and $R_{21}^i(\cdot,\cdot)>0$, for $i=1,2$. Further, because $\sigma_2(t)$ is the shadow value of $m(t)$, it will generally be positive. Finally, $\lambda(t)$, the multiplier on the balance of trade constraint, will also generally be positive. Now using this pattern of signs in equation (11), we get $\tau_p(t)>0$ and $\tau_p^S<0$. This tells us that in an optimal program, the government begins with a zero tax. It then raises this tax over the length of the program, and then lowers the tax so that in the stationary state, the pollution tax is actually a subsidy.

To see why the initial pollution tax is zero, recall that in our second best environment, the

purpose of this tax is to influence the rate of migration from the traditional to the modern sector. Now migration is an investment decision; as such, it involves balancing future benefits with current costs. A positive tax in the future discourages migration in the present period; call this the policy effect of the tax. In particular, the future tax moves the migration decision toward the socially optimal level. However, the future tax also leads to future distortions in production. Hence, from the standpoint of $t=0$, a positive tax at $t>0$ involves balancing a current benefit with a future cost. This is exactly the opposite of the private migration decision which involves balancing future benefits with a current cost. A tax at $t=0$ involves costs, but there are no previous migration decisions for this tax to influence. Put differently, a tax at $t=0$ involves costs but it has no policy effect. This is why the optimal initial tax is zero.

Why is the optimal steady state pollution tax negative, i.e., a subsidy? To answer this question, recall that the purpose of the tax is to influence the rate of migration from the traditional to the modern sector, and observe from equation (11) that the existing distortion (export subsidy) affects the optimal pollution tax at $t=\infty$ only, and at no other point in time. However, in the steady state, the private value of migration $m^S=0$. This means that workers have no incentive to migrate from the traditional to the modern sector. Hence, from the standpoint of migration or pollution control, there is nothing to control. Put differently, the optimal pollution tax has no role to play. Despite this, the steady state level of labor in the two sectors is *not* optimal. This is because the positive export subsidy draws more than the optimal amount of labor into the traditional sector. As such, to encourage some migration from the traditional to the modern sector in the stationary state, and only in the stationary state, the government grants a subsidy to the producers of the polluting good. This subsidy ensures that the steady state level of labor in the two sectors is socially optimal.

In this open loop case that we have been discussing so far, there is no welfare loss to society from the government's inability to commit to its announced pollution tax policy. This is because, by definition, the open loop policy incorporates perfect commitment. This suggests that the following conjecture is true: Doing nothing, i.e., setting a zero pollution tax at all points in time, is a suboptimal course of action. Surprisingly, this conjecture is false. A sufficient condition under which this conjecture is false is when the revenue function in the polluting sector is separable in its arguments. In this case, $R_{12}^2(\cdot, \cdot) = R_{21}^2(\cdot, \cdot) = 0$, and it follows from equation (11) that it is optimal to set $\tau_p(t) = 0, \forall t \in [0, \infty]$.

The results of this section differ substantially from the results obtained by Batabyal and Beladi (1999). They showed that the DC government's optimal open loop pollution tax policy *is* affected by the extant distortion (the import tariff) at all points in the program. In contrast, we have seen that the export subsidy affects the optimal pollution tax only in the stationary state. This suggests that the extent to which existing distortions will affect a DC government's ability to conduct environmental policy efficaciously depends critically on the sector in which the distortion lies. As compared to distortions in the non-polluting sector, distortions in the polluting sector would appear to have a more damaging impact on the ability of the DC government to conduct environmental policy effectively.

If the DC government's open loop tax policy is believed by the workers, then this policy will achieve its objectives. In particular, the pollution tax will reduce output and employment in sector 2 and slow the rate of migration from the traditional to the modern sector. However, the government's objectives will *not* be met because the government's open loop tax policy is time inconsistent. In other words, the government will have an incentive to depart from the policy it

announced at $t=0$. To see why, note that for any initial value of L , $L(0) \neq L^S$, the optimal initial shadow value of $m(t)$, $\sigma_2(t)=0$. Nevertheless, because $\delta < 1$, on the announced tax trajectory $\sigma_2(t) \neq 0$. This means that at any time $\varepsilon > 0$, the government will want to depart from the tax trajectory it announced at $t=0$, and announce a new trajectory. What this means is that in the absence of a device that can bind the government to its initially announced tax policy, this government will fail to achieve its initially announced employment and environmental objectives.

As noted by Batabyal (1998), the case of perfect commitment is unpersuasive because no government can credibly commit to policy for an infinite period of time. Consequently, we now examine the case in which the DC government commits to its initially announced policy for a finite period of time. This is the limited commitment case.

4. The Limited Commitment Case

Governments are generally in office for a limited amount of time. Consequently, the most sensible period of commitment equals the length of time during which a particular government is in office. So, let us now analyze the case in which the DC government commits to a policy for $T \in (0, \infty)$ time periods.

When the period of commitment is finite, an examination of the government's optimal program is complicated by the fact that the resulting equilibrium depends on the manner in which agents form their expectations. If workers base their expectations of future taxes on the history of taxes, then multiple equilibria can arise. To obviate this problem, we shall focus on smooth Markov perfect equilibria. "Markov" means that the decision rules of the agents at time t depend only on the current value of the state (stock of labor) and not on the manner in which the current state was reached. A prospect for an equilibrium is perfect if this prospect is an equilibrium for any possible

subgame (any possible level of the stock of labor). In particular, whether or not some agents have departed from their equilibrium strategies in the past, the continuation of these strategies represents equilibrium behavior for all the involved agents.

With this restriction of Markov perfection, we can now characterize the equilibrium that arises when the government commits to its tax policy for T periods. At points $0, T, 2T, \dots$, successive governments select their tax policies. Put differently, at each iT , $i=0,1,2,\dots$, the i th government completes its tenure in office and a new government selects its tax policy for the next T periods. At the end of T periods, each government bequeaths the current stock of labor, L_T , to its successor government. This government then pursues its environmental policy for the next T periods, and so on.

Let $V(L)$ be the value of the government's program when its period of commitment is T and when the initial level of labor in the modern sector is L . The DC government solves

$$V(L) = \max_{\{U, \tau_p\}} \int_0^T e^{-rt} U dt + e^{-rT} V(L_T), \quad (12)$$

subject to constraints (2)-(4). $V(L_T)$ is a bequest function. This function denotes the value of the stock of labor bequeathed by an arbitrary government to its successor. Note that except for the fact that the government's period of commitment is now T and not ∞ , problem (12) is the same as problem (5). This means that the first order necessary conditions to this problem will remain as in equations (7)-(10). The boundary conditions, however, will change.

Because $m(0)$ is free, it is optimal to select the tax trajectory so that $\sigma_2(0)=0$. Using this condition in equation (8), we get $\tau_p(0)=0$. As indicated in equation (11),

$\tau_p(t) = [\sigma_2(t)R_{21}^2(\cdot, \cdot) / \lambda(t)R_{11}^2(\cdot, \cdot)]$. To determine $\tau_p(T)$, let $M(L)$ ⁹ denote the equilibrium current value of m that is determined by the solution to problem (12). Then, we can write $V(L) \equiv \hat{V}\{L, M(L)\}$, for some function $\hat{V}\{\cdot, \cdot\}$. At the beginning of a particular time period iT , $i=0, 1, 2, \dots$, we have $\sigma_2(iT)=0$. Further, the assumed differentiability of the value function gives $\sigma_2 = \partial \hat{V}(\cdot, \cdot) / \partial M$ (Karp and Paul, 1994, p. 1388; Batabyal, 1998, p. 15). This means that the social shadow value of $M(\cdot)$ is equal to the marginal value of $M(\cdot)$ in the bequest. Finally, the transversality condition for σ_2 is $\sigma_2(T) = \partial \hat{V}(\cdot, \cdot) / \partial M = 0$. Using this condition in equation (8) gives $\tau_p(T)=0$. Let us now write the three tax expressions compactly. We get

$$\tau_p(0)=0, \quad \tau_p(t) = \frac{\sigma_2(t)R_{21}^2(\cdot, \cdot)}{\lambda(t)R_{11}^2(\cdot, \cdot)}, \quad \tau_p(T)=0. \quad (13)$$

4.1. Discussion

Comparing the three tax expressions in equations (11) and (13), we see that a diminution in the length of the government's period of commitment has no impact on either $\tau_p(0)$ or $\tau_p(t)$. However, $\tau_p(T)$ differs from τ_p^s . This is because the transversality condition $\sigma_2(T)=0$ —which does not apply in the perfect commitment case—can be used to simplify the expression for $\tau_p(T)$. An important implication of this is that the existing distortion (export subsidy) now has absolutely no effect on the DC government's optimal pollution tax policy. This result differs from the finding of Batabyal and Beladi (1999). In their model, the pollution tax is a function of the existing distortion (import tariff) at all points in the optimal program. Once again, this difference highlights the salience

⁹For more details on this endogenous function of the state variable, the reader should consult Karp and Newbery (1993) and Karp and Paul (1994).

of the *sector* in which the existing distortion is present. From the standpoint of policy efficacy, distortions that are not in the polluting sector are far less likely to have a detrimental impact on the DC government's ability to conduct environmental policy effectively.

As in section 3, the DC government's optimal tax policy is not always activist. In particular, if the modern sector's revenue function is separable in its arguments, then $R_{21}^2(\cdot, \cdot) = 0$ and equation (13) tells us that $\tau_p(t) = 0, \forall t \in [0, T]$. From the discussion in this section and in section 3.1, the reader will note that when the modern sector's revenue function is separable in its arguments, whether commitment is perfect or limited has *no* bearing on the government's optimal course of action. Put differently, the separability of the modern sector's revenue function is a sufficient condition for the nature of commitment not to matter.

The endogenous function of the state, $M(L)$, performs the role of an "expectations" function. When the DC government solves its maximization problem taking $M(\cdot)$ as given, the ensuing optimal program leads to an initial value of m , $m(0)$, that satisfies $m(0) = M\{L(0)\}$. This means that in equilibrium, every agent's point expectations are fulfilled. Moreover, this same optimal program leads to a final value of m so that $\sigma_2(T) = \partial \hat{V}(\cdot, \cdot) / \partial M = 0$. What this means is that at the horizon of the program, the shadow value of the state M , equals the marginal value of M in the bequest function, and these two values equal zero.

Regrettably, even in this limited commitment case, the resulting Markov perfect equilibrium is time inconsistent. To see this, imagine an infinite sequence of DC governments conducting environmental policy for T periods. Denote the tenure of each government in this sequence by $\{iT\}_{i=0}^{\infty}$. Whenever $T > 0$, governments act consistently at each i , but *not* in a period of length T . One can think of governments that begin their tenure in office with the desire to act consistently, but then

renege on the policy that they announced at the beginning of their tenure in office. Forward looking agents will not believe the policy announcements of such governments; consequently, the announced environmental policies of such governments will fail to achieve their employment and pollution objectives.

In the preceding analysis, we have seen that the steady state dependence of the pollution tax on the export subsidy, and more importantly, the time inconsistency of the government's optimal tax policy will prevent the government from achieving its employment and environmental goals. This raises the following question: How can the government's optimal tax policy be made time consistent? To answer this question, we now examine the limiting Markov perfect equilibrium in which the government's period of commitment shrinks to zero.

5. The Infinitesimal Commitment Case

In general, we would expect the DC government's Markov perfect equilibrium tax to be a function of three elements. The first element—the presence of pollution—suggests that the government adopt an activist policy to correct for this external diseconomy. The second element—the government's inability to commit to its tax policy—would appear to favor the *status quo*. As we have seen, the third element—the export subsidy—is irrelevant except in the steady state. Given this state of affairs, the important policy question concerns the relative strengths of the first two elements. In other words, does the first element dominate the second so that it is optimal to set a positive pollution tax? Alternately, does the second element dominate the first so that it is optimal to set a zero pollution tax? We now answer this question.

We follow Karp and Paul (1994) and Batabyal (1998) and begin with a discrete stage formulation of the DC government's problem. Let the government's period of commitment and the

length of each stage be ε . Further, suppose that all agents act at the beginning of each stage of length ε . Then at time t , the discrete versions of the two differential equation constraints—equations (3) and (2)—facing the government are

$$L_t = \left\{ \frac{m_t}{2\alpha\delta} \right\} \varepsilon + L_{t-\varepsilon}, \quad (14)$$

and

$$m_t = e^{-r\varepsilon} m_{t+\varepsilon} - d_t(\cdot, \cdot) \varepsilon. \quad (15)$$

In equation (14), $\{m_t/2\alpha\delta\}\varepsilon$ denotes the number of migrants in a stage of length ε . Similarly, in equation (15), $-d_t(\cdot, \cdot)\varepsilon$ represents the value of the flow of the wage differential in a stage of length ε .

At time t , with period of commitment ε , the government solves

$$V(L_{t-\varepsilon}) = \max_{\{U, \tau_p\}} [U - \lambda \{D(U, L, m, \tau_s, \tau_p)\}] \varepsilon + e^{-r\varepsilon} V(L_t), \quad (16)$$

subject to constraints (14) and (15). Here, $D(\cdot, \cdot, \cdot, \cdot, \cdot)$ denotes the balance of trade constraint described by equation (4), $m_{t+\varepsilon} = M(L_t)$, and the DC government takes the $M(\cdot)$ function as given. The first order necessary condition to problem (16) w.r.t. τ_p is

$$\lambda [\tau_p R_{11}^2(\cdot, \cdot) + \frac{\partial D(\cdot, \cdot, \cdot, \cdot, \cdot)}{\partial m_t} \cdot \frac{dm_t}{d\tau_p} + \frac{\partial D(\cdot, \cdot, \cdot, \cdot, \cdot)}{\partial L_t} \cdot \frac{dL_t}{d\tau_p}] \varepsilon - e^{-r\varepsilon} \frac{dV(\cdot)}{dL_t} \cdot \frac{dL_t}{d\tau_p} = 0. \quad (17)$$

To simplify equation (17), let us differentiate equations (14) and (15) totally. This yields

$$\frac{dL_t}{d\tau_p} = \frac{\varepsilon}{2\alpha\delta} \cdot \frac{dm_t}{d\tau_p}, \quad (18)$$

and

$$\{-h_t(\cdot, \cdot) \varepsilon - e^{-r\varepsilon} \frac{dM(\cdot)}{dL_t}\} \frac{dL_t}{d\tau_p} + \frac{dm_t}{d\tau_p} = -\left\{ \frac{\partial d_t(\cdot, \cdot)}{\partial \tau_p} \right\} \varepsilon. \quad (19)$$

Now substitute for $dL/d\tau_p$ from equation (18) into equation (19) and then simplify the resulting equation. This tells us that $dm/d\tau_p \sim O(\epsilon)$. Similarly, substituting for $dm/d\tau_p$ from equation (19) into equation (18) and then simplifying the ensuing equation gives $dL/d\tau_p \sim o(\epsilon)$. Finally, divide both sides of equation (17) by ϵ , use the results that $dm/d\tau_p \sim O(\epsilon)$ and $dL/d\tau_p \sim o(\epsilon)$, and then let $\epsilon \rightarrow 0$. The limiting first order necessary condition becomes

$$\lambda \tau_p R_{11}^2(\cdot, \cdot) = 0. \quad (20)$$

5.1. Discussion

As discussed in section 3.1, in general, $\lambda > 0$ and $R_{11}^2(\cdot, \cdot) > 0$. Hence, in the general case, the limiting Markov perfect pollution tax is zero. This means that the answer to the question posed in the first paragraph of section 5 is that in our model, the welfare loss from being unable to commit to environmental policy swamps the welfare gain from reducing pollution. As such, the limiting Markov perfect pollution tax is zero and it is optimal for the DC government to do nothing.

The limiting case that we analyzed in this section involves continuous revision of the pollution tax by the DC government. In addition to this, the limiting Markov perfect tax is not a function of the existing distortion (export subsidy). From this, we can draw two conclusions. First, when the DC government revises the pollution tax continually, the government's environmental policy is time consistent and hence credible. Second, unlike the case in Batabyal and Beladi (1999), in this limiting case, the existing distortion does *not* affect the government's optimal course of action.

Karp and Newbery (1993) have remarked that the payoff to an agent is monotonic in his period of commitment. As such, reducing the DC government's period of commitment can never make this government better off. This observation and the previous discussion of policy efficacy

enables us to rank the three pollution taxes in terms of the government's preference, and the ability

Table 1 about here

of the tax to accomplish its objectives. The government's payoff is highest with the open loop pollution tax. Consequently, as indicated in Table 1, the government will prefer this policy the most. The next best policy is the Markov perfect pollution tax, with an intermediate level of commitment. The least desirable policy is the limiting Markov perfect pollution tax which involves continuous policy revision. In contrast with this ranking, Table 1 tells us that the ranking in terms of goal attainment is exactly the opposite. The limiting Markov perfect pollution tax is credible; as such, this policy will be able to slow migration to the polluting sector and reduce pollution. The open loop and the Markov perfect pollution taxes are time inconsistent. Hence, these policies will fail to achieve the government's employment and environmental objectives. In sum, from the standpoint of goal attainment, the most desirable policy is the limiting Markov perfect pollution tax.

This discussion starkly illustrates the DC government's dilemma. The policy which leads to the highest payoff for the government is the one that is least likely to lead to the satisfaction of this government's policy goals. It is in this sense that the fear of observers who have worried that in the face of urgent employment creation needs, DC governments are unlikely to be serious about environmental protection, is justified.

6. Conclusions

In this paper, we examined the conduct of environmental policy by a DC government under three assumptions about this government's ability to commit to its announced policy. Four salient policy conclusions emerge. First, in general, the existing distortion has no effect on the optimal pollution taxes. This result and the analysis contained in Batabyal and Beladi (1999) together tell us

that the design of environmental policy in DCs should be informed by a knowledge of the sectors in which existing distortions lie. Distortions in the non-polluting sector are unlikely to have much of an impact on the government's ability to conduct environmental policy efficaciously.

Second, the inability to commit to an announced course of action is a serious roadblock to the conduct of successful environmental policy. Time inconsistent policies, particularly open loop policies, are impractical. Such policies will not be believed by forward looking agents with rational expectations. Hence, these agents will successfully thwart the DC government's policy objectives. This suggests that environmental protection should either be enshrined in the constitution, or it should be common knowledge that optimal pollution taxes will be revised frequently by the government.

Third, in contrast with the findings contained in Batabyal (1998) and in Batabyal and Beladi (1999), our analysis shows that in some situations, doing nothing, i.e., setting a zero pollution tax, is an optimal course of action. This is because in these situations, the welfare loss from being unable to commit to a specific policy swamps the welfare gain from reducing pollution.

Fourth, there is a basic tradeoff between policy credibility and policy payoff. Time consistent policies yield a lower payoff than do time inconsistent policies. This observation provides a possible explanation as to why many DC governments are loath to use time consistent policies. Moreover, this observation also tells us that the argument put forward by some observers that in the face of pressing employment creation needs, DC governments are unlikely to be serious about environmental protection, has some merit.

The analysis contained in this paper can be extended in a number of directions. In what follows, we suggest two potential extensions. First, it would be helpful to determine what impact

additional mobile factors of production have on a DC government's dynamic environmental policy.

Second, one can study the conduct of environmental policy in a dynamic and stochastic setting.

Studies which incorporate these aspects of the problem into the analysis will provide richer accounts of the nexuses between existing distortions, time consistency, and environmental policy.

Table 1: Properties and the Rankings of the Three Pollution Taxes

Criteria	Open Loop Pollution Tax	Markov Perfect Pollution Tax	Limiting Markov Perfect Pollution Tax
Government's Period of Commitment	∞	$T \in (0, \infty)$	$\varepsilon > 0$
Time Consistent?	No	No	Yes
Ranking From Government's Perspective	1	2	3
Ranking From Goal Attainment Perspective	3	2	1

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**DYNAMIC ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES WITH A
DUAL ECONOMY¹**

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1

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DYNAMIC ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES WITH A DUAL ECONOMY

Abstract

We analyze a dynamic model of environmental policy in a stylized developing country (DC) with a dual economy. This DC's economy is distorted because the government subsidizes the exports of the non-polluting sector of the economy. We analyze the employment and output effects of three different pollution taxes. These taxes incorporate alternate assumptions about the DC government's ability to commit to its announced course of action. We describe the taxes, we examine the dependence of these taxes on the extant distortion, and we stipulate the conditions which call for an activist policy, irrespective of the length of time to which the government can commit to its announced policy. *Inter alia*, our analysis shows why some DC governments may not be serious about environmental protection.

Keywords: Commitment, Developing Country, Environmental Policy, Export Subsidy

JEL Classification: O20, Q20

DYNAMIC ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES WITH A DUAL ECONOMY

1. Introduction

In recent times, issues at the interface of development and environmental economics have elicited a considerable amount of interest. On the one hand, researchers such as Bhalla (1992), Renner (1992), and Mehmet (1995) have argued that developing countries (DCs) need to take steps to design and follow through with policies that generate employment. On the other hand, the sizeable literature on sustainable development⁴ has stressed the need for implementing policies that will protect the environment for the present and future generations.

The experience of industrialized countries with environmental policies tells us that these policies can have a negative effect on employment (Christainsen and Tietenberg, 1985; Bonetti and FitzRoy, 1999). This and other similar findings have led many observers to contend that in the face of urgent employment creation needs, DC governments are unlikely to be serious about environmental protection. In other words, although DC governments may begin the process of designing appropriate environmental policies, over time, their *commitment* to such policies is likely to wane.

The purpose of this paper is to study this issue formally. We do this by analyzing a dynamic model of a DC with a dual economy. This model explicitly links the DC government's period of commitment to its announced employment/environmental policies. As Lekakis (1991) and Mehmet (1995) have noted, despite its significance, this issue has received scant attention in the economics

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For more on this literature, the reader should consult Brundtland (1987), Goldin and Winters (1995), Faucheux *et al.* (1996), and Atkinson *et al.* (1997).

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Dug Man Lee:

The editor of the Annals of Regional Science has decided to reject our paper. According to him, the referees told him that the paper was okay but the subject matter was not appropriate for the Annals of Regional Science.

We're having the worst luck with this paper. Anyway, I have now sent it to Professor Beladi's journal, the International Review of Economics and Finance (IREF). Hopefully, this time the paper will be accepted. I hope things are going well for you.

Sincerely,

Amit Batabyal

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