

ENVIRONMENTAL POLLUTION AND OPTIMUM TAXATION
UNDER MARKET DISTORTIONS
IN DEVELOPING COUNTRIES

by

Gill Chin Lim and Joon Koo Lee

Discussion Paper #100

Research Program in Development Studies

Woodrow Wilson School
Princeton University
Princeton, New Jersey

October 1981

NOTE: Discussion papers of the Research Program in Development Studies are preliminary material circulated to stimulate discussion and critical comment. Please do not refer to discussion papers without permission of the authors.

Gill C. Lim
Woodrow Wilson School
Princeton University
Princeton, New Jersey

Joon Koo Lee
Department of Economics
State University of New York
Albany, New York

ABSTRACT

This paper is a theoretical analysis to develop an optimum environmental policy for developing countries in the presence of distortions in markets. A theoretical model is constructed using a case of international relocation of industries from developed to developing countries. The model demonstrates that the Pigouvian approach does not result in a social optimum due to distortions in labor and foreign exchange markets. It is shown that the second-best optimal tax rates should differ from the Pigouvian ones as far as there exist distortions of any kind in the national economy. The analysis also illustrates that the optimal tax rates can not be zero. These results indicate that fundamental changes in current environmental policies are necessary in most less developed countries.

ENVIRONMENTAL POLLUTION AND OPTIMUM TAXATION
UNDER MARKET DISTORTIONS IN DEVELOPING COUNTRIES

Gill Chin Lim and Joon Koo Lee *

I. INTRODUCTION

In the face of rapid industrialization and urbanization, the management of environmental quality has become one of the most pressing issues of public policy in less developed countries (LDC's). Nonetheless, studies of environmental policy based on the unique institutional and economic characteristics of LDC's are rare. Most of the existing studies of national environmental policies are conducted in the context of a closed economy and without due consideration of the effect of market distortions. Studies following this tradition often suggest the Pigouvian effluent tax as a major instrument of environmental policy. However, the policy guidelines derived from the existing studies may not be appropriate for LDC's, since they do not properly take into account the peculiar economic conditions of these countries.

In this paper, we present a theoretical analysis to develop a guideline for an optimum environmental policy for LDC's in the presence of market distortions. In order to investigate the unique nature of environmental pollution in LDC's in relation to international economic interdependencies, a theoretical model is formulated by using a case of relocation of industries from more developed countries (MDC's) to LDC's. With this model, we demonstrate that the conventional environmental policy using the Pigouvian

* Assistant Professor of Public and International Affairs, Princeton University and Assistant Professor of Economics, State University of New York at Albany, respectively. The authors are grateful to the participants in the research seminar at SUNY, Albany for their valuable comments and to Greg Provan of Princeton University for his assistance.

approach does not result in a socially optimal management of the environment due to distortions in labor and foreign exchange markets in LDC's. It is also shown that the second-best optimal tax rates should differ from the Pigouvian ones as far as there exist distortions of any kind in a national economy. Finally, the model illustrates that the optimal tax rates cannot be zero. These results suggest that most LDC's need to undertake fundamental changes in the structure of their environmental policies.

The organization of this paper is as follows. In the second section, the policy setting, assumptions and the structures of the basic model are presented. Then, in the third section, the optimal effluent tax in the presence of market distortions is derived and explained. It also briefly discusses equity issues related to the second-best environmental taxation. Finally, the last section summarizes and discusses the results of the analysis.

II. THE MODEL

2.1. Policy Setting and Assumptions of the Analysis

The objective of an LDC government is to determine an appropriate level of taxes on environmental damages caused by industries in order to maximize the social welfare. A private firm, in the meantime, tries to maximize its profit by choosing a certain scale of production, taking environmental taxes as a parameter. Specifically, we will consider a firm which is involved in a movement of production facilities from an MDC to an LDC. Increasing trends of such movements observed in recent years render our interest in the specific case worthwhile. Motivation of relocation for an MDC firm generally includes lower wage rates and favorable tax provisions available in an LDC. On the other hand, an LDC government expects benefits from increased employment opportunities, learning of new technology and occupational know-how, and possible savings

from import substitution. Since we can expect that many firms in MDC's are interested in moving their production facilities to LDC's in pursuit of such benefits, it is reasonable to assume that a firm in an LDC can freely choose a certain scale of production to maximize its profits.

Details of the assumptions for the model are as follows: First, while there is a fixed relationship between the operating capacity (q) of a certain production facility and the amount of labor required (l_q) such that

$$l_q = g(q) \quad \text{with } g' > 0$$

the relative ineffectiveness of the labor in an LDC makes it necessary to assign a larger amount of labor to the same facility. Assuming proportionality, the amount of labor required in the LDC (l_q^0) is expressed as

$$l_q^0 = \beta g(q)$$

where β denotes the index which represents the degree of relative inefficiency of an average worker in the LDC ($\beta \geq 1$). Second, all countries are assumed to be so small that none of them can affect the international price of the commodity in question, P_I , by itself. Third, the LDC is now levying tariffs on the commodity at the rate of f . The tariff rates are assumed to be set optimally in view of specific objectives of the LDC government, the most important of which is probably the balance of payments considerations. Fourth, the externalities considered in this study are assumed to be of the public variety. It is also assumed that the only way to change the level of the emission of pollution is by changing the level of outputs. Fifth, without loss of generality, it is assumed that the official exchange rate vis-à-vis a representative foreign

currency is 1. Sixth, the firm in the LDC which imports production facilities is the single producer of the commodity in domestic markets.

2.2. Behavior of a Private Firm

A firm in an LDC which has imported a production facility from an MDC tries to maximize its profit by deciding on a certain level of production. The firm's profit can be defined as total revenue less labor costs, rental price of the production facilities payable in foreign currencies,^{1/} and effluent charges. Thus, we obtain

$$(1) \quad \text{Max}_q \pi = P(q)q - w_1 \beta g(q) - r(q) - t_1 \alpha(q)$$

where $P(q)$ = price of the product

w_1 = market wage rate in the LDC

$g(q)$ = amount of labor inputs

$r(q)$ = rental price of the production facility

t_1 = pollution tax rate in the LDC

$\alpha(q)$ = amount of pollution emitted.

Before we discuss the conditions for profit maximization, some explanations about the shape of the function $P(q)$ are necessary. Let us suppose that the domestic demand schedule in the LDC is given by a differentiable inverse demand function,

$$(2) \quad P_D = D(q) ,$$

where $D'(q) < 0$.

In an open economy, the maximum price a domestic producer can charge is given by^{2/}

$$(3) \quad P_M = (1+f)P_I.$$

We should also note that the producer would not sell in domestic markets if the domestic price is less than P_I . Therefore, the minimum price he can charge for his product is

$$(4) \quad P_N = P_I.$$

Then the effective demand schedule of the firm is as follows:

$$(5) \quad \begin{aligned} P(q) &= P_I \quad \text{for } q > q_2 \\ &D(q) \quad \text{for } q_1 < q \leq q_2 \\ &(1+f)P_I \quad \text{for } q_1 \geq q \end{aligned}$$

where q_1 and q_2 denote the quantities which satisfy

$$(6) \quad D(q_1) = (1+f)P_I \quad \text{and}$$

$$(7) \quad D(q_2) = P_I, \quad \text{respectively.}$$

This relationship and the corresponding marginal revenue curve are presented graphically in Figure 1.

Assuming that the second-order condition is satisfied, the first-order condition for a profit maximization is

$$(8) \quad P'(q)q + P(q) - w_1 \beta g'(q) - r'(q) - t_1 \alpha'(q) = 0$$

for $q \neq q_1, q_2$

and

$$(9) \quad \lim_{q \rightarrow q_1^+} P'(q)q + P(q) \leq PMC(q_1) \leq (1+f)P_I$$

for $q = q_1$.

The first two terms of (8) represent the marginal revenue and the remainder the private marginal costs of the firm. Note that the private marginal costs in this case include effluent taxes.

A unique solution is obtained from the first-order condition, when the marginal cost curve is located above (or on) PMC_3 or below (or on) PMC_5 in Figure 1. However, if the marginal cost curve lies between PMC_3 and PMC_5 , there may exist more than one solution. Therefore, for a marginal cost curve such as PMC_4 in Figure 1, we should check the following:

$$(10) \quad \pi(\tilde{q}) \begin{matrix} > \\ \equiv \\ < \end{matrix} \pi(\hat{q}) .$$

2.3. Criteria for a Social Optimum

As described above, the choice of a profit maximizing scale of production by a private firm is solely based on market prices. In defining a social optimum, however, market prices often turn out to be an inappropriate criterion. This is especially true in an LDC in which various kinds of distortions exist in various sectors of the economy for institutional as well as economic reasons. In the presence of market distortions, social preferences, which are often articulated by means of national objectives, may not be appropriately transmitted by the market system into the pricing of goods and services. It is, therefore, necessary to adjust market prices to reflect the underlying opportunity costs. In the context of this paper, two sources of distortions make the use of market prices inappropriate in defining a social optimum. The first one is the distortion in labor markets. It is widely acknowledged that the market wage rate in LDC's is a poor indicator of the social value of labor. The other distortion comes from foreign exchange markets. A typical LDC government tends to keep its domestic currency overvalued for various reasons.^{3/} These considerations lead us to use an appropriately calculated shadow price to define the social optimum.

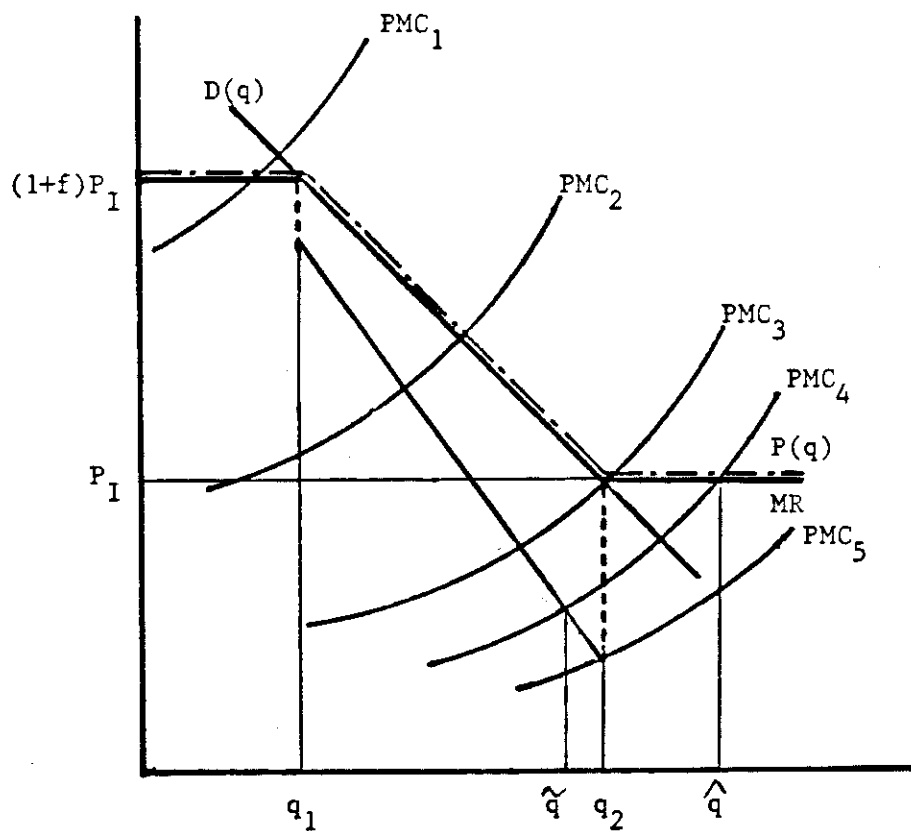


Figure 1

Let w_s and e_s be the shadow wage rate and the shadow price of foreign exchange which reflect the social values of labor and foreign exchange, respectively. Then, the social cost of production $SC(q)$ becomes,

$$(11) \quad SC(q) = w_s \beta g(q) + e_s r(q) + E(\alpha(q)).$$

The rental price of the production facility used by the LDC is multiplied by the shadow price of foreign exchange, since it should be paid in foreign currencies. We should also include the cost of environmental damages generated by the production facilities, $E(\alpha(q))$, in the social cost. Thus, using $e_s P_I$ as the shadow price of the product, the net social surplus from the production activity can be expressed as

$$(12) \quad V = e_s P_I q - w_s \beta g(q) - e_s r(q) - E(\alpha(q)).$$

The socially optimal scale of production is the one which maximizes the net social surplus.

III. OPTIMUM ENVIRONMENTAL TAX

3.1. Derivation of Optimal Effluent Tax

It was shown in the previous section that a private firm tries to maximize its profit by taking the rate of effluent tax, t_1 , as a parameter. Therefore, the scale of production, q , is determined by the chosen level of the effluent tax rate. The objective of the LDC government is to set an optimal level of t_1 , so that the private profit maximizing scale coincides with the socially optimal one. The maximum net social surplus can be obtained by a certain rate of tax per unit of pollutant. The first-order condition for a social optimum is, then,

$$(13) \quad \{e_s [P_I - r'(q)] - w_s \beta g'(q) - \frac{dE}{d\alpha} \alpha'\} \frac{dq}{dt_1} = 0.$$

Since dq/dt_1 is not zero, the expression contained in the bracket should be zero. Substituting (8) into (13) yields

$$(14) \quad e_s [w_1 \beta g'(q) + P_I + t_1 \alpha'(q) - P'(q)q - P(q)] \\ - w_s \beta g'(q) - \frac{dE}{d\alpha} \alpha'(q) = 0.$$

Solving (14) for t_1 , we obtain the following:

$$(15) \quad t_1^* = \frac{dE/d\alpha}{e_s} + \frac{P'(q)q + P(q) - P_I}{\alpha'(q)} \\ + \left(\frac{w_s}{e_s} - w_1 \right) \frac{\beta g'(q)}{\alpha'(q)}$$

for $q \neq q_1, q_2$.

This is the expression for the optimal effluent tax which maximizes the net social surplus. The Pigouvian tradition suggests that the optimal rate of effluent tax be set equal to its marginal environmental damage, i.e., $dE/d\alpha$ in the context of this model. But, the above solution shows that in the presence of market distortions the optimal effluent tax does not always match with the marginal impact on the environment (see Figure 2). The Pigouvian prescription coincides with the above solution only if there is no distortion in the LDC, and if the domestic producer's marginal revenue, $(P'(q)q + P(q))$, is exactly the same as the international price.

The first term of the expression for t_1^* shows that the marginal environmental damage should be either deflated or inflated by the shadow price of foreign exchange. Intuitively, this is appropriate, because the import substitution (or export) made possible by the domestic production activity results in savings in foreign exchange, and an adjustment should be made for the distortion of foreign exchange markets in evaluating the value of the savings incurred. If the shadow price of foreign exchange is higher than the official exchange

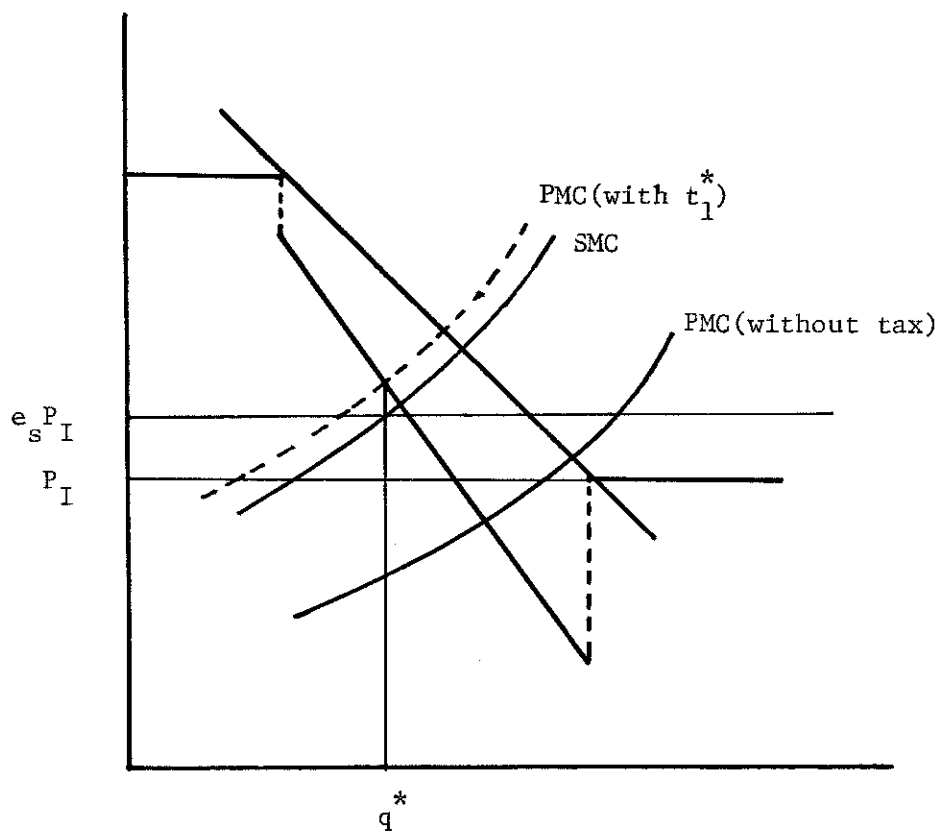


Figure 2

rate, i.e., $e_s > 1$, the tax rate directly attributable to the environmental damage should be smaller than that prescribed by the Pigouvian approach.

The second term of (15) contains two factors. The first term, the numerator, $P'(q)q$, is an adjustment for the monopoly power of the producer. As shown by Barnett (1980), if the producer has some monopoly power in the market, the tax rate may be lowered to reduce the distortion caused by underproduction.^{4/} The remainder of the numerator, $P(q) - P_I$, adjust for the discrepancy between the domestic price and the international price. If, in the neighborhood of the social optimum, the domestic price is higher than the international price, the tax rates should be raised. This implies that a producer who supplies at the price higher than the international price, which can be associated with the opportunity cost of the product, should be penalized.

The last term of (15) represents an adjustment for the distortion in the labor market. Suppose that the current wage rate seriously underestimates the true opportunity cost of labor. Then, w_s should be greater than w_1 . If the difference between the two is so large that w_s/e_s is larger than w_1 , the second-best tax rates should be raised accordingly. In cases where the shadow wage rate is higher than the market wage rate, the private firm, whose production decision is solely based on market prices, tends to overexpand the scale of operation. Raising the tax rates will offset this tendency. If, on the other hand, w_s/e_s is smaller than w_1 , the tax rates should be lowered. This is because the firm is paying more to labor than what it is actually worth from the viewpoint of the society.

Unless we have all the information necessary to determine the second-best optimal tax rates, we cannot tell, on a a priori ground, whether these are higher or lower than the Pigouvian tax rates. The sign differs depending upon the location of the social optimum. The sign of the third term is also

ambiguous. We do not know offhand whether the shadow wage rate in a certain country is higher or lower than the market wage rate. Most of the existing studies on cost-benefit analysis suggest that, for unskilled labor, w_s is likely to be lower than w_1 , while the opposite holds for skilled labor. The value of the last term will be determined by the values of w_s , e_s and w_1 in a specific country in question.

It should be also noted that, when the socially optimal scale of production is equal to q_1 , not just a single tax rate, but a whole band of tax rates can induce the private firm to choose the specific scale of operation. This situation is graphically explained by Figure 3. The other point to note is that it is impossible to induce the private firm to choose some level of production around q_2 with the second-best optimal tax since there is some discounting in the profit maximizing scale of production for this firm around q_1 (see Figure 1). In this case, other policy instruments may be needed to induce the firm to choose the socially optimal scale of production.

As indicated by (15) the second-best optimal tax rate does not depend on the existence of tariffs in any significant way. Therefore, the whole analysis could have been carried out without assuming the existence of tariffs. Had we assumed that no tariff exists, equation (15) itself would have remained the same. Only the value of the second term of (15) would have been changed.

To summarize the foregoing analysis, it seems important to emphasize first that the second-best optimal tax rates should be different from the Pigouvian ones as long as there exist distortions of any kind in the national economy. Second, the optimal tax rates cannot be zero. It is under very unusual circumstances that the value of t_1^* becomes zero. Typically, LDC governments do not levy taxes on pollutions generated by industrial facilities coming from MDC's. The justification for this practice is usually based on employment

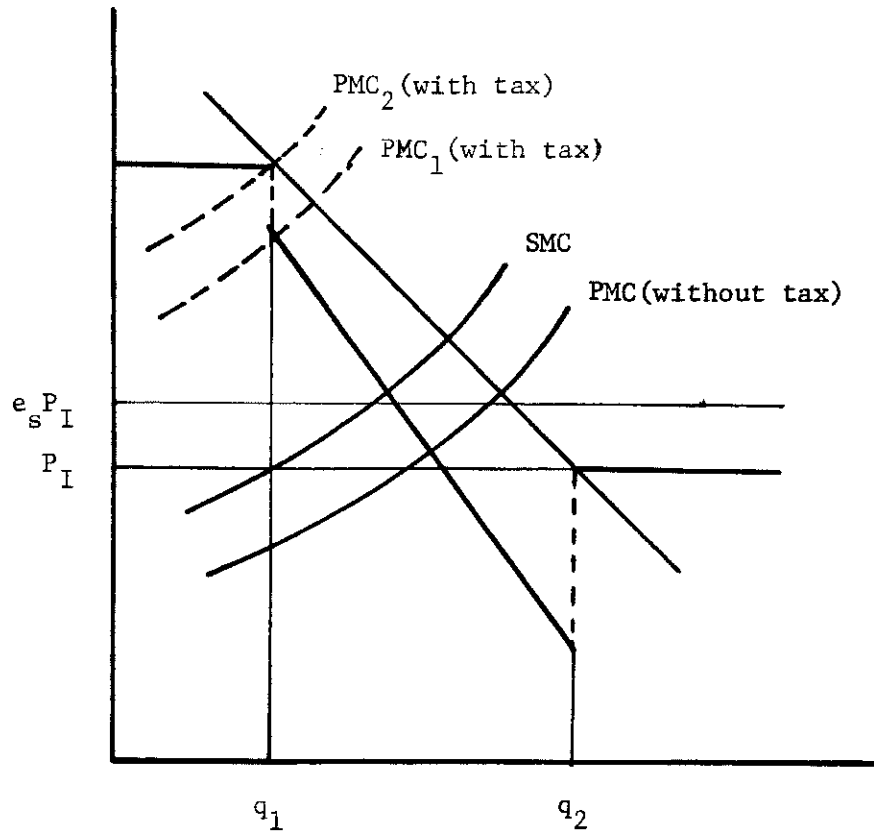


Figure 3

effects or foreign exchange savings effects which can be brought about by accommodating industrial facilities from MDC's. The present analysis shows, however, that in maximizing the net social surplus, it is normally desirable to use positive rates of the effluent tax.

3.2. Equity Considerations

The analysis in this study is mainly focused on the efficiency aspect of the problem. The control of pollution is considered from the viewpoint of maximizing the absolute level of net social surplus. More complicated problems arise once equity issues come into the picture. Unless the LDC government pursues an appropriate redistributive measure to deal with equity problems caused by the tax rule proposed here, our claim for a second-best optimality may not be justified. Although most LDC's actually employ some kinds of redistributive measures, some points of caution are in order.

First, the adjustment for various distortions proposed in this study may affect different economic groups in different ways, although the exact directions of effects are difficult to predict. For example, the adjustment for the monopoly power, included in the second term of the expression t_1^* , is in effect giving a subsidy to a monopolist for its monopoly power. In general, in the context of a typical LDC, it is difficult to justify such a kind of subsidy on economic or political grounds.

Second, as far as the production facility imported to the LDC is owned in its entirety by its own nationals, appropriate redistributive measures can accommodate some of the inequity problems caused by the proposed measure. However, if the production facility is partly or solely owned by the nationals of the exporting country or any other foreigners, no domestic redistributive policy can deal with inequity issues.^{5/} In reality, foreign ownership is a rule rather than an exception for many production facilities in LDC's imported

from MDC's. Therefore, if the firm in question is actually owned at least partially by foreigners, the governments of the LDC need to consider equity issues across nations in an explicit manner.

IV. SUMMARY AND DISCUSSIONS

In this paper, we have presented a theoretical analysis of an optimum environmental policy in LDC's under market distortions. We have noted that the conventional approach to environmental policy using the Pigouvian concept is not appropriate for our problem. To control environmental pollution optimally, it is necessary for an LDC government to levy an environmental tax which is different from the Pigouvian one. It was shown that the divergence of the second-best optimal tax rates from the Pigouvian ones is a result of distortions in LDC markets. However, we note that the second-best optimal tax proposed here does not itself deal with equity problems that may rise. In particular, in a case where a production facility in an LDC is at least partially owned by foreigners, a very difficult problem of distribution may take place across countries.

The analyses presented in this paper have considered a special case of environmental problems arising from relocation of production facilities from MDC's to LDC's. But, the basic framework of the model is applicable to a problem in a more general setting. For example, the framework of the present model can be usefully employed for an analysis of an optimal pollution control of purely domestic industrial facilities in a country with market distortions.

Probably the most difficult problem in the implementation of the second-best optimal effluent tax is the collection of relevant information. First of all, the calculation of shadow prices is by no means an easy job. Second, it is also difficult to obtain proper measurements of the environmental effects

of production activities. These problems are not unique to our case. It is one of the most difficult and well-acknowledged problems in the implementation of the Pigouvian tax (Baumol and Oates, 1975). Finally, substantial amounts of econometric analyses are required to estimate the demand and the cost functions.

FOOTNOTES

1. Rental price is simply defined as the cost of using the production facility by the LDC firm. We have used various specific definitions of the rental price and found out that they do not result in a significantly different result for our purpose.
2. There is no reason to expect that the tariff on the specific product will be abolished in the LDC with the acceptance of production facilities. We also assume that transportation costs of products are negligible.
3. While pure theories of international finance suggest that a country has good reasons to keep its own currency undervalued, a surprisingly large number of LDC's have shown just the opposite tendency. Concerns over the inflationary spiral prompted by increasing prices of imported goods and political pressure from businessmen, most of whom are debtors in foreign currencies, among others, are the most commonly cited reasons for taking such a seemingly paradoxical step.
4. Note that this situation arises when $P'(q)q \leq 0$. But, in case of $q < q_1$ and $q > q_2$, $P'(q)q$ would be equal to 0, and therefore monopoly adjustment is not necessary.
5. For discussion of equity issues, see Lee and Lim (1981).

REFERENCES:

- [1] Barnett, A.H. "The Pigouvian Tax Rule under Monopoly," American Economic Review, 70 (1980), 1037-1041.
- [2] Baumol, W.J. "On Taxation and the Control of Externalities," American Economic Review, 62 (1972), 307-322.
- [3] Baumol, W.J. and W.E. Oates. The Theory of Environmental Policy. Englewood Cliffs, New Jersey: Prentice-Hall, 1975.
- [4] Carbone, R. and J.R. Sweight. "Equity and Selective Pollution Abatement Procedures," Management Science, 23 (1976), 361-380.
- [5] Castleman, B.I. "The Export of Hazardous Factories to Developing Nations," International Journal of Health Services, 9 (1979), 569-606.
- [6] Chatterji, M. "A Balanced Regional Input-Output Model for Identifying Responsibility for Pollution Created by Industries Which Serve National Markets," International Regional Science Review, 1 (1975), 87-94.
- [7] Gilpin, R. U.S. Power and the Multinational Corporation. New York: Basic Books, 1975.
- [8] Harris, J.R. and M.P. Todaro. "Migration, Unemployment and Development," American Economic Review, 60 (1970), 139-149.
- [9] Johnson, H. "The Efficiency and Welfare Implications of the International Corporation," in Charles Kindelberger (ed.) The International Corporation. Cambridge, Mass.: MIT Press, 1970, 35-56.
- [10] Kenen, P. "Economic Aspects of Private Direct Investment," in Taxation and Operations Abroad. Princeton: Tax Institute of America, 1960, 102-115.
- [11] Lee, J.K. and G.C. Lim. "Efficiency and Equity Implications of International Movements of Polluting Industries." A paper presented at the Northeast Regional Science Association Meeting. Rutgers University, New Jersey, May 1981.
- [12] Leonard, H.J. and D. Morell. "Emergence of Environmental Concern in Developing Countries," Stanford Journal of International Law, (1981).
- [13] Lewis, W.A. "Economic Development with Unlimited Supplies of Labor," The Manchester School, (154), 129-131.
- [14] Mills, E.S. The Economics of Environmental Quality. New York: Norton and Company, 1978.
- [15] Walter, I. International Economics of Pollution. New York: John Wiley and Sons, 1975.

RECENT RESEARCH PROGRAM IN DEVELOPMENT STUDIES DISCUSSION PAPERS

83. "The Estimation of the Two-Gap Model," by Mark Gersovitz, November 1978, pp. 27.
84. "LDC Participation in International Financial Markets: Debt and Reserves," by Mark Gersovitz and Jonathan Eaton, December 1978, pp. 37.
85. "Technical Efficiency and Economic Performance: Some Evidence from Ghana," by John M. Page, Jr., April 1979, pp. 35.
86. "Uncertainty, Information and the Inflation Tax in LDCs," by Mark Gersovitz, December 1979, pp. 27.
87. "Subsidized Industries, Managerial Effort and X-Inefficiency," by John M. Page, Jr. and John P. Martin, December 1979, pp. 30.
88. "Portugal and Europe: The Channels of Structural Interdependence," by Jorge Braga deMacedo, June 1980, pp. 52.
89. "Import Competition from Developed and Developing Countries," by Gene M. Grossman, September 1980, pp. 48.
90. "Portfolio Diversification Across Currencies," by Jorge Braga de Macedo, November 1980, pp. 55.
91. "Perspectives on the Stagflation of the 1970's," by Pentti J.K. Kouri and Jorge Braga deMacedo, December 1980, pp. 66.
92. "Exchange Rate Behavior with Currency Inconvertibility," by Jorge Braga deMacedo, December 1980, pp. 60.
93. "A Theory of Exportation and Deviations from Perfect Capital Mobility," by Jonathan Eaton and Mark Gersovitz, December 1980, pp. 43.
94. "Poor Country Borrowing in Private Financial Markets and the Repudiation Issue," by Jonathan Eaton and Mark Gersovitz, December 1980, pp. 59.
95. "Alternative Theories of Wage Determination and Unemployment: The Efficiency Wage Model," by Joseph E. Stiglitz, June 1981, pp. 44.
96. "External Influences and Domestic Politics: The Economies of Barbados and Jamaica in the 1970s," by DeLisle Worrell, June 1981, pp. 37.
97. "Income Distribution and Fertility Decline: A Skeptical View" by Bryan L. Boulier, August 1981, pp. 35.
98. "Currency Inconvertibility, Portfolio Balance and Relative Prices" by Jorge Braga de Macedo, August 1981, pp. 42.
99. "Technology Policy and Development Planning: A Guide for Planners in Developing Countries" by S.M. Ravi Kanbur, October, 1981, pp. 77.
100. "Environmental Pollution and Optimum Taxation Under Market Distortions in Developing Countries" by Gill C. Lim and Joon Koo Lee (October, 1981) pp. 18.