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ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES:

A DYNAMIC ANALYSIS

by

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Amitrajeet A. Batabyal

ABSTRACT

I construct a dynamic model of the environmental policy formulation process in a stylized developing country (DC). Next, I analyze the employment and output effects of three pollution control policies. These policies embody different assumptions about the DC government's ability to commit to its announced course of action. I characterize the timepath of the government's policy variable, and then I show that optimality calls for an activist policy, irrespective of the length of time to which the government can commit to its announced policy. However, the effects of this activist policy depend fundamentally on the government's period of commitment.

JEL Classifications Numbers: O20, Q20, D90

ENVIRONMENTAL POLICY IN DEVELOPING COUNTRIES: A DYNAMIC ANALYSIS¹

1. Introduction

In recent times, there has been considerable discussion on the general question of environmental policy in developing countries (DCs). There is general agreement among scholars, such as Bhalla (1992), Mehmet (1995), and Renner (1992), that a concerted attempt must be made by DC governments to design and implement policies which generate employment. However, in order to protect the environment, these same governments will also have to implement appropriate pollution control policies. The developed country experience with pollution control policies—see Christainsen and Tietenberg (1985)—tells us that these policies will often have a negative effect on employment. Consequently, DC governments may find it difficult to institute policies which ensure that the twin goals of employment creation and environmental protection are met. Given this state of affairs, concern has been expressed about a DC government's ability to realistically commit to environmental policy for any reasonable length of time. Indeed, some observers have noted that in the face of pressing employment creation needs, DC governments may not be serious about the question of environmental protection. Alternately put, although DC governments may initiate the process of establishing pollution control policies, their will to continue with such policies is likely to be limited.

Despite the importance of the issues discussed in the previous paragraph, the

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employment/environment question in DCs has received very little attention in the literature.² As such, the primary objective of this paper is to construct and analyze an employment driven dynamic model of the environmental policy formulation process in a stylized DC. The secondary objective of this paper is to show how the DC government's optimal course of action is closely related to its ability to commit to its announced policy.

The rest of this paper is organized as follows. In section 2, I describe my theoretical framework in detail. In section 3, I analyze a dynamic model of the conduct of environmental policy by the government of a stylized DC, under three different assumptions about the ability of this government to commit to its announced policy. In section 4, I offer concluding comments.

2. The Theoretical Framework

My model is in the tradition of papers such as Mussa (1978), Pindyck (1982), and particularly Karp and Paul (1994), which study the implications of government/ regulatory policies in a dynamic framework. I shall use the specific factors model to study a small two-sector trading DC. In order to stress the employment aspect of the underlying story, I shall assume that the DC economy is dualistic. In other words, the two DC sectors consist of a modern, high wage, environmentally intensive sector in which production causes pollution. The second sector is the traditional, low wage, environmentally benign sector in which there is no pollution.

In order to earn higher wages, workers migrate from the traditional sector to the modern sector. This migration, which is unplanned from the perspective of the DC government, results in increased employment in the modern sector, increased production, and hence greater

²See Lekakis (1991) and Mehmet (1995) for a more detailed corroboration of this claim.

pollution.³ Although workers, in their role as consumers, are adversely affected by pollution, they do not factor pollution into their migration decisions. As a result, the marginal migrant pays less than the marginal social cost of migration. In other words, in the absence of governmental policy, migration takes place too quickly and hence there is excessive pollution in the economy. In this situation, the first best policy is to tax pollution directly. However, in many DCs the government simply does not possess the wherewithal to tax pollution directly. As such, in this paper I shall assume that the DC government operates in a second best environment in which it controls pollution by means of a production tax.

Initially, the DC economy is in disequilibrium, owing to the fact that the government does nothing to correct distorted producer incentives and hence ensure environmental protection. A movement toward equilibrium requires a reduction in the production of the polluting good over time. Alternately put, a move toward equilibrium involves slowing the rate at which workers migrate from the traditional sector to the modern sector. I assume that workers have rational expectations, which is equivalent to assuming that they have perfect foresight in this deterministic model.

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. $L^i(t)$, $i=1,2$, is the labor employed by the i^{th} sector at time t ; time is continuous. Let $\bar{L}$ denote the DC's total labor endowment, i.e., $L^1(t) + L^2(t) = \bar{L}$. Good 2 is the polluting good. All my subsequent results are independent of whether good 2 is the export

³In addition to having an adverse environmental impact, unplanned migration can be problematic in other ways as well. For more on this, see Swaminathan (1993).

good or the import competing good. The government's policy variable is a production tax, $\tau(t)$, which is levied on the production of good 2. Following Dixit and Norman (1980) and Karp and Paul (1994), I shall use duality theory to model consumption and production decisions in the DC. The production function of the i^{th} sector, $i = 1, 2$, is $f^i(L^i)$ and the corresponding revenue function is $R^i(p^i, L^i)$. As is well known, R_1^i and R_2^i denote the output supply of good i and the wage in sector i , respectively.⁴ Let the world price of good 2 be $p = p^2/p^1$, where $p^1 = 1$. Further, let $L^2 = L$, and let $L^1 = \bar{L} - L$.

There is a continuum of identical workers in each sector of the DC economy and a single capitalist is the residual claimant. I shall assume that all agents have homothetic preferences. Then, following Dixit and Norman (1980, p. 326), the expenditure function of agent j , $j = 1, 2, 3$, can be written as $E(1, p, w^j) = U^j E(p)$, where $E(p)$ is the unit expenditure function and U^j is agent j 's real income. National income for the DC is $U \equiv (\bar{L} - L)U^1 + LU^2 + U^3$, where the superscript 3 refers to the capitalist.

Let $m(t)$ denote the private value of migration for any worker at time t , i.e., $m(t)$ denotes the discounted value of the wage differential between the high wage polluting sector and the low wage nonpolluting sector. Mathematically

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

where r is the discount rate. The integral equation in (1) can be converted into a differential equation. This equation is

$$\dot{m} = rm + R_2^1(\bullet) - R_2^2(\bullet). \quad (2)$$

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. However, because workers do not factor

⁴For more on the properties of these dual functions, see Dixit and Norman (1980, chapter 2).

pollution into their migration decisions, the social cost of migration is not equal to the private cost of migration. Let the social cost of migration be quadratic, i.e., $C(\dot{L}) = \alpha(\dot{L})^2$, where $\alpha > 0$. The reader will note that I am thinking of migration as the change in the labor stock. Now because the average social cost, $\alpha\dot{L}$, is less than the marginal social cost, $2\alpha\dot{L}$, in the absence of governmental intervention, migration for high wage employment takes place too rapidly, thereby increasing environmental degradation. To capture the fact that the private cost of migration is lower than the social cost, suppose that workers base their migration decision on a fraction δ , $\delta \in (0,1)$, of the marginal social cost $2\alpha\dot{L}$. Alternately put, the migrating workers do not internalize the environmental externality stemming in part from their decision to migrate. Now equating the private value of migration with the private cost of migration, an equation for the dynamics of labor migration can be obtained. This equation is

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

Since this DC economy is open and because I am not allowing for the possibility of international borrowing, in equilibrium, trade must be balanced. That is,

$$D(U, L, m, \tau) \equiv UE(p) + \{m^2/4\alpha\delta^2\} - R^1(1, \bar{L} - L) - R^2(p - \tau, L) + \tau R_1^2(p - \tau, L) = 0. \quad (4)$$

The first term in this “balance of trade deficit” expression refers to consumption expenditures.

Equation (3) tells us that $C(\dot{L}) = m^2/2\alpha\delta^2$. Hence, the second term of equation (4) denotes the social cost of pollution. The third and the fourth terms give the value of production, and the fifth term denotes tax revenues. The tax revenues are redistributed in lump sum fashion.

I shall be particularly interested in studying the DC government’s optimal dynamic environmental policy under three assumptions about its ability to commit to a particular course of action. In the first case, the government commits to a tax trajectory for an infinite period of time. The reader should interpret this infinite period of commitment as a case in which

environmental protection is enshrined in the DC constitution.⁵ When this is done, it does not matter which government is in office, because the dictates of the constitution will have to be followed. In the second case, the DC government commits to a tax trajectory for a finite period of time. This finite period of commitment is more reasonable, and this finite period should be thought of as the length of time during which a particular government is in office.

Unfortunately, in both these cases, the optimal tax policy is dynamically inconsistent. That is, the government announces a tax trajectory at time $t = 0$. However, at some time $\epsilon > 0$, the government will want to deviate from the trajectory that it announced at $t = 0$. As a result, the government's announced policy at time $t = 0$ will not be credible. This means that forward looking workers will not believe that the government will actually carry through with its initially announced policy, and hence this policy will fail to accomplish its objectives.

Since the credibility of governmental policy has been an important issue in many developing countries, *a priori*, it would seem necessary to study the implications of the DC government following a dynamically consistent course of action.⁶ This is the third case that I shall study. In this scenario, the government commits to a tax trajectory for an infinitesimal period of time. In the limiting case in which the period of commitment approaches zero, the government's tax policy is time consistent. This completes my discussion of the theoretical framework. I now turn to the DC government's problem when it can commit to its tax policy for an arbitrarily long period of time.

⁵If the DC in question were India, this period would be 1976. This is because until 1976, environmental protection did not figure anywhere in the Indian constitution. See Batabyal (1993) for further details.

⁶Recall the section 1 discussion about the concern as to the lack of commitment in DC governmental policies. In this connection, also see Fanelli, Frenkel, and Rozenwurcel (1992).

3a. Environmental Policy with Perfect Commitment

In this case, the DC government is able to make a binding commitment and choose its tax trajectory over $(0, \infty)$ at $t = 0$. In the language of control theory, 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. As discussed earlier, because the economy is in disequilibrium at $t = 0$, the initial value of L , $L(0) = L_0$, does not equal the steady state value of labor in the polluting sector of the economy. It is important to note that the private value of migration at any time t , $m(t)$, is determined by the current *and* the future values of the tax. In other words, the constraint represented by equation (2) is a jump state constraint.⁷ This means that the initial value of m , $m(0)$, is endogenous to the problem. The reader should note that this feature of the model makes the government's problem a nonstandard control problem. In this setting, the government's objective is to solve

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

subject to equations (2), (3), and (4), with initial condition $L(0) = L_0$. The current value

Hamiltonian for this problem is

$$H = U - \lambda [UE(p) + \{m^2/4\alpha\delta^2\} - R^1(\bullet) - R^2(\bullet) + \tau R_1^2(\bullet)] + \sigma_1 \{m/2\alpha\delta\} + \sigma_2 \{rm + R_2^1(\bullet) - R_2^2(\bullet)\}, \quad (6)$$

where λ is the Lagrange multiplier on constraint (4), and σ_1 and σ_2 are the costate variables

corresponding to constraints (3) and (2), respectively. The first-order necessary conditions are

$$\lambda = 1/E(p), \quad (7)$$

$$\lambda \{\tau R_{11}^2(\bullet) - 2R_1^2(\bullet)\} + \sigma_2 R_{21}^2(\bullet) = 0, \quad (8)$$

⁷Many problems in economics are characterized by the existence of jump states. In monetary economics, the exchange rate is generally a jump state because it is affected by current interest rates and agents' expectations of the future money supply. For more on jump state constraints, see Batabyal (1996a, 1996b), Karp and Newbery (1993), and Karp and Paul (1994).

$$\dot{\sigma}_1 = r\sigma_1 + \sigma_2 h(\bullet) + \lambda\{d(\bullet) + \tau R_{12}^2(\bullet)\}, \quad (9)$$

and

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

where $d(\bullet) \equiv R_2^1(\bullet) - R_2^2(\bullet)$, and $h(\bullet) \equiv R_{22}^1(\bullet) + R_{22}^2(\bullet)$. That is, $-d(\bullet)$ denotes the current private value of migration, and $h(\bullet)$ denotes the sum of the slopes of the marginal product of labor in the two sectors. The reader should note that $h(\bullet) = \partial\{-d(\bullet)\}/\partial L < 0$.

My main interest lies in characterizing the optimal pollution tax trajectory and the magnitude of the optimal pollution tax. To this end, denote steady state values by the superscript S . Then from equation (3), it follows that $m^S = 0$. From equation (2), I get $d^S(\bullet) = 0$.

Equation (10) implies that $\dot{\sigma}_1^S = 0$. From equation (8), it follows that

$\sigma_2^S = [-\lambda\{\tau R_{11}^2 - 2R_1^2\}/R_{21}^2]^S$. From equation (9), I get $\sigma_2^S = [-\lambda\tau R_{12}^2/h]^S$. Setting these last two expressions equal, I get $\tau^S = [2R_1^2 h / \{R_{11}^2 h - R_{12}^2 R_{21}^2\}]^S$. From equation (8), it follows that $\tau(t) = [\{2\lambda(t)R_1^2 - \sigma_2(t)R_{21}^2\} / \{\lambda(t)R_{11}^2\}]$. Because $m(0)$ is free, as Simaan and Cruz (1973)

have noted, the appropriate boundary condition for σ_2 is $\sigma_2(0) = 0$. In other words, the DC government chooses its tax trajectory in such a way so that the social shadow value of m is zero at the beginning of the program. Using $\sigma_2(0) = 0$, it follows that $\tau(0) = 2R_1^2 / R_{11}^2$. I can now state

Proposition 1, Case (i): Suppose that the revenue function in sector 2 is separable in its arguments. Then the optimal program with perfect commitment involves setting $\tau(0) = 2R_1^2 / R_{11}^2$. *Case (ii):* Suppose that the supply function for good 2 is linear, upward sloping, and that the cross partial derivatives of the sector 2 revenue function are positive. Then the optimal program with perfect commitment sets $\tau(0) > \tau^S > 0$. *Case (iii):* Suppose that the sector 2 revenue function is arbitrary. Then optimality calls for setting $\tau(0) > \tau^S > 0$, as long as

$$[R_1^2(0)/R_{11}^2(0)] > [R_1^2/\{R_{11}^2 - (R_{12}^2 R_{21}^2)/h\}]^S.$$

Proof, Case (i): Separability of the revenue function implies that $R_{12}^2 = R_{21}^2 = 0$. Substituting this into the expressions for $\tau(0)$, $\tau(t)$, and τ^S , the claimed result follows. *Case (ii):* If the supply function of good 2 is linear and upward sloping, then R_{11}^2 is constant. Using this fact along with $R_{12}^2 > 0$, $R_{21}^2 > 0$ in the tax expressions above, the claimed result follows. *Case (iii):* It is easy to check that if $[R_1^2(0)/R_{11}^2(0)] > [R_1^2/\{R_{11}^2 - (R_{12}^2 R_{21}^2)/h\}]^S$, then it is optimal to set $\tau(0) > \tau^S > 0$. ■

Proposition 1 describes the nature of the DC government's optimal dynamic policy under certain specific conditions. Under the sufficient case (i) condition, there are no price or labor interaction effects. Consequently, the government's optimal course of action is to set a pollution tax that is constant over the entire length of the program. On the other hand, under the sufficient case (ii) and the necessary and sufficient case (iii) conditions, the optimal policy involves beginning with a "bang." In these two cases, the DC government moves toward an equilibrium by starting with a large pollution tax. It then gradually lowers this tax to the steady state level. Note that the government's open loop tax policy calls for an activist course of action. In other words, it is typically not optimal to set a zero tax at any point in the program. The intuitive reason for this is as follows. In this open loop case, there are no welfare losses from being unable to commit, because the open loop tax policy incorporates perfect commitment. As such, the case for doing nothing, which potentially arises when the government cannot commit, is ruled out. Hence, the government corrects for the domestic distortion, and its tax policy is activist.

While proposition 1 provides conditions for a constant and a declining tax trajectory, these are not the only possible trajectories. If the conditions described in proposition 1 do not

hold, it is possible for the pollution tax to exhibit more complex dynamic behavior. Specifically, it is possible for the tax to exhibit nonmonotonic behavior. This tells us that the pursuit of open loop policies can lead to taxes which exhibit complicated dynamic behavior.

If the DC government's optimal tax policy, as described in proposition 1, is believed by all agents in the economy, particularly by the migrating workers, then this policy will achieve its objectives. That is, the pollution tax will reduce output and employment in sector 2 and slow the rate of migration from the nonpolluting sector 1 to the polluting sector 2. However, these objectives will not be met because the government will have an incentive to deviate from the policy that it announced at $t = 0$. To see this, note that for any initial value of L , $L(0) \neq L^S$, the optimal initial shadow value of $m(t)$, $\sigma_2(0)$, is zero. However, because $\delta < 1$ on the announced tax trajectory, $\sigma_2 \neq 0$. As a result, at any time $\epsilon > 0$, the government will want to deviate from the tax trajectory it announced at $t = 0$, and announce a new trajectory. In other words, the government's open loop tax policy is dynamically inconsistent. This means that unless there is some mechanism by which the DC government can be bound to its initially announced tax trajectory, this government will fail to achieve its initially announced employment and environmental objectives.⁸

From a practical perspective, this case of perfect commitment is clearly implausible because no government can realistically be expected to commit to its policy for an infinite period of time. Consequently, I now analyze the case in which the DC government is able to commit to its announced policy at $t = 0$, for a finite period of time only. This is the limited commitment case.

⁸The extent to which the government will fail to achieve its objectives depends on the nature and the direction of deviation from the initially announced tax policy.

3b. Environmental Policy with Limited Commitment

Given that governments are in office for a finite period of time, the most reasonable period of commitment would seem to correspond to the length of time during which a particular government is in office. As such, I now study the case of limited commitment in which the government commits to a policy for $T \in \mathbb{R}_{++}$ time periods.

When the period of commitment is finite, an analysis of the equilibrium trajectory of the pollution tax is made complex because the resulting equilibrium depends on the manner in which agents form their expectations. If migrating workers base their expectations of future taxes on the history of taxes, then multiple equilibria are possible. As such, there is a sort of “generic indeterminacy” to the outcome of the imposition of the pollution tax. To eliminate this indeterminacy, I shall restrict attention to smooth Markov perfect equilibria. By Markov I, mean that the agents’ decision rules at any time t , depending only on the current value of the state, i.e., the stock of labor, and not on the manner in which the current state was reached. A candidate for an equilibrium is said to be perfect if this candidate is an equilibrium for any possible subgame, i.e., for any possible level of the stock of labor. In particular, whether or not some agents have deviated from their equilibrium strategies in the past, the continuance of these strategies represents equilibrium behavior on the part of all the agents involved.⁹ From a practical standpoint, the Markov assumption is useful because it makes the DC government’s equilibrium tax policy insensitive to agents’ mistakes.

With this restriction of Markov perfection, the equilibrium that emerges when the government makes a commitment for T time periods can be characterized. At time periods

⁹Markov perfect equilibria are sometimes also known as strong Markov perfect equilibria. The word “strong” emphasizes the fact that current decisions are based *only* on the current state and *not* on actions undertaken in any previous time period.

$0, T, 2T, 3T, \dots$, successive governments choose their own tax trajectories. That is, at each iT , $i = 0, 1, \dots$, the i^{th} government completes its term in office, and a new government chooses its tax trajectory for the next T time periods. At the end of T time periods, each government bequeaths L_T , the current labor stock, to its successor government. This government then pursues its environmental policy for the next T time periods, and so on.

With this interpretation of the limited commitment case, let $V(L)$ be the value of the government's program when its period of commitment is T periods and when the initial level of labor in the polluting sector is L . Now, the government solves

$$V(L) \equiv \max_{\tau, U} \int_0^T e^{-rt} U dt + e^{-rT} V(L_T), \quad (11)$$

subject to equations (2), (3), and (4). Note that $V(L_T)$ is a bequest function. This function

denotes the value of the labor stock bequeathed by an arbitrary government to its successor.

Also note that problem (11) is the same as the problem described in section 3a, with the exception that the government's period of commitment is now T as opposed to infinity. This means that the boundary conditions at the horizon of the program will be different, although the first-order necessary conditions themselves remain as in equations (7) through (10).

As in section 3a, the fact that $m(0)$ is free tells us that it is optimal to choose the tax trajectory so that $\sigma_2(0) = 0$. Using this last condition in equation (8), I get $\tau(0) = [2R_1^2/R_{11}^2]$.

To determine $\tau(T)$, let $M(L)$ be the equilibrium current value of m , which is determined by the solution to equation (11).¹⁰ In my case, I can write $V(L) \equiv \bar{V}\{L, M(L)\}$ for some function $\bar{V}\{\bullet\}$. At the beginning of a specific time period iT , $i = 0, 1, \dots$, it is clear that $\sigma_2(iT) = 0$.

Further, the assumed smoothness of the value function gives $\sigma_2 = \partial \bar{V} / \partial M$ (Kamien and

¹⁰The properties of this endogenous function of the state have been discussed elsewhere and hence I shall omit an elaborate discussion. For further details, see Karp and Newbery (1991) or Karp and Paul (1994).

Schwartz, 1991, p. 165). That is, the social shadow value of M is equal to the marginal value of M in the bequest. Finally, the transversality condition for σ_2 is $\sigma_2(T) = \partial \bar{V} / \partial M = 0$. Using this condition in equation (8), I get $\tau(T) = [2R_1^2 / R_{11}^2]$. I can now state

Proposition 2, Case (i): Suppose that the sector 2 revenue function is separable in its arguments.

Then the optimal program with limited commitment has $0 < \tau(0) = \tau(T) = \tau(t), t \in (0, T)$.

Case (ii): Suppose that the sector 2 revenue function is arbitrary. Then the optimal program with limited commitment has $0 < \tau(0) = \tau(T) \neq \tau(t), t \in (0, T)$.

Proof, Case (i): Separability of the revenue function implies that $R_{12}^2 = R_{21}^2 = 0$. Substituting this into the expressions for $\tau(0)$, $\tau(t)$, and $\tau(T)$, the claimed result follows. *Case (ii):* The expressions for $\tau(0)$ and $\tau(T)$ tell us that these two taxes are positive and that they are not functions of the mixed partial derivatives of the sector 2 revenue function. As contrasted to this, $\tau(t)$ is a function of the mixed partial derivatives of the revenue function. Hence, we have $0 < \tau(0) = \tau(T) \neq \tau(t), t \in (0, T)$. ■

Under the conditions specified in proposition 2, an optimal program once again calls for an activist pollution control policy. The DC government sets a positive pollution tax even though it can commit to its announced policy for only a finite period of time. A comparison of the first case in propositions 1 and 2 tells us that when the sector 2 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 revenue function is a sufficient condition for the nature of commitment not to matter. As contrasted to this, a comparison of case (iii) of proposition 1 and case (ii) of proposition 2 tells us that the timepaths of the pollution tax in these two programs are quite different when the revenue function is arbitrary. In particular, while the perfect commitment case calls for starting with a high tax and then lowering

this tax to its steady state value, the limited commitment case calls for equalizing the tax at the beginning and at the end of the program.

Note the important role played by the endogenous function of the state, $M(L)$. This function performs the role of an “expectations” function. When the DC government solves its optimization problem taking this expectations function as given, the optimal tax trajectory results in an initial value of m , $m(0)$, which satisfies $m(0) = M\{L(0)\}$. That is, in equilibrium, every agent’s point expectations are fulfilled. Further, this same optimal tax trajectory results in a terminal value of m such that $\partial \bar{V}(\bullet) / \partial M = \sigma_2(T) = 0$. As indicated earlier, 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.

While this limited commitment scenario is quite plausible, this equilibrium too is dynamically inconsistent. To see why, think of the Markov perfect case just studied as one in which an infinite sequence of governments conduct environmental policy during a time period of length T . Further, denote the tenure of each government in this infinite sequence by $\{T\}_{i=0}^{\infty}$. As long as $T > 0$, each government behaves consistently at each i but *not* within a period of length T . Put differently, the government begins its tenure in office with the best of intentions, but some time later, it will want to renege on the policy it announced at the beginning of its tenure. As a result, forward looking agents will not believe that the government will actually carry through with its initially announced policy. In turn, this means that the government will not succeed in accomplishing its policy objectives. Pollution and employment in sector 2 will not be reduced, and the rate of migration from the traditional sector to the modern sector will not be slowed.

So far, I have shown that the dynamic inconsistency of the government’s optimal tax policy is responsible for the nonattainment of the DC government’s employment and

environmental goals. This suggests a need to make the government's policy dynamically consistent. I now proceed to do this by studying the case in which the DC government commits to a specific tax policy for an infinitesimal period of time. In this setting, I shall be particularly interested in the limiting Markov perfect equilibrium in which the government's period of commitment shrinks to zero.¹¹

3c. Environmental Policy with No Commitment

Intuitively, one would expect the Markov perfect equilibrium to depend on the government's period of commitment. That is, one would expect the government's equilibrium tax to be a function of two opposing forces. The first force, the presence of pollution, would appear to necessitate an activist policy designed to correct for this domestic distortion. The second force, the government's inability to commit to its tax trajectory, would appear to favor the *status quo*. Given this scenario, the relevant policy question is this: Are there circumstances in which the welfare loss from being unable to commit dominates the welfare gain from reducing pollution, so that it is optimal to do nothing?¹²

In order to study the limiting case, I shall follow Karp and Newbery (1993) and Karp and Paul (1994) 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 time period of length ϵ . The state constraints facing the government at any time t can be written as

$$L_t = \{m_t / 2\alpha\delta\}\epsilon + L_{t-\epsilon} \quad (12)$$

¹¹For an alternate approach to the construction of dynamically consistent policies, see Batabyal (1996a, 1996b).

¹²In this context, doing nothing refers to the case in which the DC government sets a zero tax.

and

$$m_t = e^{-r\epsilon} m_{t+\epsilon} - \{-d_t(\bullet)\epsilon\}, \quad (13)$$

where $d_t(\bullet) \equiv R_2^1(\bullet) - R_2^2(\bullet)$. In equation (12), $(m_t/2\alpha\delta)\epsilon$ represents the number of migrants in a period of length ϵ . Similarly, in equation (13), $-d_t(\bullet)\epsilon$ denotes the value of the flow of the wage differential in a time period of length ϵ .¹³ At time t , with period of commitment ϵ , the government's dynamic programming problem is

$$\max_{U, \tau} [U - \lambda \{D(U, L, m, \tau)\}\epsilon + e^{-r\epsilon} V(L_T)], \quad (14)$$

subject to equations (12) and (13). Note that the function $D(\bullet)$ represents the "balance of trade deficit" constraint embodied in equation (4), that $m_{t+\epsilon} = M(L_t)$, and that the government takes the function $M(\bullet)$ as given. After some algebra, the first-order necessary condition w.r.t. τ can be written as

$$\begin{aligned} \lambda [\tau R_{11}^2 - 2R_1^2 - \{\partial D / \partial L_t\} \{dL_t / d\tau\} - \{\partial D / \partial m_t\} \{dm_t / d\tau\}]\epsilon \\ - e^{-r\epsilon} \{dV / dL_t\} \{dL_t / d\tau\} = 0. \end{aligned} \quad (15)$$

In order to simplify equation (15) further, it will be necessary to differentiate equations (12) and (13) totally. This gives

$$dL_t / d\tau = \{\epsilon / 2\alpha\delta\} \{dm_t / d\tau\}, \quad (16)$$

and

$$\{h_t(\bullet)\epsilon - e^{-r\epsilon} M'(L_t)\} \{dL_t / d\tau\} + \{dm_t / d\tau\} = \{\partial d_t / \partial \tau\} \epsilon. \quad (17)$$

Now substitute for $dL_t / d\tau$ from equation (16) into equation (17), and then simplify the resulting equation. This gives $dm_t / d\tau \sim O(\epsilon)$. Similarly, substituting for $dm_t / d\tau$ from equation (17) into equation (16) and then simplifying the resulting equation yields $dL_t / d\tau \sim o(\epsilon)$. Now divide both sides of equation (15) by ϵ , use the preceding two results regarding $dm_t / d\tau$ and $dL_t / d\tau$, and then let $\epsilon \rightarrow 0$. The limiting first-order necessary condition becomes

¹³Equations (12) and (13) represent constraints (3) and (2) in discrete form.

$$\lambda [\tau R_{11}^2 - 2R_1^2] = 0. \quad (18)$$

This leads to

Proposition 3: In an optimal program in which the government's period of commitment $\epsilon \rightarrow 0$, the limiting Markov Perfect equilibrium tax is positive and equals $2R_1^2/R_{11}^2$.

Proof: Since $\lambda > 0$, equation (18) can be simplified to yield $\tau = [2R_1^2/R_{11}^2] > 0$. ■

Proposition 3 provides us with an answer to the policy question posed at the beginning of this section. This proposition tells us that even when the government displays no commitment to its tax policy, the welfare loss from being unable to commit is never as large as the welfare gain from reducing pollution. Consequently, the optimal pollution tax is positive. Put differently, the passive aspect (do nothing) of governmental policy is dominated by the activist aspect (control pollution). This explains why the limiting pollution tax is positive.

While proposition 3 and the discussion preceding it provide a rigorous characterization of the limiting pollution tax, the same characterization can be obtained intuitively. To see this, recall the discussion of the government's optimal policy immediately preceding the statement of proposition 2. According to this discussion, $\tau(iT) = 2R_1^2/R_{11}^2$, $i = 0, 1, 2, 3, \dots$. Now note that by choosing T sufficiently small, the equilibrium tax trajectory can be kept arbitrarily close to its initial value which equals $2R_1^2/R_{11}^2$. Not surprisingly, this is also the value of the limiting pollution tax.

This limiting case involves continuous revision of the pollution tax by the DC government. When the government revises its policy continually, the resulting policy is dynamically consistent. In other words, the government's tax policy is credible. Hence, this policy will be successful in reducing pollution in the modern sector and in slowing the rate at which workers migrate from the traditional sector to the modern sector.

As Karp and Newbery (1993) have noted, the payoff to an agent is monotonic in his period of commitment. In the context of this paper, this means that reducing the government's period of commitment can never make the government better off. With this observation and the previous discussion of policy efficacy in mind, it is possible to rank the three policies in terms of (i) the government's preference and (ii) the policy's ability to achieve its goals. From the DC government's perspective, the most desirable policy is the open loop policy; this policy allows the government to make a commitment for an infinite period of time. The second best policy is the Markov perfect tax policy with a finite period of commitment. The least desirable policy is the limiting Markov perfect tax policy. As contrasted to this ranking, the ranking in terms of goal attainment is exactly the opposite. The limiting Markov perfect tax policy is credible; as such, this policy will be able to reduce pollution. The other two policy instruments are not credible; hence they will fail to achieve the government's environmental goals. Of these two noncredible policies, the finite commitment Markov perfect tax is more plausible. This discussion highlights the DC government's basic dilemma. The policy which results in the highest payoff to the government is the one that is least desirable from the standpoint of goal attainment and social welfare.

4. Conclusions

In this paper I used the specific factors model to study a stylized and dualistic DC economy in which there is domestic pollution. Next, I studied the conduct of environmental policy by the DC government under three assumptions about this government's ability to commit to its announced policy. A number of important policy conclusions emerge.

First, the analysis of this paper provides some answers to hitherto little studied questions

about the employment/environment interface in DCs. In particular, the analysis tells us that as long as the private cost of migration is less than the social cost of migration ($\delta < 1$) successful environmental policy involves continuous revision of the relevant policy instrument (tax).

Second, the analysis shows that doing nothing, i.e., setting a zero tax, is typically not an optimal course of action. I demonstrated that although the nature of the underlying equilibrium depends on the government's ability to commit to its announced policy, the welfare loss from the inability to commit does not dominate the welfare gain from reducing pollution. As such, an optimal course of action generally requires that the pollution tax be positive.

Third, the analysis points to the unrealistic nature of dynamically inconsistent, particularly open loop policies. Such policies cannot be believed by forward looking agents with rational expectations. Hence, such agents will successfully thwart the DC government's policy objectives. This stands in sharp contrast to the limiting Markov perfect tax policy which is dynamically consistent. In this case, the equilibrium is characterized by an endogenous function of the state and the government continuously revises its tax trajectory. Continuous revision implies credibility, and, in turn, this means that the government's environmental policy will achieve its intended objectives.

Fourth, there is a basic tradeoff between policy credibility and policy payoff. Credible policies yield a lower payoff than do noncredible policies. This observation provides a possible explanation as to why many DC governments are loath to use dynamically consistent policies which involve continuous policy revision.

The analysis contained in this paper can be extended in a number of directions. One such extension would involve making the migration equation, equation 3, depend on m and the tax τ . This would permit an analysis of policy when the government's tax has a direct effect on

migration decisions. Preliminary research along this line suggests that the DC government's optimal course of action can be quite sensitive to the manner in which the migration decision is modeled.

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